



Denmark, a **Powerhouse** of Robotics and Automation

By Carsten Steno
& Malene Grouleff



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By Carsten Steno and Malene Grouleff, 2020

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Authors' Foreword

Denmark is a small country with a population just shy of six million people. Yet within the last 10 years, Denmark has become home to one of the world's most successful robotics and automation industries.

The cluster of robotics and automation companies in Denmark has achieved critical mass and competes toe to toe with the giants of the robotics world in the USA, Germany, Korea and Japan. Danish robot manufacturers, integrator companies and suppliers work very well together. Moreover, unlike many of the other clusters around the world, the Danish robotics cluster is not specialized to support any one particular industry, such as automotive manufacturing.

This means that Danish robotics companies are in a strong position to provide flexible, complete solutions for production companies around the globe and in any industry. In addition, Danish companies are developing service robots for use outside the factory floor.

Robotics as an industry is growing in Denmark and the rest of the world as new robotics technologies are gaining momentum in multiple disciplines and a variety of industries.

As edits to this book were concluding in March of 2020, the robotics industry in Denmark and internationally was experiencing a slowdown in demand, especially from the automotive industry, which is making the switch to electric cars. At the same time, China, which is both a major purchaser of robots and a supplier of components to the robotics industry, was experiencing an economic contraction as it struggled to stop the spread of the corona virus.

The infection later spread to Europe and the rest of the world with significant societal and business consequences. Obviously, the robotics industry was also affected.

And while short term forecasts for robotics technology sales had to be adjusted, most analysts agree that, even with a long-term recession, demand for flexible robotics technologies will increase, so that production could respond to fluctuating demand. This could be beneficial for the Danish robotics industry in particular. In the years following the financial crisis, the number of robots increased significantly in Denmark.

How has Denmark created such a strong robotics and automation industry? What are the strengths and weaknesses of the Danish robotics cluster? What companies and institutions make up the cluster, and how do they contribute to its success? These are questions being asked more and more around the world. This book intends to provide the answers.

The book came to fruition after many conversations with the cluster's most important players and industry experts and exhaustive research. We are extremely grateful for all their input and time. The opinions expressed within these pages are solely those of the authors.

We hope that the book will be enlightening and inspiring for anyone interested in the international robotics and automation industry.

Copenhagen / Aarhus on the 6th of March 2020
Carsten Steno and Malene Grouleff

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Self-driving Danish disinfection robots are used at hospitals in 40+ countries. The invention increases the safety of both staff, patients and their relatives by reducing the risk of contact with bacteria, viruses and other harmful microorganisms.



The Robots Are Coming - From Denmark!

In less than 10 years, a Danish cluster of automation and robotics companies has captured a strong position on the world map. How did a small nation with only six million citizens manage such a feat? The secret lies in an interdisciplinary approach, mutual trust, demanding customers, creativity and a very pro-robot population.

On May 22, 2019, a jubilant Dane, Claus Risager, stepped down from the stage at Palais des Congrès in Montreal, Canada. At the Innovation and Entrepreneurship in Robotics and Automation (IERA) Awards honoring science-industry collaborations in the field of robotics, his company, Blue Ocean Robotics, had just won the award of the year. Who wouldn't be happy? The IERA Award is awarded by The International Federation of Robotics (IFR) and The IEEE Robotics & Automation Society (RAS), the world's largest professional technical organization with some 420,000 members in more than 160 countries.

The award went to the company's UV Disinfection (UVD) Robot; a mobile disinfecting robot that increases patient safety in hospitals by reducing the risk of contracting infections. It won after fending off an effort by Mobile Industrial Robots (MiR); another Danish-based robot manufacturer with a mobile transport robot that automates internal logistics in the healthcare, manufacturing and logistics industry. The UVD Robot that won actually uses a mobile platform component developed by MiR.

MiR has received numerous other international awards, the likes of which have rained down on automation companies and robot manufacturers from the small Scandinavian country way up north.

Not just directed at service robots like the UVD and MiR, but also robots and automation solutions for industrial companies working hard to rapidly digitize their production according to the concepts of Industry 4.0.

This is also true for one of the Danish flagships, Universal Robots (UR), whose six-axis flexible col-

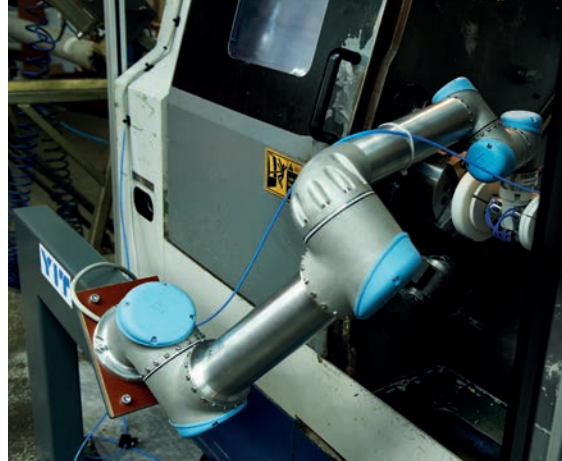


Photo: Universal Robots

In 2008, Linatex installed the first robot from Universal Robots – UR5.

laborative robot was the first to be installed in the world. The flexible collaborative UR robot was installed in 2008 at a Danish manufacturer of plastic components, Linatex, when the company wanted to automate the feed of its CNC machines.

Only this time, instead of installing the robot behind a safety fence, shielded from humans (as has been the case with industrial robots for decades), the UR robot was working side-by-side with the employees. And instead of hiring external programmers for complex programming, Linatex's employees were able to program the robot themselves via a touch-sensitive screen without any prior programming experience.

The UR robots have since been developed and are now called "cobots," short for collaborative robots, noting the concept of the robots working alongside humans. Universal Robots has received many awards, including the internationally recognized magazine, Automation World's "Leadership in Automation First Team Honoree" for three consecutive years. Co-founder and technical director Esben Østergaard won the IERA Award in 2012.

Even the Danish integrator-companies that build complete automation solutions and the Danish research within robot technology receive recognition worldwide.

The integrator aspect in Denmark goes all the way back to the late 1800s when industrialization took off. It was companies such as ProInvent that delivered award-winning automation equipment to a large number of big Danish companies, and Jorgensen Engineering that helped automate international giants in the food industry, e.g. Nestlé and Danone.

Within research and development at higher education institutions, Danish universities have excelled significantly in recent years. For instance,

in October of 2018, Team Robotics from the University of Southern Denmark (SDU) won the unofficial World Cup in industrial robotics, the World Robot Challenge in Japan. They had created their bid for the future flexible robot cell for production. It consisted of two robots from Universal Robots working together on each side of a cobot workbench, developed by Danish Technicon.

Since then, SDU has invested more than \$15 million on a so-called Industry 4.0 Lab that will be part of new groundbreaking research projects and help Danish companies to advance their automation proficiencies.

Other Danish higher education institutions, such as the Technical University of Denmark (DTU), Aalborg

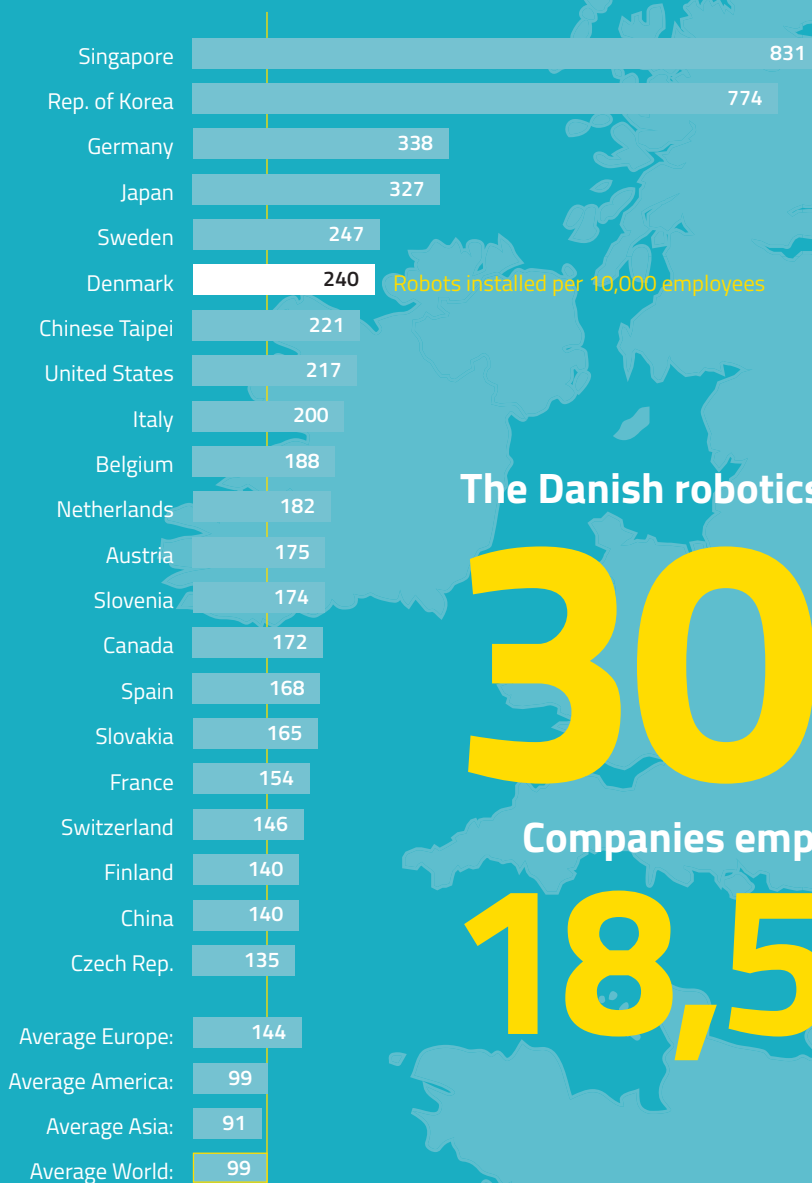


Photo: MiR

Thomas Visti (b. 1974), CEO of MiR

Thomas Visti is a trained electrical engineer and started his career as sales director at Sauer-Danfoss. Subsequently, he has twice shown that he can develop and continuously execute on an ambitious growth strategy. First, as a VP of Sales and Marketing, he played a key role in Universal Robots from 2009 to 2014. During that time, he soon established an international distribution network and offices worldwide and the company's global revenue grew from \$5 million to \$15 million. He was well prepared when he joined the newly established MiR in 2014 as CEO and principal shareholder, and in a few years, he and his team geared the company to global success. Teradyne saw the potential in MiR and bought the Danish company for \$256 million in 2018.

Robot density in the manufacturing industry 2018



DENMARK

6 million inhabitants

16,600 square miles

● 335 square miles of airspace dedicated to drone flights

Robots installed per 10,000 employees

The Danish robotics industry:

300+
companies

Companies employing
18,500
people

Danes Embrace Robot Technology

Danish workplaces automate at breakneck speed. There are 240 robots per 10,000 employees in Denmark. The world average is 99. Denmark has one of the most pro-robot nations in the world.

44%

of all Danish manufacturing companies use robots, according to the Danish Technological Institute.



University, and Aarhus University are also focused on researching robots and automation.

At DTU, experts are on the cutting edge of developing fault-tolerant control, a way to calculate algorithms in the control loop so that they can withstand a sensor failure without the control itself lapsing. This is a mission-critical step in the development of autonomous vehicles, for example.

At Aalborg University, a research team has developed a whole new robot type, that moves about on a ball. It should get all the app developers jumping to contribute with ideas for how the robot can help with directions, searching and more.

It is a far cry from a traditional development program identifying a project or a problem that a robot needs to solve, and then developing an application that can solve that particular task. Instead, the goal of their project is to develop an app-based platform that has to solve two well-known challenges with apps and robots.

The first challenge is to get users to actually use the services already developed into apps. The ball robot, whose face is a tablet computer, simply brings the app directly to users, such as customers at a mall or relatives visiting patients at a hospital looking for directions.

The second challenge is the lack of engineers with a knowledge of robot development. In creating a platform, that challenge is overcome by making the project available to app developers on a large scale.

Danish universities and colleges are also trying to solve the lack of robotic and automation engineers and forecast for future needs by educating an increased number of engineers and technicians with cutting edge skills. Universities and colleges are therefore also included in the Danish robotics cluster.

A cluster with deep roots and strong growth

The robotics cluster has roots far back in Danish industrial history, but has experienced exponential growth within the past decade.

Today, the cluster consists of around 300 companies throughout Denmark. Research, development, and production for the global market has already created 8,500 jobs. With an annual \$2.7 billion in revenue and exports accounting for more than \$1.5 billion, Denmark is in prime position to expand its dominance in this business sector.

Including subcontractors, the cluster employs even more: 18,500 employees, with a revenue of \$4.4 billion. With mobile and industrial robots working beside people, Danish companies command an impressive global market share of more than 50 percent.

In addition to the 300 companies in the cluster, there's also a growing number of business angels and institutional investors who are interested in scaling Danish robotics companies to gain critical mass on the rest of the world stage. They are keeping a close eye on the Danish startup scene, where robotics and automation companies have become more prevalent, even though industrial and service robots are costly and harder to introduce globally

than software robots. This is due, in part, to robots and automation requiring deep skills in multiple facets, including software, electronics and mechanics. Sales and service also require a significant setup effort.

An example of a business angel and venture fund-investment is the drone startup QuadSat. The company has developed a technology that can reduce the noise from the many satellites in space, allowing the navigation systems in aircraft, ships and cars that rely on proper and fast satellite communication, to work optimally.

QuadSat's technology allows drones to test and calibrate antennas for satellite communications autonomously, thus ensuring a constant flow of high-speed Internet.

QuadSat utilizes the University of Southern Denmark's new drone lab as part of the Hans Christian Andersen Airport near Odense on the island of Funen. At the facility, researchers are able to experiment with drones in the surrounding airspace reserved for testing drones as part of Denmark's national drone strategy with its 327 square miles of its airspace dedicated to drone flying. The airspace is one-of-a-kind internationally as it gives drone companies the opportunity to fly farther and fly above the sea.

The national drone strategy, in part, answers why the robot and automation industry in Denmark has grown dramatically in recent years. This important development is backed by competent and flexible authorities playing a significant role in the environment that has helped shape the industry.



Photo: Combine

Polaris, an interactive robot that moves about on a ball, was developed to offer a new way to assist customers as a guide or provide information in public facilities, such as airports. Six entities are collaborating on the development of the ball robot: Combine, MapsPeople, Det Gode Firma, The Danish Technological Institute and the University of Aalborg.

The full answer to the questions remain elusive. Just how did a small country like Denmark achieve a leading role in a drastically growing global robot and automation market? How is the Danish robot industry able to keep ahead of the rapid technology development of artificial intelligence (AI), machine learning, 3D printing and big data? How long can translating opportunities into solutions that provide the global industry with the tools needed



Photo: SDU

Eleven robotics researchers from University of Southern Denmark are among the world's best in industry robots. The team, SDU Robotics, won within the category of industry robots at the World Robot Challenge in Japan in 2019. Together, they have created their proposition for the robot production cell of the future. And they have done this so persuasively that among 250 applicants from all over the world then won the competition. The Winning Team from SDU Robotics is Christian Schlette, Christoffer Sloth, Iñigo Iturrate San Juan, Henrik Gordon Petersen, Dirk Kraft, Frederik Hagelskjær, Simon Mathiesen, Thomas Nicky Thulesen, Anders Prier Lindvig, Aljaz Kramberger and Mads Høi Rasmussen.

to produce this kind of flexibility be sustained as a business model?

The benefits of a small country

Nigel Edmondson is the head of the association MADE (Manufacturing Academy of Denmark), a national network of advanced production conducting research and innovation within the usability of flexible automation and robots.

He points out that Danish universities and colleges have an application-oriented approach to research

in advanced production. Moreover, Danish society is built on a high degree of trust, which makes it easier to share knowledge.

At MADE, big and small companies work together to develop new automation solutions using inspiration from the research community. Also, Denmark does not have one dominant industry, in which big companies are watchful competitors, e.g. Germany's automotive industry. The majority of Danish companies operate in global niches. It makes it easier for them to collaborate.

"It is my observation as a foreigner that the Danish community is built around a high degree of trust between the various partners. You build networks across companies. You know each other and cherish valuable relationships, because you may have to meet the other person in other contexts," says Edmondson.

For example, Danish universities and large Danish companies such as Danfoss and the LEGO Group work with small companies like the electronics manufacturer Danchell and the integrator company Technicon. The common task? How Danchell can automate a small batch production by using digital models and simulation.

The challenge has been to teach robots assembly assignments and operations – that is often the bot-

tleneck which determines the speed of the process. Working together has resulted in the development of flexible automation, making it easier to change production.

Interdisciplinary work is paramount

The practical and application-oriented approach in the development of robot technology manifests itself in several important ways throughout the Danish educational institutions. By its very nature, the merging of robot development and automation solutions requires a plethora of skills, making its effective work cycle interdisciplinary.

"Our students spend half their time on projects in the companies," explains professor Ole Madsen, Aalborg University's Department of Materials and Production (M-TECH). He adds that the university



Together with G4S, the world's largest security company, Lorenz Technology have developed a solution for drone and AI-optimized security and logistics operations in maritime ports.

Photo: Lorenz Technology



FarmDroid is an innovative field robot that helps farmers and plant growers reduce the costs for sowing and weeding of crops while keeping it CO₂ neutral and organic. FarmDroid ApS was founded by Jens Warming and Kristian Warming together with pre-seed venture capital investor Syddansk Innovation A/S and robot expert Esben Østergaard.

Photo: FarmDroid

has a strong focus on being able to understand processes and transform them into an input that a robot can obtain.

"For example, welding processes are complex. It is a lot about hearing, smelling and seeing. It is a challenge to transform it into something mathematical, but we work with the companies on it," he says.

The same practical attitude prevails for Kasper Hal-lenborg, head of Maersk McKinney Møller Institute at the University of Southern Denmark, who works with research and development in robotics and automation. "In Japan, they are building humanoid robots that can solve all sorts of things. We do not believe in that – we would rather make specific

robots that perform specific functions and possibly combine to solve more complex tasks – a la the Lego principle. It makes it easier to adapt a robotic solution to a current need," he says.

Global mindset

Another benefit of being a small nation is that new businesses must aim globally if they are looking for a large market.

Torben Frigaard Rasmussen, a prominent Danish business angel who has made several investments in the Danish robotics industry, says:

"Many of the Danish startups that have had success are 'born global.' It is in our DNA that we consider that a product must be sold in other countries from



Photo: Universal Robots

Esben Hallundbæk Østergaard (b. 1974), Co-founder of Universal Robots

Esben Østergaard Hallundbæk came to Odense University in 2000, where he earned his PhD degree and became an adjunct professor and later assistant professor of robotics. He is also a former world champion in robot soccer. Østergaard founded, together with Kristian Kassow and Kasper Støy, Universal Robots (UR) in 2005. Østergaard earned \$14 million on the sale of UR to the American company Teradyne. He served as technical director at UR until 2019, establishing his own investment and consulting business, Relinvest Robotics, with the aim of investing in robotic companies that can make the world a better place.

the get-go. It is simple. The Danish market is small. Large software companies in Germany and France are thinking about their home market. But if they suddenly need an English version of their software, they may need to start all over again. In Denmark we start in English.”

One example is the world’s first manufacturer of line-marking robots, Turf Tank, that prepare fields for football, rugby and a great many other sports with a Danish-developed robot that marks the white lines. From their headquarters in Hjørring, Northern Denmark, Turf Tank has supplied robots to more than 100 customers in countries such as the United States, Japan, New Zealand, Sweden, the Netherlands, Ireland and Australia.

Turf Tank is also an example of how the public and the private sector across the country work together on strengthening the foundation for Danish businesses.

Odense, in southern Denmark, is the epicenter of the Danish robotics cluster with a third of the companies located there. In 2015, the Municipality of Odense offered its 55 football clubs the chance to become the very first users of the innovative line-marking robot, Intelligent One. Since then, more than 20 other Danish municipalities have been inspired to automate the line marking of their fields.

Flat hierarchy

The Danish robotics cluster also cooperates with the authorities in other areas. This impressed American Brad Beach, who was invited to Odense in 2015 to be the head of the new drone center, SDU UAS, which is affiliated with the University of Southern Denmark.

“Denmark has a flat hierarchy. I can pick up the phone and talk to both the Minister for Transport and the Minister of Higher Education and Science,” says Beach, who points out that Denmark’s national drone strategy is a result of these contacts.

The strategy is, of course, about regulation, but clever in that it accommodates companies, research and the local community, that must be reassured about the proper use of drones.

Beach also points out that Denmark has a well-educated workforce, which makes them flexible and farsighted, and their inventions scalable and made with export in mind.


Jens Nyeng, CEO of Jorgensen Engineering, which delivers production systems to leading global food companies, agrees with this explanation:

“We have competitors with more than 8,000 employees, where we are only a few hundred total. But we have a Scandinavian open management style, where we encourage employees to take responsibility. Big foreign clients can tell a difference when our service technicians are visiting. Our technicians are diagnosing the problems and offering suggestions on how to resolve them. They don’t have to ask the headquarters first.”

Fact-based discussions

Mark Jagiela, CEO of Teradyne, a publicly traded American technology company, which owns two of the leading companies in the Danish robotics cluster, Universal Robots and MiR, has seen the same tendency:

U.S. Military Leader Heading the Danish Drone Industry

A man in a dark suit, light blue shirt, and red patterned tie is shown from the chest up, looking upwards and to the right. He is holding a white quadcopter drone in his right hand. The background is a bright, overcast sky. A thin white line connects the text block to the drone.

Brad Beach (b. 1966), Director,
SDU Drone Center, Center leader,
Unmanned Aerial Systems,
Mærsk McKinney Møller Institute



Brad Beach has put the Danish drone industry on the world map. A test center, research labs, drone training, startup hub, and business park will secure the industry's international breakthrough.

In 2015, Brad Beach decided to seek new challenges. Beach wanted to live in Europe. He had a background as a program manager for unmanned aircraft systems in the United States Marines Corps and more than 30 years of experience in aviation in the U.S. During his 23-year career in the U.S. military, he was responsible for \$1.5 billion in projects and investments.

Beach's network contacts led to the municipality of Odense and the University of Southern Denmark, which had the idea of converting an old airport near Odense into a drone center. The airport is now called the Hans Christian Andersen Airport.

Beach agreed to spearhead UAS Denmark, as the new center is called.

UAS (Unmanned Aerial System) Denmark serves as an international drone-testing center. The center has a 327 square miles airspace over the northern part of the island of Funen and surrounding seas for testing drones. This area allows them to test drones BVLOS (Beyond Visual Line of Sight), among other things. In addition, UAS Denmark is home to laboratories for research and development of new drone technologies, drone training and a startup hub.

UAS Denmark is a leading force in a cluster of Danish drone companies with 140 affiliated members. The center also has a business park.

"There are half a dozen drone airports in Europe, including in Spain, the Netherlands and Norway, but we are unique in our location so close to a city with many companies and colleges. In addition, we have a large airspace for testing drones over land and sea. Another advantage we have over most countries is that our drone airport is run by civil authorities rather than the military," says Beach.

Beach's vision for the drone center is for it to be a world-renowned drone center by 2021, and it's well on the way. Institutions such as MIT and drone companies in California and Boston regularly contact him asking to collaborate. At the same time, more and more new drone companies are moving to the startup hub at UAS Denmark.

Beach sees an opportunity to integrate planes and drones at the center, where plans are also to extend the business park.

At UAS Denmark, they develop drones as both delivery vehicles and as platforms for applications. In addition, they collaborate with the Danish military on drone development and test missions.

UAS Denmark is a cornerstone of the Danish government's drone strategy with the purpose of developing the drone business in Denmark.



The percentage of elderly people in Denmark is growing rapidly, and it is increasingly difficult to recruit staff for elderly care. Therefore, the Danish health and wellness sector is heavily investing in robots and automation. This aligns with calls from trade unions to increase the use of robots and automation in the public sector.

"I am thrilled to see the pragmatic way these companies work. It is very much in line with the way Teradyne works. Discussions are fact-based. You address things directly, and there is no politics."

No fear of robots

Politics is another explanation why a robotics cluster of international importance has emerged in a country like Denmark.

The Danish labor market has a high degree of organization. Unions play a significant role, both in the private and the public sector. But even though the unions are there to negotiate the best possible conditions for their members, they are not afraid that the robots will take their members' jobs.

On the contrary, Danish Metal, one of the unions organizing industrial technicians, urge companies

directly to introduce as many robots as possible. They know that without them, companies will fail to maintain corporate international competitiveness. The focus is on maintaining and returning production to Denmark. One does not see such an attitude in for example France and in the other southern European countries, where parts of the trade union movement is more militant, such as protests via the blocking of work sites due to the implementation of automation.

Thomas Sølby, chief economist in Danish Metal explains; "We are defending the workers, not the jobs."

He refers to the flexible Danish labor market model, the aptly-named flexicurity model which makes it possible to hire and fire people easily, but the unemployment benefits are relatively high. Also,

One trade union's recommendations for Denmark's robot strategy:

1. Add more robots in Danish service and industrial companies
2. Use robots in libraries
3. Create a robot and digitization fund under the Growth Fund
4. Hire more technology experts
5. Use local business councils as technology intermediaries
6. Attract foreign leaders
7. Increase understanding of technology on governing boards
8. Attract top foreign researchers
9. Require the utilization of robots and automation in the public sector

Source: Dansk Metal

there's a well-developed system of continuing education, which makes it easier for workers to be moved to new jobs in production.

Thomas Kochan, professor of Work and Employment Research at the MIT Sloan School of Management, agrees:

"It's about participating actively in the design of how new technology is used. Here, workers and unions must play a role. The alternative is that more jobs will disappear and inequality will increase."

A pro-automation attitude is also found in the Danish public sector, where service robots are expected to free up labor for care tasks that are more complex.

In general, Danes welcome automation and robots. A survey from 2017 by the polling institute Nordstat shows that the number of Danes who are excited about robots and new technology on the labor market is double the number of Danes who are concerned about it.

According to another survey from Gallup from the same year, six out of 10 Danes say that the media creates unnecessary fears that robots will take over work functions.

Overall, this attitude has helped Denmark rise to be one of the countries with the most robots in production per capita.

Denmark has 240 robots per 10,000 citizens according to IFR. With the exception of Singapore, the countries that are ahead of Denmark, Korea, Japan,

Germany and Sweden, all have a major automotive industry.

Additionally, Denmark earned a prominent second place in an index of patent applications within robotics. The number of Danish patent applications has doubled from 2010 to 2018. Only China can beat that.

Megatrends are driving the growth

What drives the development and growth in the Danish automation and robotics cluster, is the same megatrends that we see globally.

- The need to reduce costs and be closer to the market promotes local and more flexible production. So does the increased demand for customized products and the demand for sustainability.
- Rising labor wages and cheaper robots and automation equipment means more incentives to upgrade the production lines.
- Growing middle class and longevity have increased the demand for a wide range of products and services using technology, e.g. in the health sector.
- Digital hardware is constantly improving, making robots and automation equipment cheaper and better. Among other things are storage, but sensors, cameras and batteries are also seeing a constant improvement in quality.
- New software technologies i.e. machine learning, AI and voice recognition make it easier to get robots to act more autonomously and at a higher level.



Photo: Sjørring Maskinfabrik

Sjørring Maskinfabrik is one of the companies working with digitalisation in product design and automation of processes and documentation. The company produces large loaders for construction machinery. With an annual output of more than 4000 loaders, Sjørring Maskinfabrik is Europe's largest. The image above shows one of the factory's welding robots, which, after it has finished welding one loader, can retrieve another loader from a supply line.

- New developments within connectivity makes it easier to communicate between various devices. Internet of Things-units are growing tremendously in numbers, but so is cloud robotics. The new 5G network makes it possible to create new applications for robots.

Four key trends

What is the focus of the Danish robotics and automation industry during this time of technological evolution at a rapid pace?

Overall, there are four key trends.

The first is about how we make production, especially small batch production, more flexible and profitable to automate.

The second is about how we, where mass production is required, make the manufacturing process fully automatic in an economical way.

The third is about how we handle the interaction between robots and humans.

The fourth is about how we develop robots and automation solutions that work outside of the factory floor.

Automation of small batch production

The majority of Danish companies are small and medium-sized. Most manufacture niche products in relatively low numbers. At the same time, labor and production costs are relatively high for these companies.

For the past 50 years, robot manufacturers, integrator companies and machine builders have been keenly focused on automating unilateral repetitive processes similar to those on production lines in the automotive industry.

In Denmark, robotics companies are now increasingly focused on automating small batch production, which can accommodate the evolving demands of consumers, who are looking for more customized products and shorter delivery times.

In the past, when a company asked an integrator company to build a robot cell, the company was often told that they would see how the cell worked when it was fabricated. With today's modern software, you can simulate an entire production line – not just how it looks and its components, but the entire process from start to finish.

This is done by creating digital twins, digital models of a physical system. The models make it possible to test the design of factories without risk and much lower cost.

Modules versus sections

The new opportunities to simulate production processes also make it possible to build a flexible production based on modules.

It is a philosophy the Danish integrator business Technicon swears by.

"We want customer-based solutions and products, which requires the ability to quickly switch production. We must have high production efficiency, but also adaptability – and modular production is the



Photo: ProInvent

ProInvent Integrator has automated the production at Pressalit, the largest manufacturer of toilet seats in Northern Europe. The goal was to reduce production costs significantly by cutting salary costs in order to maintain competitiveness and retain jobs in Denmark. Smart automatization has made the Pressalit production flexible to such an extent that 64 toilet seat variants may be produced with the same equipment – with a turnover time of only 5-10 minutes.

answer to that. Society expects people to be adaptable in order to succeed in the modern globalized society. Why shouldn't we have the same requirements for companies?" says Casper Hansen, CEO of Technicon.

The vision is that production is done by combining modules dependent on what needs to be produced.

Production is organized in islands, connected by mobile autonomous transport robots.

Other Danish integrators are skeptical of the model – partly because it is expensive for especially big companies to produce in this way. Instead, they see the main goal as ensuring that the new flexible robots can collaborate with each other, eliminating the human factor from the production line.

"Our ambition is to make it profitable to produce fully automated, even when the product structure consists of small batches and many variants. If the product contains elements that are too hard for a machine, then we use intelligent robots. If they are not capable enough, we work with the product and change the design to make it easier to produce," says the CEO Leif Dalum of the integrator company ProInvent, which develops products and production lines for Danish companies in the medical and pharmaceutical industries.

Dalum points out that the Food and Drug Administration in the United States that approves all drug imports, requires major pharmaceutical manufacturers to automate their clean room-production to prevent bacteria transfer from humans.

Instead of building a production in modules, ProInvent and other Danish integrators work with section-based production systems. A production system can consist of dozens of sections. When the customer needs to produce a new product; they might be able to just replace 10 sections with newly developed sections.

Another big Danish integrator company, Jorgensen, also focuses on full automation. Some of their major customers in the global food industry, however, are also interested in module-based production.

"Large food factories would prefer to produce 400 cans of peeled tomatoes per minute, which we can buy cheaply in a supermarket. Now they have also started talking about more individualized products, but they are still hesitant due to the cost," says Jens Nyeng, CEO of Jorgensen Engineering.

According to these integrators, the human role will be to develop, design, manufacture and maintain automated production systems.

Denmark's largest automation company, BILA A/S, has optimized the Danish manufacturing industry for 30 years. Now, they are building fully automated solutions and automation techniques based on a close collaboration between employees and cobots. BILA A/S offers a number of Danish automation inventions devised in-house, and they take orders. Their management believes that, despite Denmark's sixth place in robot density, the automation potential in the Danish industry remains a substantial business opportunity.

"There are still a lot of tasks that continue to be solved completely manually, which hamper productivity, prolong delivery times and weaken competitiveness. Therefore, we are pleased to be able to help the manufacturing industry and realize ambitions for productions that are more efficient and promote a healthy work environment. We keep an eye on international groups around the world, and optimize and service both at home and abroad," says Per Bech, COO of BILA A/S.

Most recently, BILA A/S built one of the world's largest salmon handling facilities in Hirtshals in collaboration with the Norwegian salmon producer Hav-Line. The concept increases profit while reducing CO2. The environment benefits and consumers get fresher fish of a higher quality.

The turnaround time from ocean to the dining table is now twice as fast as before because ships with salmon arrive directly from Norway. The newly



The world's largest salmon processing facilities are located in northern Denmark in Hirtshals. Automated Guided Vehicles and robots pack and palletize more than one ton of salmon per minute.

built cargo ship Norwegian Gannet pumps the fish directly from the farming sites along the coasts of Norway and Scotland. As soon as the fish are on board, they are slaughtered, put into tanks, and cooled to below 32F degrees, while the ship sails to the facility in Hirtshals. Here, the fish are quickly pumped from the ship into the automatic sorting system, after which they are packed with ice in boxes. Then, they are transported to a large palletizing plant developed by BILA A/S. Four robots palletize up to 48 boxes per minute, while two others manage up to record-breaking 20 boxes per minute for each robot.

In the past, salmon were picked up by farms in Norway and slaughtered onshore before being packed with tons of ice and put on a truck to Europe or sent by plane to the U.S. or Asia. Now, higher quality salmon are shipped to Europe in half the time, which also removes many transport trucks from the roads.

Humans must recapture the factory floor

Esben Østergaard, founder of Universal Robots, who invented the first commercially viable cobots, sees further developing the interaction between robots and humans as a key task to be reckoned with.

The goal is for people to recapture power over the factory floor, making it a platform for innovation.

Østergaard envisages that we are approaching what he calls Industry 5.0. Here, the production conforms to the fact that customers want individual products – produced in collaboration with a designer or other expert provided by the supplier.

This is not possible in mass production efforts, but it is possible with flexible production based on production islands, such as the ones Technicon produces – and the increased use of UR robots.

It also leaves space for people on the production floor. They have to do what a robot or automation solution still can't.

We have not reached that stage. Yet. Professor Henrik Gordon Petersen from the University of Southern Denmark is a veteran of Danish robotic research. In the 90s, he helped to develop the technologies that have been the basis for collaborative robots, a major part of the Danish robotics cluster.

“A robotic cell should be like buying a tool that you just plug in. It is not meant to just be a simple statement – it's supposed to be a cool move,” he says.

“Others try to solve the problem but in Denmark, we are ahead because we have demanding end-users with requirements for their small batch productions.”

New solutions outside the factory floor

The working environment and reserving manpower for tasks that create greater value are on the agenda for many Danish companies nowadays. This is especially true for the agriculture and food industries, and the health and construction sectors – all significant industries in Denmark.

In these business sectors, it is difficult to recruit new employees. At the same time, there is a recog-



Photo: Volodymyr Pishchany

nition that more automated solutions are needed to remove unilaterally repetitive work while increasing the precision and accuracy of the tasks to be performed. There is also a focus on sustainability and resource savings.

These needs are being met by a growing undercurrent of Danish companies with a focus on service robots using the latest technology in the field.

An example is the innovation the Intelligent Transport Box headed by Aalborg University Hospital and the technology company Intelligent Systems in collaboration with Odense University Hospital, LT Automation A/S, Farusa Emballage A/S, RoboCluster and University of Southern Denmark.

The innovation allows blood samples to be transported from the general practitioner to the

hospital in the Intelligent Transport Box, which has built-in temperature monitoring and traceability. When blood samples arrive for analysis in the hospital's biochemistry department, it is automatically unpacked and handled by the robotic solution, thereby relieving the bioanalysts of that repetitive assignment.

The advent of the Intelligent Transport Box has created a safer way of handling the blood samples and carry out the analysis. For instance, this solution avoids that the samples are shaken during transportation, in which case they would have to be retaken, as well as maintaining them at a constant temperature of 70F. This means an increase in patient safety and trust during the diagnosis process.

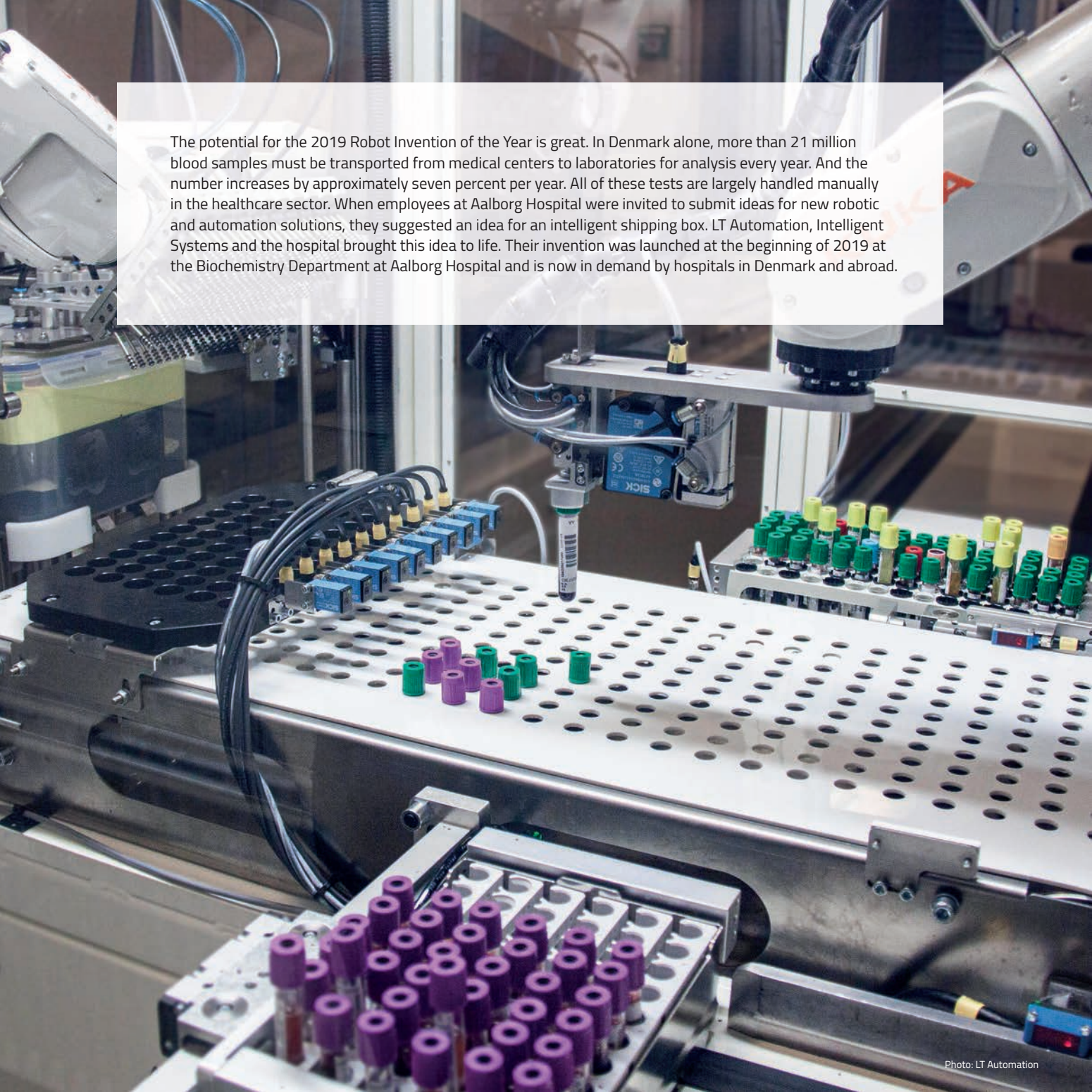
The potential for this invention is great. In Denmark alone, more than 21 million blood samples annually



Photo: LT Automation

Lasse Thomsen (b. 1972), Founder of LT Automation

Lasse Thomsen founded the company LT Automation in Aalborg, which has been responsible for the development of a wide range of automation and robotics solutions for industry and the health sector. This applies, among other things, to the rehabilitation robot Robert, which is now sold on the European market under the auspices of Life Science Robotics. In addition, Lasse Thomsen is one of the driving forces behind the invention The Intelligent Transport Box, where, in collaboration with Aalborg University Hospital and the IT company Intelligent Systems, he has created a total solution concept for intelligent logistics and automated handling of blood samples – from requisitioning and sampling to sample analysis in hospitals' biochemical laboratories.

A detailed view of a robotic arm, likely a SICK brand, performing a task in a laboratory. The arm is positioned over a white perforated metal tray. It is holding a small, clear vial with a white label. Below the tray, there are several racks of test tubes and vials. Some have green caps, some have purple caps, and some have yellow caps. The background shows more of the laboratory equipment, including a black tray with many small holes and various cables and connectors. The overall scene is a clean, professional laboratory environment.

The potential for the 2019 Robot Invention of the Year is great. In Denmark alone, more than 21 million blood samples must be transported from medical centers to laboratories for analysis every year. And the number increases by approximately seven percent per year. All of these tests are largely handled manually in the healthcare sector. When employees at Aalborg Hospital were invited to submit ideas for new robotic and automation solutions, they suggested an idea for an intelligent shipping box. LT Automation, Intelligent Systems and the hospital brought this idea to life. Their invention was launched at the beginning of 2019 at the Biochemistry Department at Aalborg Hospital and is now in demand by hospitals in Denmark and abroad.



Robots offer solutions to many of the challenges the world faces. Clas Nylandsted Andersen, Chairman of the Danish Technological Institute, emphasizes that robots can and must also play a role in solving environmental and climate issues, for example in sorting waste and recycling.

Photo: Teknologisk Institut

must make their way from the general practice to the biochemistry department for analysis – and the number increases by approximately seven percent a year. Today, all of these samples are handled manually, except in Aalborg, where the Intelligent Transport Box solution was launched just last year.

Another example is Farmdroid, an electric field robot that sows and cleans crops using positioning data from GPS satellites. It is a sustainable solution, as the robot is CO₂ neutral and runs using solar energy.

At Sund & Bælt, which operates Europe's largest payment bridge over the 18 km wide Danish waters, the Great Belt, autonomous drones are used for inspection and repair of bridge elements.

Similarly, a wide range of full and semi-automated solutions was developed for the construction business – including the voice-controlled cutting robot, Amigo. It has a mobile framework and a tool adapter for various types of grinders, routers, circular saws, and the like, as well as advanced software with speech recognition and speech output.

Carpenters control it with a headset, so their hands remain free to measure and mount. In addition, by using easy voice control of precision cutting, they can save a significant amount of time.

A green profile

In our world today, you cannot avoid developing production systems and new solutions with global warming and customers increasing demands for sustainability in mind.

However, the Danish robotics cluster even has green transition solutions up their sleeve.

First and foremost, the many Danish robotic solutions make small batch production cheaper to carry out locally. This makes it possible to move production close to the markets, thus avoiding waste production as seen in the companies that in the 00s moved production to Asia. Moving production back home and closer to the markets also reduces energy consumption.

Danish production solutions make it profitable to produce small batches of higher-value goods, manufactured locally. By directing consumption towards locally produced long-lasting products of high quality, you also make sure the consumption is sustainable.

The chairman of the board of Danish Technological Institute (DTI), Clas Nylandsted Andersen, points to Danish sorting robots, which ensure that residual products that can be recycled are not thrown out. This applies to robotic sorting of electronic waste, which makes it easier to recycle precious metals.

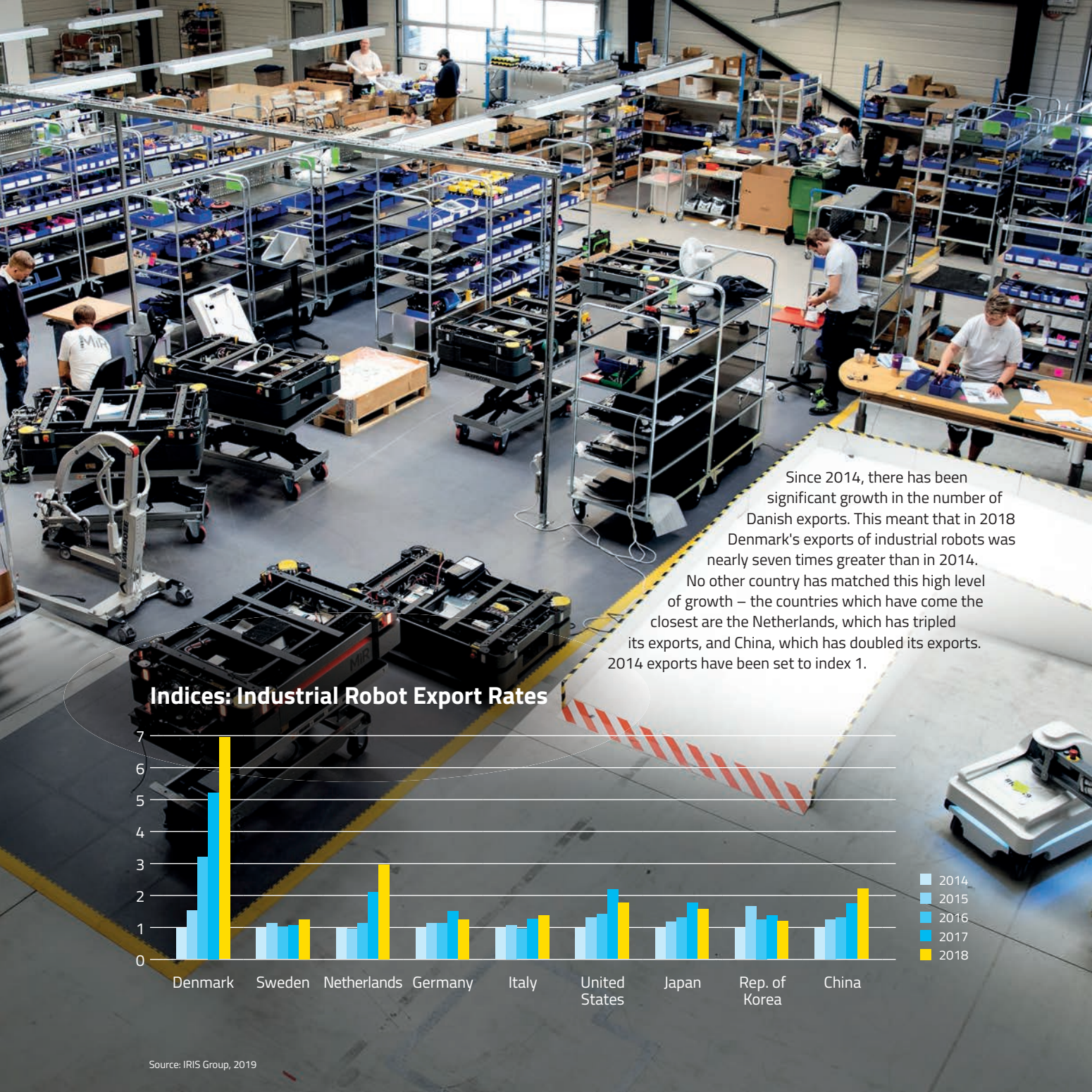
At the same time, Danish companies are working to make the production of the robots sustainable, so that they are part of a circular economy. Properly used, Danish robots and automation tools are seen as part of a green transition, not as part of the problem.

In realizing Denmark's ambitious political goal of reducing the country's CO2 emissions by 2030 by 70% compared to 1990, partnerships have formed between the government and companies in various industries, particularly among the IT and manufacturing industries.

For this purpose, automation and robotic companies' main task is to help other companies with solutions that make production energy-efficient and create sustainable products.

The Danish automation and robotics industry is, therefore, a national position of strength that can contribute solutions, not just in Denmark, but also on a global scale.

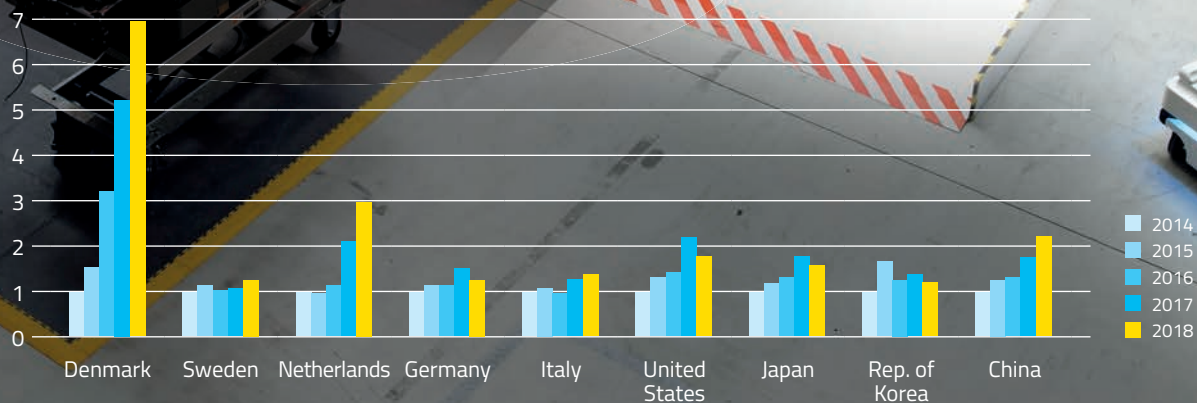
In a recent update of the Danish government's national robotics strategy, it is emphasized that Danish-developed robotics technology can contribute to the development and implementation of sustainable solutions. Especially in agriculture, construction and production. At the same time, SMEs are being encouraged even more than now to introduce robotic technology to remain competitive. The updated strategy contains 10 initiatives to develop the Danish robot cluster - the main emphasis is on research, education and training of the workforce to adapt to new technology.



Since 2014, there has been significant growth in the number of Danish exports. This meant that in 2018 Denmark's exports of industrial robots was nearly seven times greater than in 2014.

No other country has matched this high level of growth – the countries which have come the closest are the Netherlands, which has tripled its exports, and China, which has doubled its exports. 2014 exports have been set to index 1.

Indices: Industrial Robot Export Rates



Three Hundred Companies – \$4.5 billion

The Danish robotics and automation cluster has made huge strides within the development of collaborative and mobile robots. Service robots are a dominant growth driver and experienced integrator companies are the preferred suppliers of automation solutions for leading industrial companies.

Cobot sales worldwide

23%

11,000

2017

13,530

2018

Source: International Federation of Robotics (IFR)

Rapid growth and substantial value creation often take place in industries with a high degree of specialization within a concentrated geographical area. The software and IT industry in Silicon Valley, California, with iconic companies such as Apple, Google, Facebook and others, is a prime example.

When educational institutions and public authorities contribute to the development of specialized enterprise clusters such as these, a country or region gains a meaningful competitive advantage.

Up to 40 percent of a country's per capita value-added growth can be attributed to the competitive advantage gained through specialized business clusters. Clusters and networks promote knowledge – sharing and skills development, which leads to innovation, as well as development and research in all types of companies. Four times as many small and midsize businesses develop innovations when participating in cluster and network activities, compared to those companies not benefitting from cluster partnerships.

This connection has been demonstrated by the American business economist, professor Michael Porter. He concludes in his research that the geographical concentration of companies in a cluster amplifies a host of innovation and productivity effects:

- Transaction costs are reduced.
- Information and creativity flow more efficiently.
- Local institutions respond more quickly to the specific needs of businesses and competition between them becomes more intense.

- The existence of clusters stimulates new startup businesses.
- It is easier for entrepreneurs to discover a need for a new product or service that is not already covered by a company in the cluster.
- There is easy access to research-based knowledge, skilled labor and specialized suppliers.
- Venture capital is easier to obtain, as the financial players are familiar with the cluster companies and their associated risks.

All of these effects can be seen in the Danish automation and robotics cluster, which has grown significantly over the past decade. In addition, the Danish cluster checks another important box: the density of companies' physical locations. From one day to the next, employees at one cluster company would be able to find a new job in another cluster company only a couple of hours away.

Big robotics exports from a small country

The Danish automation and robotics cluster consists of more than 300 companies with some 8,500 employees and an additional 10,000 employees providing services as subcontractors. In total, the cluster companies have a revenue of \$2.7 billion. With the subcontractors' work included, revenue increases to \$4.5 billion.

According to the Danish research firm Damvad, the cluster is expected to reach 25,000 employees by 2025 following the growth forecasts for flexible industrial robots and mobile robots, the clusters most successful business area.

The strength of the cluster is exemplified in its export figures. 60 percent of its revenue goes to exports, showing just how important international markets are for the cluster companies.

In 2014, according to figures from the International Trade Center, Danish robotics companies accounted for two percent of total industrial robot exports from the following countries: Japan, China, Korea, the United States, Italy, Germany, the Netherlands, Sweden and Denmark. In 2018, the value of Danish robot exports reached six percent of the total exports of robots from these nine countries.

Denmark also has a well-developed sector for chat robots, or software robots – used in fintech (financial technology) among other industries – but software robots are not part of the automation and robotics cluster that is the focus of this book.

The automation and robotics cluster companies are spread throughout Denmark, but with a significant concentration on the island of Funen around Denmark's third-largest city, Odense, where approximately a third of the cluster's businesses are located.

There are also strong research environments and robotics companies in the Danish capital of Copenhagen, and around the country's second and fourth-largest cities, Aarhus and Aalborg, respectively.

The cluster is particularly strong within so-called collaborative robots, also known as cobots, which are flexible robots that can cooperate with humans. The company Universal Robots (UR), which first entered the world market in 2008 with a flexible

six-axis lightweight robot, has a 50 percent market share within cobots.

Another strong player, OnRobot, has joined this market in recent years, with around \$89 million invested in the company. OnRobot's ambition is to become a leader in accessories for robots such as grippers and sensors.

A third major company is Mobile Industrial Robots (MiR), which is showing strong growth in autonomous self-driving transport robots for use in industrial production and in hospitals. The robots are already used today by large automakers such as Toyota and BMW, and they are spreading throughout the industry.

Cluster companies are also increasingly competing globally within mobile robots and service robots – defined as robots outside of the factory floor. The leader in this sector is Blue Ocean Robotics, which has developed the sterilization robot, UV Disinfection Robot. Blue Ocean sees itself as an incubator business for new companies developing service robots.

Otherwise, service robots are mainly being developed by the growing ranks of new robotics companies and startups. Nearly 40 percent of the cluster's almost 300 companies have been established since 2010, and two out of three are smaller, with fewer than 20 employees.

Integrators and resellers with extensive experience

Another important sector in the Danish robotics cluster is integrator companies. Integrators have

existed as machine builders since the industrial revolution came to Denmark in the 1870s. Because Denmark has strong agricultural and pharmaceutical industries, Danish integrators are highly competent in automation solutions for these types of businesses, but also serve a broad swath of other customers.

Among the Danish integrators staking a claim in the world market are companies such as Jorgensen Engineering, which is particularly strong in automation solutions for the global food industry. The same is true of Cabinplant, which supplies production systems for the fishing industry. Sanovo is the main supplier of egg processing machines.

Another important integrator is Proinvent, which has well-known Danish clients in the healthcare field, such as Novo Nordisk (insulin) and Coloplast (colostomy aids). Other integrators with an international presence are Gibotech, which, in recent years, has specialized in automation of hospital logistics, including automatic sterilization centers.

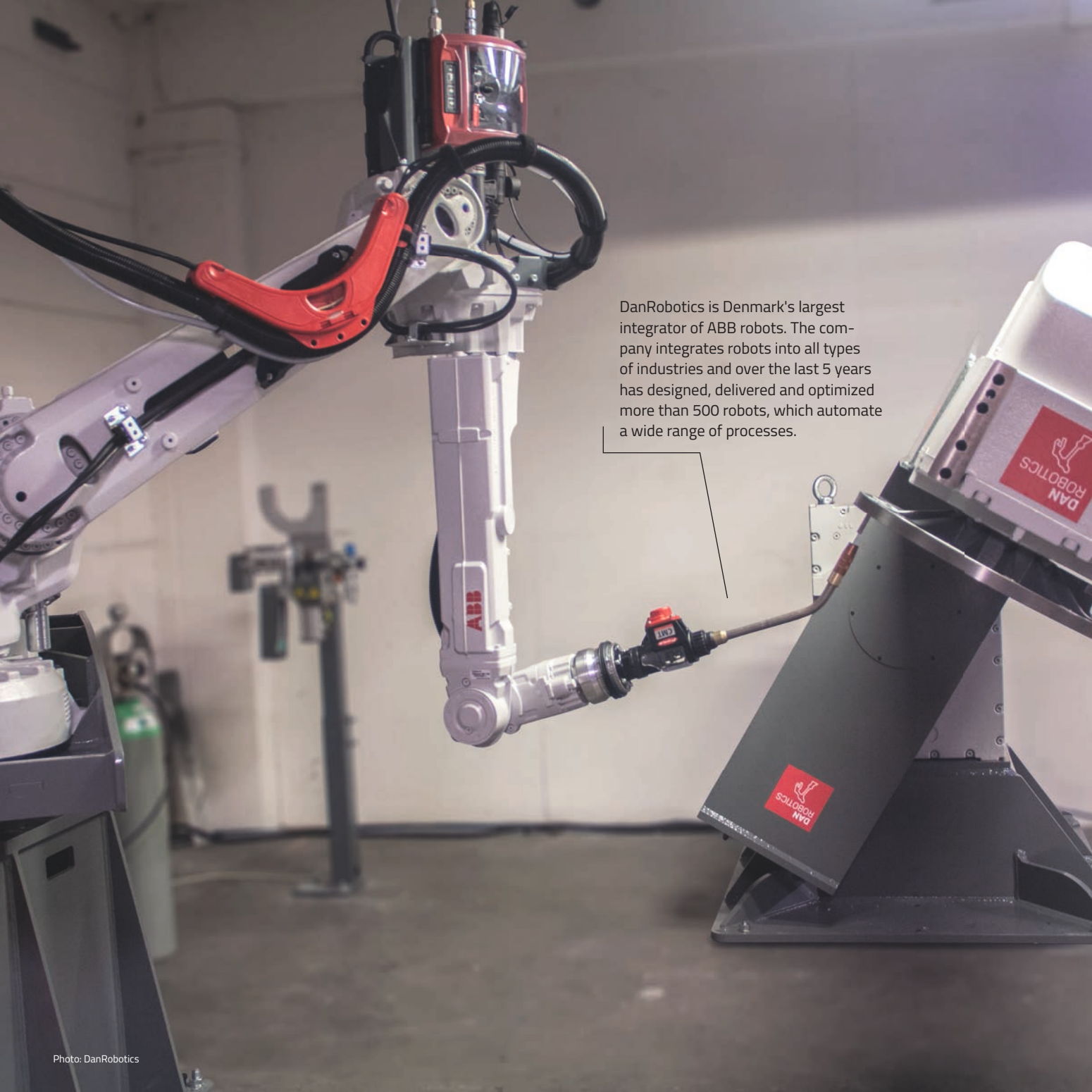
In addition, there are many substantial companies that are suppliers and advisors to the Danish automation cluster. Swedish-Swiss ABB has a large presence in Danish robotics, as do German-Chinese Kuka and Japanese Fanuc, among others.

**Enrico Krog Iversen (b. 1964),
CEO and Co-owner of OnRobot**

As director of Universal Robots, Enrico Krog Iversen had a decisive stake in driving the company to the stage where it could be sold to Teradyne. He joined in 2008 as an investor and CEO of UR. Iversen trained in the shipping business A.P. Moller - Maersk, and since then became sales manager in his parents' company that produced stoves. In 2006, the company was sold to a Norwegian company and today is called Scan A/S. In addition, Iversen and his family received just over \$110 million from the sale of UR to Teradyne. Since then, Iversen has been involved in the company OnRobot, where he has invested a considerable amount of resources and serves as CEO. OnRobot's goal is to become a world-leading provider of robotics applications and tools.



Photo: OnRobot



DanRobotics is Denmark's largest integrator of ABB robots. The company integrates robots into all types of industries and over the last 5 years has designed, delivered and optimized more than 500 robots, which automate a wide range of processes.

Danish Universal Robots' supplier, BILAA/S, which also supplies complete automation solutions, has also set its sights internationally in recent years. In addition to Scandinavia, BILAA/S has just established itself in the U.S. market, and BILAA/S is the agent for Kawasaki robots in Scandinavia.

Strong collaboration across the board

The density of the Danish cluster and the fact that the few companies compete directly with each other makes it easy to work together.

For example, the integrator Gibotech has established a joint company, Sanovo Technology Robotics, with Sanovo. They are developing a robotic cell solution that can pack and palletize eggs. As a result, Sanovo's egg processing lines are becoming fully automated.

"We have established a CEO network in the Danish cluster where we can share knowledge and ideas. Our intention is to band together and take on export orders which we are otherwise not strong enough to take on alone. Automation tasks for the automotive industry is a good example of this," says Henrik Anker, CEO of Gibotech.

Another example is Scape Technologies (bin-picking) and Odico (construction automation solutions). They both share the same chairman, who has played a crucial role in the listing of the two companies on the Danish stock exchange, First North.

Research and education

An important prerequisite for continued growth of the Danish automation and robotics cluster is the research and education efforts taking place

throughout Denmark's vast network of technical institutions.

Danish Technological Institute (DTI), which has its automation department in Odense, plays a significant role. So does the University of Southern Denmark, the Universities of Aalborg and Aarhus, and the Technical University of Denmark (DTU) in Copenhagen.

These universities participate in international research programs in automation and are very active in applied research, where they have broad interactions with Danish companies.

Horizon 2020, the EU's research and innovation program, is a good benchmark for how much Danish colleges have received in funding for the automation and robotics fields. From 2011 to 2018, the Danish institutes and the private companies with which they collaborate received some \$74 million for research in automation.

These and other educational establishments together offer a wide range of programs that target the robotics and automation industries, and they all report a rapidly rising number of admissions. However, it will take several years before the programs can supply the number of engineers and technicians that the rapidly growing Danish automation industry is demanding.

Good access to venture capital

Another important factor for the development of the Danish cluster is access to venture capital. Since 2015, around \$1 billion has been invested in Danish automation companies.

In recent years, capital for lucrative ideas has not been as big a problem as it was in the beginning before the development of the cluster really took off. Today, startup investments in robotics are hot among Danish business angel investors, especially in the area of service robots.

This investment is occurring despite the fact that robotics companies are more expensive and more difficult to scale up globally because they are not only based on software but also on electronics and mechanics. On top of that, an international sales network is often required.

In Denmark, of course, we are proud of the success the Danish automation cluster has enjoyed. But what the Danes think in one thing. What really matters is how the Danish automation and robotics cluster competes with other clusters around the world.

Denmark versus other clusters

In addition to the Danish robotics cluster, there are a number of other robotics clusters in Europe and the rest of the world. Several of these are organized into cluster organizations.

Sweden has the Robot Valley in central Sweden, north of Stockholm. Robot Valley has a history dating back to 1974, when Asea, today known as ABB, manufactured its first industrial robot. In 2003, Swedish companies such as ABB, Atlas Copco, and the area's universities and colleges were organized in a cluster. Volvo is one of its major customers.

RoboValley in Delft in the Netherlands is organized around the Delft University of Technology and other

educational institutions, where 170 robotics researchers work with industrial robots, cobots and drones. The cluster houses about 30 startups plus a few larger companies in industrial robots and drones.

In Europe, the robotics industry is strongest in southern Germany, centered on the German automotive industry, for which the robot factory Kuka and the tool manufacturer Schunk are major suppliers. In Italy there is a large integrator Comau with close connections to the Fiat factories.

Overseas, there is a strong cluster of major robotics and automation companies around Boston, Massachusetts on the U.S. east coast, with more than 120 robotics companies, including Brooks Automation (industrial automation) and iRobot (robotic vacuum cleaners) and prestigious universities such as MIT and Harvard. Around Silicon Valley, a lot of focus has been centered around autonomous vehicles by Google Robotics, among others.

In Asia, South Korea and Japan have thriving robot industries, founded around the two countries' robust automotive industries. In Korea, companies such as Samsung, LG and Hyundai are dominant, while Fanuc, Kawasaki, Omron and Honda Robotics dominate the Japanese robotics sector.

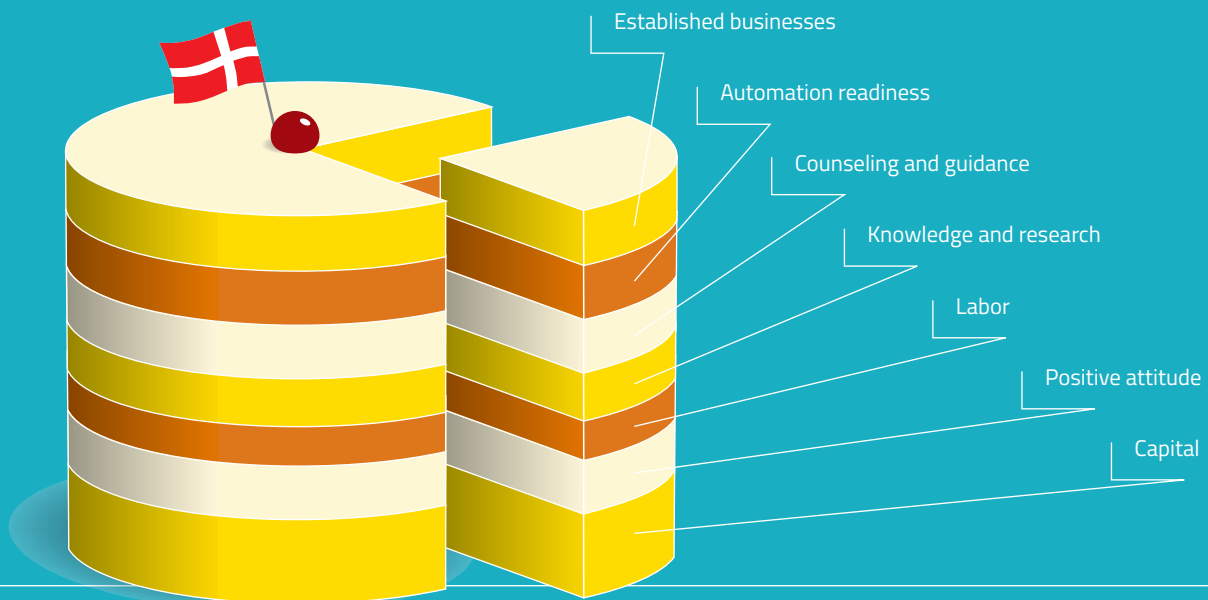
China is a burgeoning superpower in the robotics field with more than 600 companies concentrated in southern China around Shenzhen and Hong Kong. China can also boast that it has the world's largest drone manufacturer, DJI.

The Danish cluster has several strengths relative to its international robotics brethren.

The Danish Robotics Cluster is made up of:
300 robotics companies
100+ subcontractors
12 networks
7 educational programs
5 investment funds



The Danish Recipe for Robotics Success



A man in a dark suit and tie stands at a black podium, gesturing with his right hand towards a large projection screen. The screen displays a blue mobile robot and the text 'Simon Kollerup, Denmark's Minister for Industry, Business and Financial Affairs, unveils a plan for the world's largest Cobot Hub.' To the right, an architectural rendering of a modern building is shown on an easel. In the foreground, a tray of water bottles sits on the podium. The background features a wall with horizontal wooden slats.

Simon Kollerup, Denmark's Minister for Industry, Business and Financial Affairs, unveils a plan for the world's largest Cobot Hub.

In the spring of 2020, Mobile Industrial Robots and Universal Robots, both owned by Teradyne, agreed to combine offices to create a "Cobot Hub." They will move into a new building in Odense costing DKK 1 billion, which has the capacity to accommodate 1,100 employees. They aim to increase cooperation between the two companies and at the same time attract highly-qualified employees.

The decision cements Teradyne's commitment to Odense and Denmark as a center for the development and production of robotics technology.

- Unlike many of the international clusters, the Danish cluster is not connected to a specific industry, such as the automotive industry.
- The Danish cluster, in comparison with other clusters, has experienced the greatest growth in the export of industrial robots.
- Danish researchers are increasingly cited in recognized international journals, just as more and more Danes appear at international conferences in the field.
- The Danish cluster is better represented and organized as a cluster than anywhere else in the world, where one can rarely find a single organization that represents the cluster.

Denmark is recognized internationally as a force to be reckoned with

It is not difficult to find people outside of Denmark who recognize the Danish position of strength.

“The ecosystem around the Danish robotics cluster is strong and unique. No one else in Europe has come close to Denmark when it comes to building a growth strategy around robotics. There is a robust supply chain and a multiplier effect in Denmark, where many startups deliver innovation and new ideas to established robotics companies that have access to the global markets,” says Ali Muhammad, Senior Scientist at the Finnish Institute of Technology, VTT.

Mark Jagiela, CEO of Teradyne, who has invested approximately \$800 million in the acquisition of two of the powerhouses of the Danish cluster, Universal Robots and Mobile Industrial Robots, says:

“When we decided to invest strategically in the automation industry, we looked for acquisition opportunities around the world. But it was a surprise that two of the companies we had chosen to invest in were in the same small country, in fact in the same city.”

In the spring of 2020, the two Teradyne-owned companies agreed to co-locate in a new modular, expandable, sustainable 36 million USD building in Odense with a capacity of 1,100 staff. The purpose is to increase cooperation and make it easier to attract qualified workers. At the same time, the decision solidifies Odense and Denmark as a leading world-wide robotics hub.

Jagiela sees the Danes’ workforce as skilled, logical thinking, collaborative and particularly able to combine innovation with practical challenges.

“The Danish robotics companies, though small in size, have been able to create solid businesses right from the beginning, because they are operated with good business sense and focused on their customers.”

Also, according to Jagiela, Danes have a unique sense of design. “This is important when robots have to work in collaboration with humans.”

He goes so far as to say that the Danish robotic products “work in an almost friendly way, unlike any I’ve seen elsewhere.”

Editor Susanne Nördinger of the renowned German media Verlag Moderne Industrie GmbH, has examined the Danish robotics industry.



About the Robotics Alliance:

The Robotics Alliance is a national partnership with a common goal of promoting the robotics industry's development throughout Denmark and maintaining its position as one of the world's leading robot-producing countries. Partners in the alliance have roots from across Denmark: RoboCluster, Odense Robotics, UAS Denmark, Brains Business, Sønderborg Business Council.

Mikkel Christoffersen is the spokesperson for the Robotics Alliance and Cluster Director in Odense Robotics.

"Synergy between researchers and businesses is one of the things that differentiates the Danish robotics industry on the global stage and contributes to our success."

"Denmark has become known for collaborative robots. We can clearly see this at trade fairs such as Automatica in Munich, where Danish robotics companies are always a big attraction," says the editor.

American investor and journalist Frank Tobe describes the Danish robotics industry as good, comprehensive, supportive and successful as clusters in Silicon Valley, Boston/Cambridge and Pittsburgh, Pennsylvania. He notes the mechanical prowess of the Danish-made Universal Robots, which, for example, dominated at the 2018 Automatica fair in Munich.

John Santagate, who has worked for the Boston-based consulting firm IDC, agrees and points out that many robotics experts and companies have their origins in Danish universities.

Rian Whitton, analyst at British ABI-Research, emphasizes that Denmark has a particularly strong position in collaborative robots. He does not see it weakening in the coming years, although more and more competitors are coming.

Esben Østergaard, founder of Universal Robots, with experience at both American and Japanese universities, points out that Danish universities tend to be business and application-oriented. In addition, many in the Danish cluster earned a good deal of money and reinvested it in the robot environment.

"There are quite a few in Denmark who know how to make a profit in this field, and there is also a lot of capital available. Both from inside the branch and from others who would like to enter. There are many universities around the world that know a great deal about robotics, but not many use that knowledge to make businesses. Delft Technical University of the Netherlands has what they call RoboValley. But they lack the business side of it," says Østergaard.

A tough fight for skilled labor

The greatest threat to continued growth in the Danish cluster is the high demand for skilled labor. This applies to software, electronics and mechanical engineers, and it also applies to industrial technicians,



Photo: Aalborg University

Ole Madsen (b. 1964), Professor of Production and Automation, Aalborg University

Ole Madsen is a civil engineer and has been one of the leading forces in building and developing expertise in automation and robotics at Aalborg University's Institute for Materials and Production. He is active in the projects Smart Production and Little Helper, which makes it easier for small businesses to introduce automation solutions.

electricians and other skilled workers. In Denmark, there is a significant shortage of young people with competences in STEM (Science, Technology, Engineering & Mathematics). However, Denmark shares this issue with most other Western countries.

However, Thomas Visti, CEO of MIR, is optimistic:

"We have hired 150 employees in the last year and a half – we can easily recruit foreign workers to Denmark. There are many who would like to work with the cutting-edge technologies that we develop. We feel the cluster effect. There are not many places in the world where the cluster works as well as we do."

Claus Risager, CEO of Blue Ocean Robotics, is more concerned:

"We hire 500 robotic engineers in the cluster per year. Throughout Denmark, there are 100 trained per year."

He foresees that Danish companies must increasingly use outsourcing and hire the best around the world:

"We hired a great robotics talent, David Faconti, in Barcelona. He wanted to work for us so we set up a small office in Barcelona – he also had four robot engineers he wanted to bring on board."

Others point out that Danish robotics companies are continuing to open more branches abroad, in tandem with the overall globalization trend. That is why they are recruiting there. For example,



Lasse Kieffer

As a newly graduated electrical engineer, Lasse Kieffer was the first employee of Universal Robots. In addition to product development, Lasse Kieffer was the company's Global Compliance Officer and participated in numerous committees to create security standards for cooperative robots, known as cobots. In 2017, Lasse Kieffer founded Purple Robotics, which developed a vacuum gripper for cobots. In 2018, OnRobot purchased Purple Robotics for a multi-million sum of Danish kroner. Since then, Lasse Kieffer has served as an investor, sparring partner for start-ups, robot chair at Dansk Standard and judge for the DIRA technology award. At the same time, he is developing his next entrepreneurial adventure.

OnRobot has satellite companies in Hungary and the United States. Universal Robots has also purchased a Boston-based company with developers.

A three-part strategy provides labor

Mikkel Christoffersen, spokesman of the Danish cluster partnership, the Robotics Alliance describes three initiatives aimed at alleviating the shortage of skilled labor.

- Universities and educational institutions for skilled workers are increasing their number of admitted students. In the long term, this will provide more engineers and industrial engineers. The number of admitted students is so large that it has been necessary to impose tightened admission at some schools.
- In addition, continuing education opportunities are available for technicians from other fields to be trained to work in the robotics industry.
- Lastly, the Robotics Alliance is trying to recruit employees in Southern Europe where many well-qualified young people are without employment. Despite differences in weather, lifestyle and higher taxes, it has increasingly succeeded in attracting well-qualified southern Europeans to work in the Danish automation and robotics industries.

Denmark, a place where robot heroes grow

Despite differences in weather, lifestyle and tax regime, efforts to attract highly qualified talents from all over the world to the Danish automation and robotics industry is increasingly successful.



Photo: Odense Robotics

Automation Engineer Nicolas Valencia Espinoza

Nicolas is a Chilean automation engineer. Nicolas took his family with him on moving from Chile to Denmark to work with Gibotech and later with Sanovo Technology Robotics, also in Odense. He is just one of many heroes passionate about robotics and automation in the Odense Robotics cluster.

Robot jobs in Denmark:

www.odenserobotics.dk/careers



Robotic welders at
Lindø shipyard

The Danish Robotics Cluster Has Deep Roots

The cluster has grown rapidly in the last 10 years, but the foundations were seeded many years ago.

Denmark's robotics history: collaboration across the world created a breeding ground for the Danish robotics industry

1982

The network DIRA, the Danish Industrial Robot Association, is formed by Danish companies and educational institutions with interest in robot technology and automation. It has grown to 130 members by 2018.

1988

The Danish Innovation Incubator Programme is founded. Regional incubators provide professional advice and funding for innovative knowledge-intensive robotics start-ups. The innovation incubators operate at the very early stage of the investment chain, where venture capitalists and other private investors are reluctant to engage. The scheme is funded by the Ministry of Science, Innovation and Higher Education.

2001

Lindø Shipyard closes its robot department, which was lead by Niels Jul Jacobsen, due to a decision to source externally. The employees are permitted to take the technology with them, so they start a company, which ends up launching a handful of new robot and automation companies.

The research project AMROSE (Autonomous Multiple Robot Operation in Structured Environments) begins. Its funding is sourced from Lindø, The Danish Academy of Technical Sciences, the University of Southern Denmark (SDU), and an informatics program under the Danish Council for Strategic Research. The goal is to shatter the limits of conventional robotic technology.

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1985

Lindø Shipyard begins to employ welding automation and robot technology, programmed in the Shipyard's own robotic department, for cutting applications.

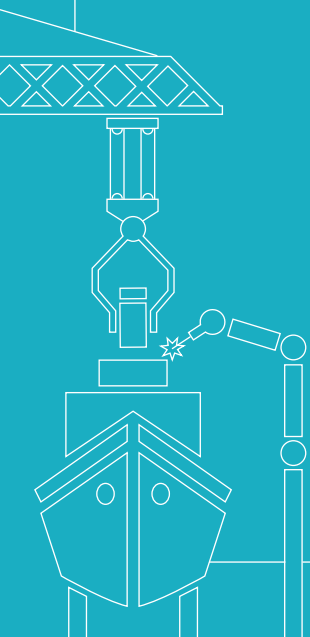
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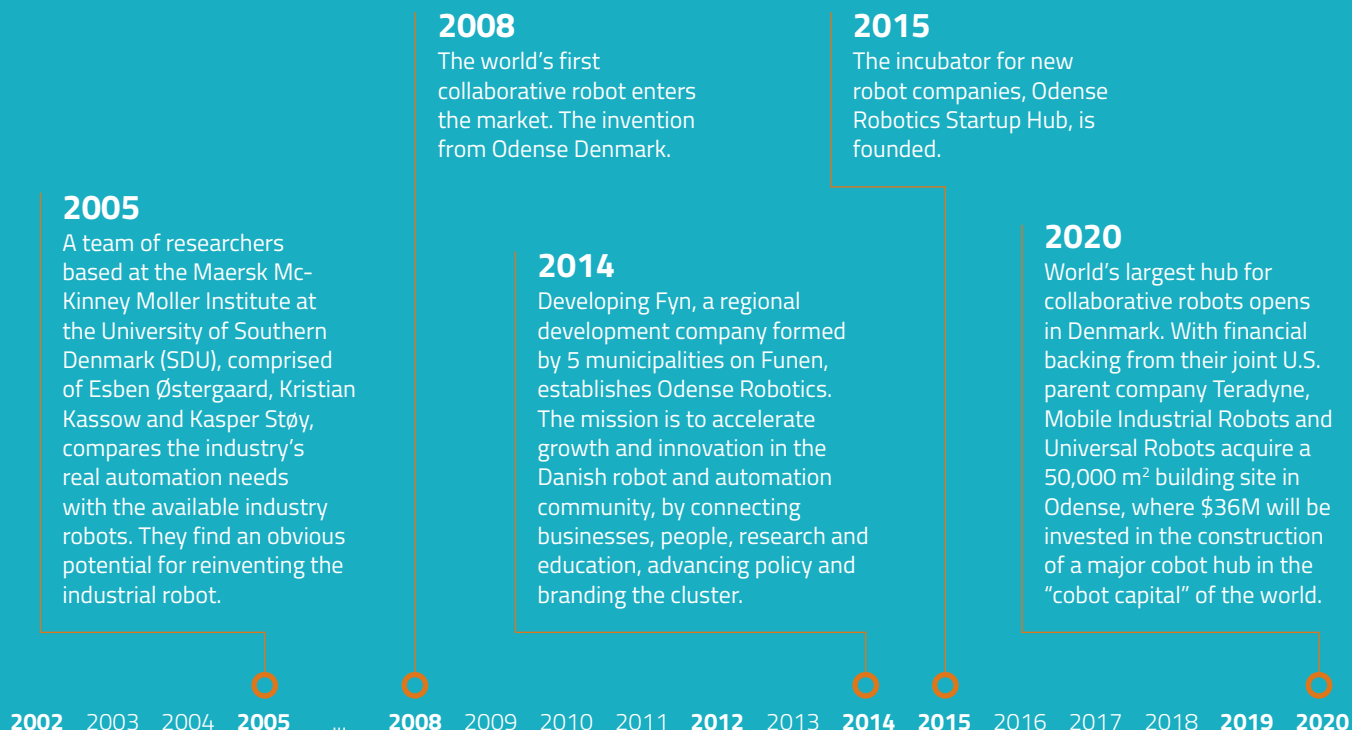
Vækstfonden is founded. This is the Danish state's investment fund, som var med til at skabe et dansk venturemarked. From 1992 – 2018, Vækstfonden has financed more than 7,900 Danish SMEs, heriblandt mange robotvirksomheder.

1999

The A.P. Møller and Chastine Mc-Kinney Møller Fund donates 75 million DKK for the construction of a building at the University of Southern Denmark (SDU). The building, the Maersk Mc-Kinney Møller Institute for Production Technology, can accommodate all facets within modern production technology.

Danish Technological Institute establishes the Centre for Robot Technology, which has become northern Europe's largest competence centre within automation and robot technology.





It is no coincidence that a strong cluster of automation and robotics companies was established in Denmark. While the cluster has grown significantly in the last 10 to 15 years, it has deep historical roots. The companies in the cluster were created to meet the automation needs of the Danish industry, and many of their solutions are now being exported.

Since the advent of industry in Denmark in the 1870s, there has been a growing sector of machine builders and integrator companies that have contributed to the high degree of automation we see in today's Danish companies. In fact, Denmark has the highest number of industrial robots per capita in the world, outside of the major automobile-producing countries. For every 10,000 employees, there are 230 robots in Denmark.

The Danish integrator companies reflect the industrial structure in Denmark, in which several sectors dominate: agricultural products, medicine, energy, machinery and chemistry.

On the island of Funen, there is a strong horticultural sector that has become an incubator for a number of agricultural businesses. The origins of these companies included needing equipment to measure, weigh and package their goods. Because these are labor-intensive industries, opportunities for automation were realized throughout the years, following common business practices used elsewhere, such as slaughterhouses, dairies and pharmaceutical companies.

The interest in automation quickly established a link to international businesses. For example,



Photo: Jysk Fynske Medier

John Perram (b. 1945), Professor of Applied Mathematics

John Perram, an Australian mathematician, came to the University of Odense as a professor of applied mathematics in 1975. He and his students developed methods for the rapid simulation of complex molecules. In the process, Perram discovered that these methods could also be used to simulate the movements of robots and find ways to control them. His research became the basis for the collaboration between the university and Odense Steel Shipyard on robot development. Perram was the co-founder and co-owner of the company AMROSE, which worked with advanced programming of robots. He then returned to his homeland of Australia, where he taught at several universities. Perram resumed his job at the Mærsk McKinney Møller Institute in 2019.

Jorgensen Engineering, founded in 1933, provides automation to international businesses including Nestlé and Danone. Another example is Cabinplant, established in 1969, which provides automation for the fish-canning industry.

Over time, a great deal of knowledge of automation has been accumulated in Odense, where many technicians of integrator companies have mastered their craft. The same is occurring at the Technical University of Denmark in Copenhagen and at the University of Aalborg.

A significant player is the Swedish-Swiss ABB group. With its well-developed business in robotics, ABB has a well-defined footprint in Denmark, especially on Funen. ABB has produced electric motors there for years and is a trusted supplier of automation equipment for Danish companies.

ABB has focused a good deal on the Danish robotics network, DIRA, which was founded in 1982. The several hundred companies in the network draw inspiration from each other and share knowledge. For example, they regularly visit each other's production facilities to share their experience with automation. One of the main forces in DIRA is Leif Dalum, a well-known figure in the Danish automation world and founder of the integrator company ProInvent.

The shipbuilding industry needed robots

Another reason for the development of the Danish automation and robotics cluster is Denmark's shipbuilding industry. In the mid-1980s the industry was dominated by the Mærsk Group, the world's largest shipping company. The Group's shipyard in

Odense was in fierce competition with Japanese shipyards that used welding robots.

The programming of welding robots was complicated so the Group sought help from the technical faculty at the University of Odense. There, Australian professor John Perram was researching mathematical modeling of processes in the physical world and in molecular biology. This same research was then applied to robotics.

The contact evolved into a joint project, with the aim of simulating the movement of a six-axis welding robot in a working area made up of many steel plates. The task was to make the robots move in a complex pattern without hitting the plates. The coordination of each step of the simulation had to be saved and reshaped into a program that the robot itself made.

The project was called AMROSE, Autonomous Multiple Robot Operation in Structured Environments. It meant to replace the rigid, inflexible robots of the time by giving the robots flexible movements. The project provided new insights and discoveries that would later further automate ship production.

AMROSE was turned into a joint venture company between the University of Odense and Maersk. In this new context, a facility was built where four nine-axis robots were developed on a telescopic rod mounted in the hall, where ship sections were brought through for final mounting by robotic welding.

The bond between the university and the company was further strengthened in 1997 by the creation of the Mærsk McKinney Møller Institute at the Univer-

sity of Southern Denmark. The institute established after a donation of \$12 million from Mærsk McKinney Møller – at the time the largest private donation ever made to a Danish university.

The institute was launched to promote the research and study of applied mathematics, robot management as well as other technical processes associated with automation.

Despite the development of advanced welding robots, shipbuilding was never profitable in Denmark. The Maersk Group withdrew from the AMROSE collaboration in the beginning of the 2000s.

Significant roles for key players

Some of the key people who later played significant roles in the creation of the Danish automation and robotics cluster were trained and educated under the auspices of AMROSE.

This includes the founder of the Mobile Industrial Robots (MiR), Niels Jul Jacobsen, whose company in 2018 was sold to the American company Teradyne for \$250 million. Another leading figure in the Danish cluster, Claus Risager, who founded Blue Ocean Robotics, Denmark's leading supplier of service robots, worked in Maersk's development department.

Professor Ole Madsen from Aalborg University, who is now a driving force in robotics and automation research in Northern Jutland, also worked at the Maersk shipyard. He then started his own company, which patented a flexible nine-axis welding process.

During this pivotal time at the beginning of the 2000s, many talented individuals began to leave the turbulent shores of Denmark and spread their experience and know-how to the four corners of the globe. However, there was a group of firebrands



Photo: MiR

Niels Jul Jacobsen (b. 1963), CSO, Teradyne

Niels Jul Jacobsen is a civil engineer and robot developer. He has taught robotics to many students at the University of Southern Denmark. He was technical director at AMROSE. In addition, he has been project manager on numerous robotics research projects. He founded Mobile Industrial Robots (MiR) in 2011, and in 2014, he brought on Thomas Visti Jensen, former CCO, VP and co-owner of Universal Robots, as co-owner and CEO. Together with other shareholders, Jacobsen sold MiR to Teradyne for \$256 million and is, today, the Chief Strategic Officer of Teradyne. Together with his wife, Charlotte Hybsch Jacobsen, they founded a venture capital company that invests in robotics startups.



Cabinplant develops processing equipment for the food industry worldwide. With industry know-how from almost 50 years of experience, they are experts at putting all the right pieces in place to increase reliability, reduce downtime, lower operating costs and minimize waste. Today, the Berkshire Hathaway company owns 80 % of Cabinplant.

left, who were passionate about the work going on around the shipyard and the university and were determined to preserve it. It was also a priority for the Mærsk McKinney Møller Institute, local educational institutions as well as the Funen County and the city of Odense. The latter was mainly motivated by the fact that Funen had already lost many traditional industrial workplaces to offshoring to Eastern Europe and Asia, where production costs were lower.

Together, they co-founded the organization RoboCluster, with the goal of gathering the splintered pieces of the local robotics network and ensuring that research and development of automation and robotics would continue to thrive in Denmark.

RoboCluster and the university managed to secure significant research funding from the EU, as well as from the Danish government. This made it possible for the university to continue current development and research projects in collaboration with interested companies.

In 2006, the Danish Technological Institute decided to relocate its robotics department to Odense, giving support to the robotics ecosystem, where new ideas began to sprout at the Mærsk McKinney Møller Institute. From this fertile ground, many strong companies were able to grow, all as a result of the decisive investment in robotics at the institute just a few years prior.

In 2004, the company Scape Technologies was founded. Its bin-picker technology added value to production companies by automating monotonous manual tasks.

In 2005, Universal Robots was founded, which would later prove to be one of Denmark's largest business successes since the turn of the millennium. The company was sold to the American company Teradyne in 2015 for \$285 billion.

In the following years, a number of other promising companies were formed by people from the Maersk McKinney Møller Institute and Universal Robots, who benefited from the gains they earned from the sale, as well as generally improved economic conditions in the wake of the difficult years of the financial crisis.

Some companies in the cluster are linked directly to Universal Robots' success, including OnRobot, PurpleRobotics, Robot Nordic and CobotLift. Others, such as Blue Ocean Robotics, worked in collaboration with other strategic partners to develop solutions to meet market needs. Companies such as Nordbo Robotics and TriVision have found other specialized niches. MiR followed in the footsteps of Universal Robots and after just five years of existence, was sold to Teradyne, which now owns two of the Danish robotics cluster's flagship companies.

Southern Jutland, Copenhagen and Aalborg

While the robotics industry was rapidly growing on Funen, development was also occurring in Jutland and in the Danish capital region of Copenhagen since the turn of the millennium.

At Aalborg University in northern Jutland, for example, they have technical faculties specializing in automation. There also is a cluster of electronics companies near Aalborg that serve as subcontractors to the mobile phone industry and the telecommunications sector. The expertise and labor force



Photo: Gert Mørk



Photo: Gert Mørk

Mærsk Mc-Kinney Møller (1913-2012), Shipping Magnate, A.P. Møller -Maersk

Shipping magnate Mærsk Mc-Kinney Møller was the driving force behind turning the Odense Steel Shipyard, Lindø, into one of the world's most advanced shipyards. He understood that substantial resources were required for robotics research at the shipyard and, in 1997, donated a new building and operational support for the Mærsk Mc-Kinney Møller Institute, a research center for automation and robotics at the University of Odense (later called the University of Southern Denmark). His donation of \$12 million was the largest ever to a Danish educational institution from a private donor. The AP Møller Foundation has since followed up with further donations to the institute.

of these companies overlap nicely with the robotics industry. Aalborg is the home of Lasse Thomsen, who, for more than 20 years, has been the driving force behind a number of companies, initiatives and robotic inventions, including LT Automation and Life Science Robotics.

Since 1985, the northern Jutland technology company Migatronic has developed automation solutions for welding and handling. In 1988, on the northern Jutland island of Mors, a machine factory emerged which later became BILA A/S, a major integrator and subcontractor in Denmark.

Moving south to the cities of Sønderborg and Nordborg near the Danish-German national border are

the companies Danfoss (heat regulation) and Linak (actuators). These two businesses have created a demand for other subcontractors and educational institutions focusing on mechatronics, which blends the disciplines of mechanics, electronics and software together.

And finally, in the region around the Danish capital of Copenhagen, there have been multiple integrator companies that have served the region's industries for many years. ProInvent is one such company. Just north of the city is the Technical University of Denmark, where in-depth research and development is conducted and whose graduates have filled technical positions throughout Denmark and around the world.



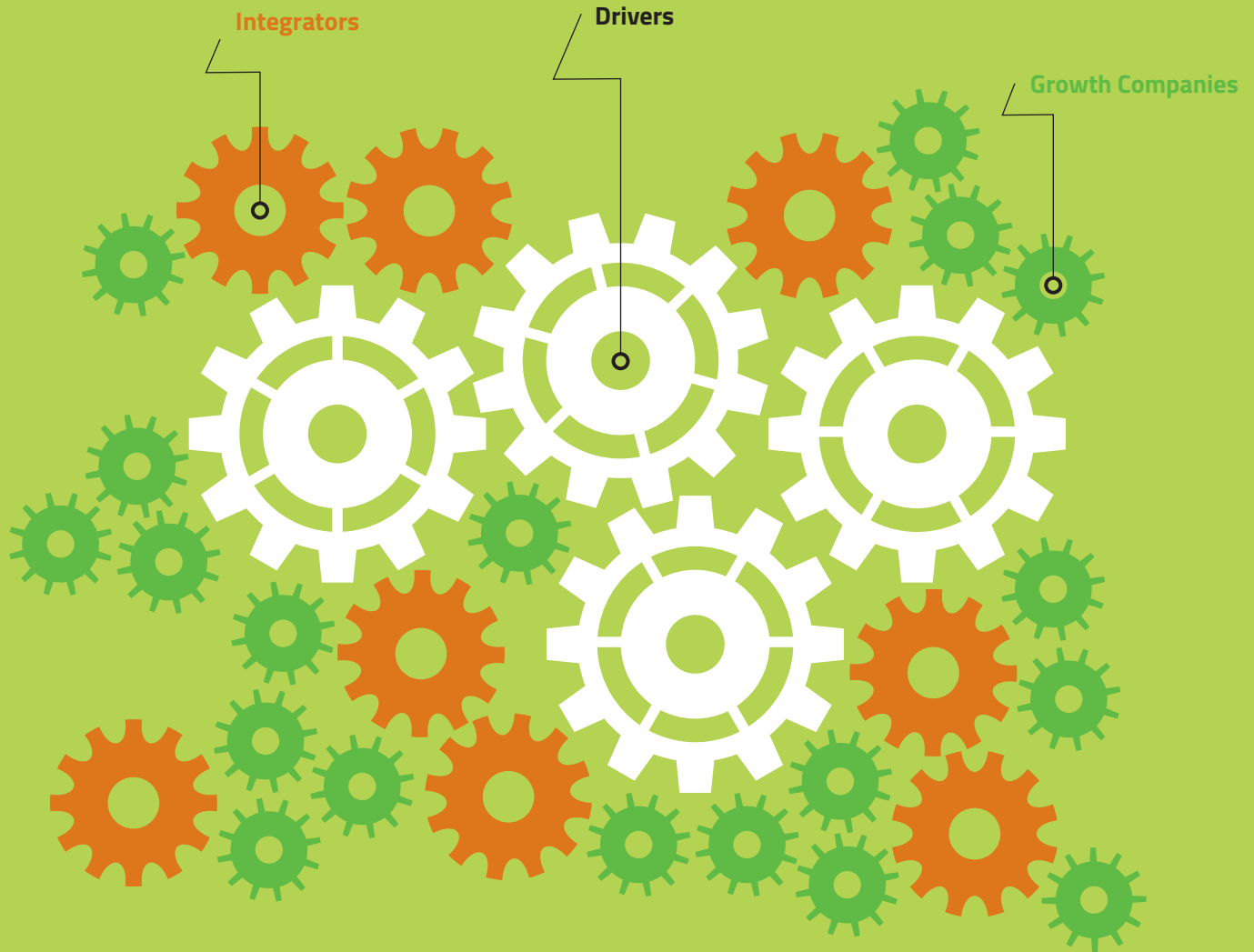
Photo: Blue Ocean Robotics

**Claus Risager (b. 1969),
Co-founder and CEO, Blue Ocean Robotics**

Claus Risager was a robotics engineer at the Odense Steel Shipyard from 1995 to 1999. Since then, he became a robotics consultant at the Danish Technological Institute and one of the driving forces behind the formation of the RoboCluster competency network. He was the founder of the Technological Institute's Robot Center in Odense in 2006 and was its leader until 2012. He has led several large interdisciplinary research, development and innovation projects focused on automation in industry. In 2013, he and two partners founded Blue Ocean Robotics, which acts as an incubator for companies developing service robots. Among other achievements, Blue Ocean Robotics cultivated UVD Robots, which markets a robot that disinfects patient rooms in hospitals.



The Mechanism of the Danish Robot Industry



The Danish Robotics Industry: Drivers, Integrators and Growth Companies

Companies in the Danish robotics and automation cluster can be divided into three categories.



The first category is made up of companies that produce industrial robots and automation solutions. These are the primary drivers of the cluster.



The second category consists of integrator companies and machine builders that supply automation solutions primarily for industrial purposes.



The third category is the growth drivers, which mainly consists of smaller robotics companies that are breaking new ground by developing robotic solutions for use outside of the factory floor.

The Drivers

The cluster's drivers, which produce robots and automation solutions.







Universal Robots Revolutionized the Robotics Industry

A Danish company, Universal Robots (UR), was the first to launch a commercially viable collaborative robot. Many competitors have since emerged, but the company still boasts well over half of the world market of collaborative robots, also known as cobots.

Universal Robots has revolutionized the robotics industry by creating a robot arm that is flexible, easy to program and relatively inexpensive – not just for large companies, but also for companies that produce small-batch series. In addition, it does not have to be fenced in as industrial robots normally do for safety reasons.

Since Universal Robots installed its first commercial six-axis UR5 robot in a small Danish company in Copenhagen in 2008, a large number of manufacturers have joined the market – including large manufacturers of industrial robots such as Swedish-Swiss ABB, Japanese Fanuc, German-Chinese Kuka, Korean Doosan, Japanese Kawasaki, American Yaskawa Motoman, Italian Comau, and others.

Another 50 manufacturers entered the market, many of them Chinese, furthermore e-commerce

giants like Alibaba and Amazon have begun to develop and implement their own cobots.

Analysis agencies estimate that the market for cobots will reach a value of \$19 billion in 2027. In 2016, 10,100 units were sold globally, and the market is expected to double in the coming years.

What kind of insight created the collaborative robots, that are now taking over the factory floor at a record pace worldwide?

It all started at the University of Southern Denmark in the Danish city of Odense, where researchers found an increasing need for robot-based automation solutions for small Danish food manufacturers. It had proven difficult to use robots because the work involved soft and fragile products like dough and meat that frequently change shape and color.

At the same time, the Danish food industry was facing increasing demands from customers to manufacture products in ever more variants, thus small batch productions.

It began with pizza dough and sausages

Through public and private funding, \$450,000 was raised for the study-project; “Flexible robots.” In his preliminary analysis, project manager Kristian



Jürgen von Hollen, President, Universal Robots.

Kassow found that robots – in principle – could solve a large number of tasks for the participating smaller companies, e.g. place cake molds on a conveyor, put bread bags in cardboard boxes, and add sausage to pizza dough. But it was not feasible to acquire stationary robots to solve each of these types of tasks. The robots were simply too expensive to operate in small batch production efforts.

However, a movable, flexible robot was an interesting concept, as it could solve more tasks and change production modes at a more rapid pace.

Kristian Kassow and the other participants in the research project built a prototype, a movable robot based on ABB's most suitable industrial robot. The robot could only handle lightweight items of about 2.2 lbs., and the robot arm itself weighed 216 lbs. The robot's electronics cabinet weighed 551 lbs.

The programming was done by entering commands, a bit like the MS-DOS programming – the first programming language in IBM's PCs of the mid-1980s.

Robot programming is about defining the points and curves of a space. Based on the new graphical user interfaces developed for professional 3D drawing applications, Kassow thought it logical to create a more graphically oriented programming language for robots, which did not require learning a command syntax.

Kassow thought it possible to make an industrial robot that weighed less, cost less, and was easier to use for people who could not program.

A civil engineer specializing in mechanics, Kassow founded a partnership with Esben Østergaard, 1998 world champion in robot soccer and assistant professor of robotics and robotics scientist Kasper Støj.

Together, the three founded Universal Robots (UR). The name had a magical ring to it in robotic circles because it derives from the Czech author Karel Capek's famous play from 1921 about the robot

builder Rossum's universal robots, which eventually revolt against the humans that they were meant to work for.

After three years of experimenting, they created the first commercial UR robot with financing from a smaller state-owned Danish venture company, Science Ventures Denmark. The robot rotated around six axes and had a lifting ability of 11 lbs. The rotation speed reached 180 degrees per second and precision ended up reaching a low 0.004 inches. However, the robot ended up weighing 41 lbs., eight pounds more than expected when the development process began. But, it was far less than the 77 - 220 lbs. a typical industrial robot with similar range and lifting capacity weighed at that time.

The price tag was also higher than the founders had originally imagined. The factory price was about \$16,000. However, it was significantly cheaper than other, smaller robots available on the market in the second half of the '00s. UR's robot was also the first to be operated via a touch screen with a graphical user interface.

Through a comprehensive testing procedure at the Danish Technological Institute, UR had confirmation that the robot would be able to function satisfactorily and safely without shielding. This would prove to be a crucial selling point.

The rest is history

The rest, as they say, is history. But, it was also a turning point in history.

The Danish market was excited about the new, affordable and flexible robot. The Danish state-

owned Growth Fund pumped capital in UR, and the new commercial management with Enrico Krog Iversen as CEO was introduced. From the beginning, Universal Robots communicated that the company did not sell technology but reduced production costs.

At the same time, an aggressive PR strategy was put in place, with Universal Robots consistently telling the story of where the company would be in two years. The trust in the robots, a new, untested product in the market, was built through up with testimonials from end-users eagerly sharing how they strengthened their competitiveness using the Danish robot arms.

Product development followed a technical roadmap outlining the path of development of robots ahead of the company's 22 lbs. robot UR10, launched in 2012. Two years later, a new generation of Universal Robots' robot arms was launched on the market.

During the process, Universal Robots focused only on the robot arm. The implementation of the robots in production was a task for Universal Robots' distributors, including many integrators. The distributor network was expanded globally in 2015 when the company was sold to the American company Teradyne, which had decided to invest in the Industrial Automation (IA) business arena. In the meantime, not only smaller companies, but also large ones such as the German automobile manufacturer BMW, had signed on as customers.

During the development process, one of the original founders, Kristian Kassow, left Universal Robots to start his own business, while co-founder Esben



SHAD, a Spanish manufacturer of accessories for motorcycles, deploys Danish cobots in their facility, optimizing their production line and improving the work environment of their employees.



Photo: Universal Robots

Universal Robots has strong momentum in the United States, where there are still enormous growth opportunities. This is partly due to the fact that the US market is teeming with smaller manufacturing companies that are gradually starting to use robots, and will have to in the future if they want to survive. Pictured here is RCM Industries, which used cobots to counteract increased competition from similar manufacturers in Mexico.

Østergaard stayed on as Technical Director until 2019 and then settled as a business angel and tech entrepreneur for ReInvest Robotics.

By the time Teradyne acquired UR, its annual revenue had reached \$62 million, with an operating profit of \$8 million, and employing 154 people.

In 2018, the revenue had tripled to \$220 million, the operating profit reached \$43 million, and the num-

ber of employees had risen to 489. The result was a 20 percent profit margin.

New platform paves the way for Universal Robots' products

While the task in the pioneering years was to develop the robots and build a sales and service apparatus, Teradyne's ownership's goal became to exploit the global sales potential for cobots that analyses had forecast.

In a world that is increasingly characterized by instability, UR sells the message that cobots are what companies need during unstable times – a production apparatus with great flexibility.

For this purpose, the specialized product platform, UR+, developed by Universal Robots for application developers, plays a crucial role.

Universal Robots is focused on further developing and refining the robot arm itself while leaving the application to developers, just as Apple had successfully done it with its iPhone.

Hundreds of products are tested and approved to work with cobots from UR. From grippers and accessories to vision systems and software. These UR+ products are collected on one portal (<https://www.universal-robots.com/plus/>.)

The big ones defined cobots wrong

Universal Robot's president, Jürgen von Hollen, does not see UR's many competitors as their biggest challenge.

"We have over 50 competitors, but many of them have only just begun within the last 18 months. They only have a concept. Our biggest challenge is dealing with customers who are in doubt about whether they should automate or wait. If you have an old CNC machine, you may not be thinking of additional automation, unless you can see specifically what a robot can do for you. We need to bring that insight to our customers. Together with our distributors and integrators, we help them invest in automation," says von Hollen.

He points to UR's business model as a determining factor, where you help the customers obtain proof of concept, so robots come into play, possibly on financing or leasing terms. The distributor-network and developer-community that Universal Robots has built is not that easy to emulate.

Through the years, many have wondered why the big traditional manufacturers of industrial robots left the cobot market to Universal Robots and didn't target it aggressively until later.

"We are so lucky that the conventional players defined cobots wrong. When they saw what Universal Robots was doing, they said; 'It's about safety.' Safety gets you into the game, but it is the intuitive design and robot user-friendliness that is key. The conventional competitors have made their cobots safe, but they use the same software as they have used for the big industrial robots," states von Hollen.

Today, Universal Robots works closely with Energid in Cambridge, Massachusetts, which Teradyne acquired in 2018 as part of their investment in IA. Energid has developed robotic control systems, simulation software and vision systems. The expectation is to create synergy across companies, as is the case with the other large Teradyne-owned Danish company, Mobile Industrial Robots (MiR).

www.universal-robots.com



Mobile Industrial Robots Optimize Logistics in Global Industry

The Danish manufacturer is in the process of capturing the world market for internal transportation.

Niels Jul Jacobsen is one of the veterans of the Danish robotics world. He has taught and researched robotics at the University of Southern Denmark and co-founded the pioneering company, AMROSE, which provided the first nine-axle flexible welding systems for the now-defunct Odense Steel Shipyard.

He knows all about technical robot development. In 2013, Jacobsen succeeded in designing a mobile robot, which industries found feasible using to automate internal logistics. Today he remains in the top management of MiR, which have conquered 60-70 percent of the world market for mobile robots used for internal transportation. In total, 4000 mobile robots have been built in Odense and delivered to factories all over the world.

The mobile robots can replace both conveyor belts, trucks and employees who manually push carts around in a production or workspace. The technology improves the working environment and optimizes logistics at the same time.

"There are many mobile transport robots on the market, but most are not sufficiently user-friendly or profitable. If robots with internal transportation tasks are to pay for themselves, the payback period must be less than two years. And that's what we have managed with our mobile transport robots.

If the robots cannot do enough work compared to the total cost, they will not be sold. That is the challenge we have solved at Mobile Industrial Robots," explains Jacobsen.

The robot must be able to move autonomously and drive around obstacles – whether it is things or people. The safety requirement dictates that the robot should be able to drive among humans and collaborate with them. The founder of MiR solved this challenge by designing a mobile robot, based on standard components at a time when both computing and vision systems were taking huge technological leaps while simultaneously decreasing in price. To navigate, the MiR robots use laser scanners and 3D cameras, which help the robot locate themselves and see obstacles. In addition, Jacobsen and his developer team understood from the start how to program efficient and robust algorithms that could interpret all the information the robot collects on its way. That is how the MiR's robots run independently and safely.



Photo: MiR

Thomas Visti, CEO, Mobile Industrial Robots.

The MiR100 was MiR's first robot, but the assortment of MiR-robots has expanded, and they have developed further since. They have gained greater lifting capacity, reach, pallet-size models, option to pull carts with a hook as well as a loading capacity from 220 to 2.205 lbs.

The sale of MiR's robots were kickstarted in 2014 when Niels Jul Jacobsen hired Thomas Visti, former Universal Robots sales director, as its new CEO and co-owner.

"It's part of our company's DNA that we are first-movers. We operate in a market with extremely high potential, and we are constantly setting new standards for internal logistics robots with innova-

tive features that meet customer needs. We have chosen to think big and to go global from the very beginning, which is why we are market leaders in our field today," says CEO Visti.

MiR has thus succeeded in becoming a supplier to the giants in the global industry, which uses the technology from Funen, Denmark, to optimize and automate their internal logistics at factories around the world. Today, MiR's robots are moving components around in manufacturing environments, but also, for example, sterile equipment and medicine in hospitals.

"At Universal Robots, we were first-movers with cobots. Many of the customers were small companies but they had an idea of what they needed a robot for – to perform very specific tasks. Here [at MiR] we became first-movers by teaching distributors and end-customers to rethink and streamline their entire internal logistics with the new possibilities of our technology," explains CEO Visti.

The big clients have a clear business case

Unlike UR's first customers, many of MiR's customers are large, multinational companies. The first companies to test and implement the new transportation technology were primarily from the automobile and electronics industries, but today, MiR covers a wide range of other segments and has high hopes for the logistics and e-commerce segment, among others. MiR's customers today include companies such as the Dutch Unilever, Japanese Toyota, American Ford, German DHL, British Honeywell, and French-English Airbus. That's because, according to Visti, the big companies have the resources to be first with new technology,



ICM, a wholesaler in Odense, Denmark, automates logistics with locally-produced robots. The company's high-rise warehouse utilizes a mix of employees, mobile robots and trucks. Their typical setup uses three mobile robots, three manned trucks, 10 manual stackers and 26 dedicated employees.

Mobile robots have significantly increased the efficiency of ICM. They have also improved working conditions for employees, who do not have to spend a total of 40 hours a week manually running pallets on a stacker to and from the high-rise storage facility.

just like they have big factories of corresponding big potential for optimization of internal transportation. In the long term, MiR is confident that medium-sized companies will also adapt to the technology to make the best use of their employee resources.

The potential is great. MiR points out that 1.3 million forklifts are sold globally a year. That is an indicator of how much of the internal transportation can be automated with mobile robots.

The pace depends to some extent on when more production companies go over to flexible modular production. The expectation is that factories of the future are built with mobile robots in mind. ABI Research forecasts a steep growth for mobile robots; and by 2030, annual sales will reach six million mobile robots.

“Today, mobile robots are primarily installed in existing production environments, where we install 15-20 mobile robots per factory. In the factories of the future, we expect mobile robots to be included in the layout, and we envision 75-100 robots per site,” says CEO Visti.

In 2018, MiR’s revenue rounded \$30 million. In the same year, American Teradyne, which also owns UR, purchased MiR for \$250 million. Prior to that, Esben Østergaard, founder of Universal Robots and now a robot entrepreneur, had invested in MiR, as did the two business angels, Torben Frigaard Rasmussen and Søren Juul Jørgensen.

There is room for further development in MiR as new technologies are emerging.

“Our goal should be for robots to differentiate between different people, for example via voice or face recognition. It could be that a robot has to deliver something to a certain person, e.g. medicine in a hospital. And to give robots an understanding of human intent so it can make the decision: should it avoid or interact?” says MiR’s founder Niels Jul Jacobsen.

Therefore, in 2019, MiR introduced artificial intelligence (AI) to the navigation system in their mobile robots. This allows the robots to recognize different dynamic elements, such as a person and a forklift, and subsequently act on it. These are the first steps on the road to more intelligent mobile robots that interact even more effectively with their surroundings.

MiR now has the same owner as the Boston-based company AutoGuide, which Teradyne acquired in late 2019. AutoGuide manufactures mobile robots and other vehicles for carrying heavier items and these can complement MiR’s mobile robots.

www.mobile-industrial-robots.com

Teradyne Aims to be a Major Player in Industrial Automation

CEO Mark Jagiela: "The ROI offered by Danish companies to customers is attractive, regardless of economic conditions."

Teradyne is a renowned American developer and manufacturer of semiconductor test equipment. Teradyne, headquartered in North Reading, Massachusetts, had a revenue of \$2.1 billion in 2018 and employs 5,000 worldwide.

Under CEO Mark Jagiela's leadership, Teradyne started in 2015 to look for business areas that could complement their already successful (but a bit dated) test application business.

Among several alternatives, industrial automation (IA) stood out. As part of the establishment of this new business area, Teradyne purchased two of the leaders in the Danish automation and robotics cluster, Universal Robots and MiR.

Teradyne has already invested almost \$677 million in the two Danish companies, which happen to be located in the same Danish city, Odense. According to Jagiela, Teradyne expects that sales of cobots and mobile robots from the two Danish companies and their sister companies will reach \$2 billion by 2025.

For a U.S.-listed company such as Teradyne, it is crucial to live up to shareholders' expectations – both in the short and long-term. If not, shareholders expect their money back in the form of, for example, stock buybacks or extraordinary dividends.

So why go all in on IA, when you have a proven test application business with good returns? Jagiela is not in doubt:

"Our test business has a growth rate on par with GDP annually. This is not bad, but it is not very exciting for shareholders or employees. Therefore, shareholders allow us to invest in businesses that are related to Teradyne's core business, provided we can deliver and create success. The truth is, if our investments in IA had failed, shareholders would be very reluctant to allow us to pursue these opportunities. But the fact that the acquisitions of Universal Robots and Mobile Industrial Robots have been a spectacular success has given them more confidence and encouraged us to do more. The returns we have been able to generate in this business are much better than what they could have achieved through alternative investments."



In the long term, Teradyne's CEO sees several synergies between the group's companies within IA.

Over time, both local integration and cross-border cooperation will take place. In this context, it is important that Teradyne, as a parent company, contribute more than monetary resources.

As an example, Jagiela points to the companies' supply chain, where Teradyne has ensured that the Danish companies have a higher status with the subcontractors, which has yielded advantages in both quality and cost. And Teradyne has helped businesses with local expansion, for instance, MIR's Japanese branch is now sharing an office with Teradyne in Tokyo.

The importance of the right portfolio

Strategically, Jagiela points out that Teradyne will assist the Danish companies by putting together the right portfolio of IA companies that can help each other and create synergy.

Jagiela is not afraid Teradyne's IA business will suffer during a recession:

"The return on investment that Universal Robots and MIR offer customers is significant regardless of the macroeconomic climate, but I believe that human nature and companies may not always work logically. Therefore, a recession will also have an impact on Universal Robots and MIR's business in the form of a short-term decline. But when one comes out of the next recession, their business will be even better. However, when customers increase activity again, they will be even more interested in automation. This will in turn make the business model stronger."

Jagiela envisions that Teradyne's IA business will eventually be larger than the group's test application business:

"It may happen by 2025 if all goes well. We want to buy more IA companies, which we add more value than they can manage individually."

He predicts that one day they will achieve critical mass with a revenue of \$1 billion and recognizes that there are possible scenarios in which Teradyne is no longer the right owner.

"It's always possible, even if it's hard to think about right now. A business case for a new owner is hard to spot, but in the business world, anything can happen. The outcome will depend on what is best for Teradyne's shareholders and what is best for Teradyne," Jagiela says.



OnRobot to be a Total Supplier in Robot Applications

Large investments in making a Danish company the biggest in robotic tools for leading brands.

The flexible six-axis Danish-developed cobot from Universal Robots has many application possibilities. But to create value for the customer, it must be fitted with effective tools such as grippers, sensors, vision systems, and programming software – all the things that make the robot solve tasks in a production flow.

That is the way it is for all cobots, regardless of make. However, where do customers find the tools that make it possible for cobots to create value?

The easiest, of course, would be if they could find them all from one source. And that's exactly the solution that Denmark-based OnRobot A/S set out to offer its customers.

OnRobot A/S was established in 2018 as a merger of three smaller and innovative robotic tooling companies that develop and produce tools for collaborative robot applications robots:

Denmark-based On Robot, which the new group has taken its name from, the Hungarian-based Op-toForce and the U.S.-based Perception Robotics.

The group's entrepreneurs used their robotics industry background to develop a power-based cable-free gripper. It is adjustable so it can lift both a cream puff and a 4 lb. metal block. It also features force/torque sensors that bring the sense of touch to production, and a gecko-inspired gripper for handling large, flat objects, using the unique sticking technique with millions of small fibers adhering to smooth surfaces.

Since then, several companies have been acquired. This applies to the Danish Purple Robotics, where former Universal Robots employees developed a double vacuum-gripping arm with suction cups. Also, OnRobot bought the assets of the Danish bankrupt corporation, Blue Workforce A/S, that built an automation platform for handling and packaging in the industry. More acquisitions are expected in the coming years.

Experienced director and investors are experts in executing

The strategy behind the OnRobot group is formulated by Enrico Krog Iversen, now CEO of OnRobot, and former CEO of Universal Robots for eight years.

Through the sale of Universal Robots to Teradyne, the Krog-Iversen family has gained close to \$110 million. Part of the money is now invested in OnRobot, in which Danish Growth Fund and the



Photo: OnRobot

Thanks to the automation solution from OnRobot, the small-series manufacturer Donk Industries in the Netherlands can counteract the shortage of skilled workers. Employees now have more time to concentrate on demanding tasks such as technical drawings or quality inspection. To handle individual products, Donk Industries has developed special gripper tips that employees can mount to the OnRobot grippers in just a few minutes.

American venture fund Summit has also stamped in as shareholders. Enrico Krog Iversen would like to see another \$85 million invested in OnRobot to get the company where it needs to be.

In the fall of 2019, OnRobot launched the WebLogic system, which makes it possible to program robots from eight of the largest manufacturers on one platform. In fact, WebLogic can be used in simple

applications in all robots – the only requirement is digital control in the form of a digital input-output feature, and they all have that.

The new and common mechanical and electronic interface for all OnRobot's end-of-arm tools can be used together with a wide selection of collaborative and lightweight industrial robot brands. An additional Dual Quick Changer has the same new

features, but at the same time, it allows you to use two tools in the same cycle.

Enrico Krog Iversen and the other shareholders in OnRobot are risk-takers but expect a large return over time. Of course, it depends on market trends, but as investors, they are confident that OnRobot is a solid player in the end-of-arm applications for robots on the global market by 2024-25.

Feasibility is fueled by the steep increase in sales of collaborative robots worldwide. According to IFR, 14,000 cobots were sold in 2018, an increase of 3,000 compared to the year before. Yet, they only represent a fraction of the combined 419,000 industrial robots sold worldwide the same year.

However, according to forecasts from reputable analysis agencies, the world market for cobots will grow by 31 percent a year from \$710 million in 2018 to \$12.3 billion in 2025. This is mainly due to its low cost, which facilitates the installation of cobots in small and midsize enterprises, as well as increasing investment in larger companies related to Industry 4.0, improved human-machine interfaces, and increased use of AI to mimic human behavior.

OnRobot's opportunity to exploit this potential is mostly about execution. And Enrico Krog Iversen has shown his abilities on this front at Universal Robots.

A whole new task

He is, however, well aware that this job is different.

"At Universal Robots, we gradually built the organization with only one product to sell. Here we have

50 products, and at the same time, we are building an organization of a number of acquired companies and a large global distributor network. It is a complex task," says Iversen.

It doesn't make it any less complex that there are more players on the market with the same business idea as OnRobot.

Canadian Robotiq is certainly one, offering a wide selection of accessories for collaborative robots. Robotiq has established a European headquarters in Lyon, France and has 190 distributors worldwide. Behind the Canadian company, which has 10 years of experience, also has investors in the venture capital industry.

OnRobot is similarly busy expanding its global distributor network – among them, integrators that help small and midsize enterprises integrate automation solutions using flexible robots.

"The job is to train distributors and integrators to sell value. Many integrators are technicians, not distributors. But we have to go out and sell these solutions to end customers. We need to make them understand what they can use these new technologies for," says Iversen.

www.onrobot.com





Blue Ocean Robotics Serves as a Venture Factory for Robotics Companies

The Danish company develops service robots in close collaboration with customers.

It's no coincidence that the business book *Blue Ocean Strategy* has sold millions of copies since it hit the streets in 2005. The two authors, professors W. Chan Kim and Renée Mauborgne from the INSEAD business school in France, advised companies to avoid the fierce competition-wave on the "Red Sea." Instead, they advised to ride the waves of the blue ocean and create their own market through creativity and new ideas.

Claus Risager, software engineer, former head of the Danish Technological Institute's robotics department and veteran of the Danish robotics environment, adopted the message early on.

The same can be said of Rune K. Larsen and John Erland Østergaard. They are also veterans of the Danish robotics environment. First mentioned as the former director of the robotic companies AMROSE and Scape Technologies and head of the robotics network RoboCluster, the latter as professor and head of department at the University of Southern Denmark's MMI Institute.

These three robotics veterans founded Blue Ocean Robotics, which has become what they call the world's first "Robot Venture Factory." The company develops professional service robots from problem, idea and design to commercialization and scaling.

Each of their developed robots belongs to its own subsidiary with separate sales, customer service, support and everything else aimed at the market and customers globally. The parent company handles all development and production of the robots and owns the IP rights to the technology.

Disinfection, mink, and beam

Following this concept, one of these robots developed by Blue Ocean Robotics is the so-called UVD robot. The robot is developed, produced and marketed for ultraviolet disinfection of e.g. hospitals and won the robot industry's Oscar equivalent, the IERA Award, in 2019.

In collaboration with a Danish company, Hedensted Group, Blue Ocean Robotics has also developed a feeding robot that automates the feeding of mink on mink farms, thereby increasing the mink farms' earnings by \$3 per fur.

Equally significantly, Blue Ocean Robotics has acquired all assets and rights to the robot Beam from Silicon Valley-based Suitable Technologies, Inc. By the end of 2019; however, formal approval of the deal was pending from a U.S. court.

Beam is a remote-controlled mobile robot that allows communication via a screen, camera, and

microphone, and can be navigated to be mobile in the farthest corners of the globe – a so-called “telepresence robot.”

A number of other service robots are being developed in collaboration with potential customers.

The three founders of Blue Ocean Robotics, Claus Risager, John Erland Østergaard, and Rune K. Larsen, have built their business upon an important insight they have gained by virtue of many years in robotics: the difficult part is not to design and develop robots. The difficult part is getting customers to use them.

And the latter is more a matter of organization than engineering. Therefore, robots must be developed based on customer needs and offered with a financial plan. This is how you sell a successful robot to a wider market.

The key is to industrialize the very difficult process of moving from idea to design, development, commercialization, and finally to a mature company with profits.

All of Blue Ocean's mobile robots are developed and produced by recycling a set of generically usable modules/components. The methods, IT systems, and even contracts with distributors, customer service systems, purchase-, sales-, leasing-, and RaaS- (Robot as a Service) models are reusable from robot to robot. This makes the entire factory efficient, but also ensures a significantly lower risk for each new robot that is developed.

2018 was the worst year ever for the robotics industry. Never before have so many robotic companies gone bankrupt. This was partly due to the record amount of new startup robot companies, but it also shows that no matter how much capital is avail-



Photo: Blue Ocean Robotics

Rune K. Larsen (b. 1965), Co-founder and Director of Blue Ocean Robotics

Rune K. Larsen is the focal point for many activities in the Danish robotics environment, where he has been active as a manager, owner, adviser and business developer. Among other things, he has been director of AMROSE, the first company in Odense, which worked with welding robots for shipyards. He has also been the director of the network organization, RoboCluster, as well as being in the management of the bin-picking company Scape Technologies. For many years, he was an advisor at the Technological Institute's robotics department.



The telepresence robot Beam is all about enabling people to connect with each other in a more human way no matter where they are physically. Blue Ocean Robotics acquired all assets and rights associated with Beam® from Sutable Technologies, Inc. in Silicon Valley. The execution of the agreement is subject to a formal approval in the United States.

able, a high degree of competence, technology and foolproof strategy must be present for a business to become a success. And this industrialization of robot entrepreneurship is what Blue Ocean Robotics is aiming for.

The original idea was to build a portfolio of products to reduce risk while ensuring market access through customers.

Since then, Blue Ocean Robotics has attracted venture capital and adjusted its concept. It is still based on customer involvement in the development phase and as a test partner, however, now to a lesser extent based on customer co-financing. Blue Ocean Robotics has been able to afford to take on a greater part of the risk, thus allowing the opportunity to make a bigger part of the profit if the robot development is successful.

Explosive growth in service robots

Blue Ocean Robotics' business model is established against the backdrop of the explosive growth in demand for service robots. According to IRF, 100,000 service robots were sold in 2018. In 2021, sales doubled to 200,000. That's the growth forecast that Blue Ocean Robotics has its sights set on.

In particular, the company is targeting the health, construction and agriculture sectors. All of these have low productivity growth, and they are pressured by developments in wages and work environments.

For the health sector, Blue Ocean Robotics has developed PTR Robots. It is a robot tasked with safely transferring and rehabilitate patients in hospitals, care centers, rehabilitation centers, and the like. The

PTR robot is advantageous because of its mobility, but also because it combines the transfer process and rehabilitation – the first of its kind on the market.

"We are in contact with many customers who are inquiring about making a robot for a specific purpose. At any given point, we have 100 ideas on the table. Therefore, we have to be selective – and go with a handful. We don't have the resources to handle them all," explains Claus Risager.

Blue Ocean Robotics manufactures all its robots themselves, though largely outsourcing smaller modules and components. For each robot, they have established a subsidiary that can be sold when the robot and the market it caters to has become more mature.

The production strategy of Blue Ocean Robotics is "Asset Light." The company mounts, tests and packages. All inventory management is done by subcontractors. All the basic components such as screws, bolts, circuit boards, controller systems and motors are insourced, as well as smaller modules that are not platform-based. The main modules are unique to each product.

Backed by dansk venture capital investors, the main mission of Blue Ocean robotics is to focus on service robots with large global growth potential, such as the sterilization robot, UVD, meeting the needs of hospitals around the world.

"It's about creating robotic inventions that have value in what they can offer customers," says Risager.

www.blue-ocean-robotics.com



Photo: Gibotech

Integrators

Integrator companies and machine builders supply automation solutions primarily for industrial purposes.

Among other things, Gibotech builds facilities for Norwegian fish factories, where robots improve working conditions and reduce sick leave. In the past, employees had to manually lift 50 to 150 pounds of frozen fish. Now the robots can handle the heavy lifting.

Jorgensen Engineering Automates for the World's Largest Food Companies

Tight project management, Scandinavian management and extensive experience have paved the way for the Danish integrator company.

The Danish island of Funen has been known for its production of vegetables and fruits for centuries.

Plantation owners traditionally picked, measured, weighed and packed their products but were looking to get help from machines.

When Rasmus Bøg Jørgensen, a Danish engineer, returned to Funen in 1933 after a stay in the U.S., he saw this need and founded his business.

Today Jorgensen Engineering is a leading supplier and integrator of production lines and packaging management systems. The company's customers are world-leading players in milk powder, food, pharmaceutical articles, and animal feed. Europe is the largest market with companies such as Danone, Arla, and Nestlé as key customers.

Jorgensen's orders are obtained in competition with large machine builders such as German Krohns and others with many thousands of employees.

The course was altered

Jorgensen in Odense employs 140, all of whom specialize in automation. The company's growth took off in 2003 when a new management team headed by CEO Jens Nyeng altered the course.

Instead of building machines for smaller local customers, Jorgensen aimed to be a project supplier and only manufacture special key machines. The expertise was developed to focus on controlling plants and integrate robots, among other things.

That strategy has proven to lead to growth and development – so much so that the Swedish XANO group decided to buy Jorgensen in 2016. Today Jorgensen has a revenue of about \$45 million.

Nyeng emphasizes that Jorgensen is a company with Scandinavian leadership characterized by openness and a flat hierarchy. Everyone has something to contribute and the company is transparent, which is noticeable on a practical level as soon as you enter the door in the main office where almost all space separations are made of glass.

Jorgensen's agenda these days is characterized by the thinking of Industry 4.0, where the digital and the physical world are merging. The plants developed by Jorgensen are simulated and emulated on the computer first so that the customer can see a model of how they will work in practice.

"We develop a whole lot of machines – but in fact, we don't sell machines, we sell safety and confi-



CEO Jens Nyeng reshaped Jorgensen's strategy in 2003. Since then, they have experienced strong growth.

dence. We sell solutions based on deep and broad knowledge and experience with automation,” says Nyeng.

This makes good sense for the customer, but also for Jorgensen, who has made a profit every year since 2003.

Project management is the key to success

The key to Jorgensen's success as an integrator is project management. All projects are managed in an agile stage/gate model. Every Friday, the management reviews the current 20-30 projects, the number of projects that Jorgensen is working on at all times.

In this process, Nyeng sees himself as the customer's representative, whereas CFO is ready with a whip while the engineers involved continuously assess the technical challenges presented in the solution proposal presented by the project manager.

For Jorgensen and the customers, it is all about quality and safety, including traceability. The milk

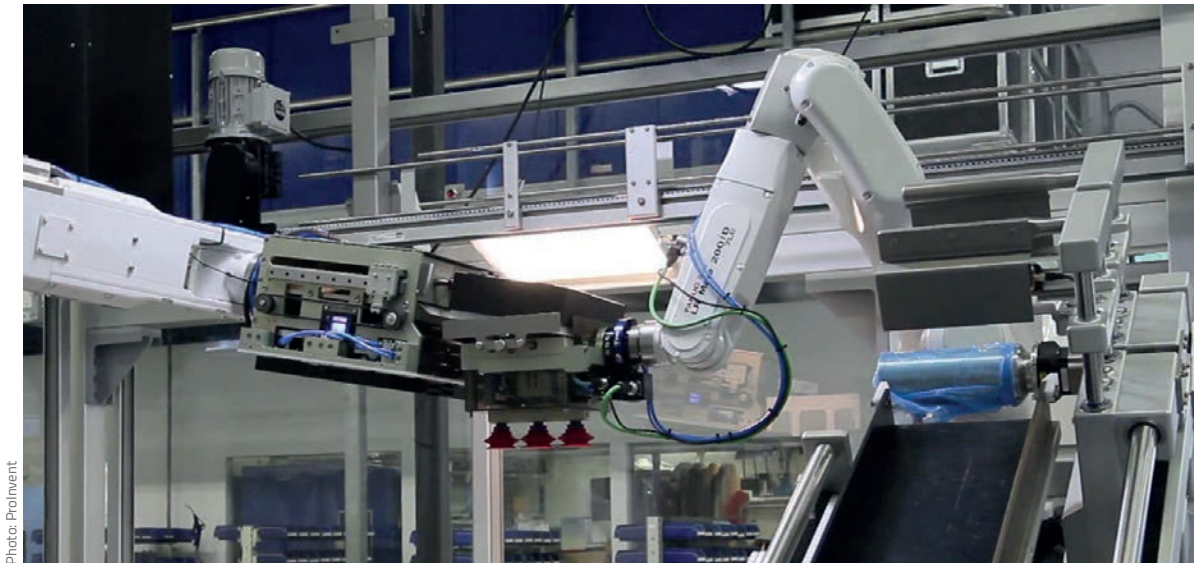
powder scandal in China in 2008 - when intermediaries added melanin to milk powder - cost Danone, Arla and other major food companies millions, even though they had nothing to do with the scandal.

Now, however, the scandal benefits Jorgensen, because manufacturers, including those based in China, are demanding European machine suppliers to help give Chinese consumers a sense of security.

As a machine builder and integrator, Jorgensen sees itself as part of the Danish robotics cluster. The related educations at the Denmark educational institutions benefit Jorgensen in the recruitment process.

However, Nyeng emphasizes that the cluster focuses more on automation than on robots. The robots are only one component, albeit a significant one, in a production line. Value add is created by delivering to the entire value chain that is in automation.

www.jorgensen.dk



In 2019 ProInvent developed a production system which is able to inspect, all in one go, up to 400 small glass vials for medical drugs, or "cartridges", for chips and cracks. These cartridges arrive from the glass manufacturers in standardised boxes on pallets, and the heavy and monotonous workflows have now been switched from manual to robotized processes.

ProInvent provides integrated product and production development

Major Danish companies in the medical-equipment and pharmaceutical industries have turned to ProInvent to assist them with innovative product development and to develop and build their manufacturing lines. The aim is full automation using production droids.

Leif Dalum, M.Sc. Eng., founder and main owner of the product and technology development company ProInvent A/S, holds up a small plastic object that is distinctively shaped in both ends.

The object is actually a medico-technical product which ProInvent helped develop for a major client. It is more hygienic, practical and private, than older models on the market.

And it is a product which Leif Dalum is particularly proud to show - as a great example of what ProInvent is capable of performing.

The goal is to help the client in order to develop an innovative product, that can be manufactured in a fully automated process. To accomplish this, all product development and production planning must take place in a parallel process, which was exactly the case here.

"For many years it has been my mission to help Danish companies automate even the most difficult processes - not least in order to maintain part of the manufacturing industry in Denmark. Now I see it as my job to assist in the development of new Danish products that can be manufactured in our fully automated lines wherever they are marketed and sold," Leif Dalum says.

A quantum leap forward

ProInvent was founded by Leif Dalum back in 1994, and celebrated its 25th anniversary in 2019. Over

the years, ProInvent has built a large number of innovative automated manufacturing lines for Danish companies, being a pioneer in vision guided robots.

For example, in 2004 ProInvent developed a production system for Pressalit, a Danish manufacturer of toilet seats with several hundred production variants. The assembly line included 10 robots, 12 component feeders, 36 cameras and a through-going transport system without fixtures. Instead of expensive fixtures, vision is used for positioning seats and lids on the belt, and the feeding of components takes place by means of flexible feeders - using vision guidance as well. This assembly line was a great leap forward for both ProInvent and Pressalit.

"We succeeded because Pressalit allowed us to change the design of the components in a DFM process, and because they were very skilled in using the new vision and robot technology that we were developing. We are pioneers, and succeeded in making the most advanced industrial vision-



Photo: ProInvent

Leif Dalum (b. 1958), CEO, ProInvent

Leif Dalum is a trained civil engineer and has been involved in integrated product development, automation and robots for most of his professional life. He founded the technology development company ProInvent in 1994 and chaired the DIRA automation and robotic network from 1996 to 2010. Dalum and ProInvent have been responsible for the implementation of hundreds of automation projects in Danish and foreign industrial companies.

and robot technology at the time," Leif Dalum notes. Today, the assembly line is still well functioning and is the subject of much focus and interest from both manufacturing professionals and technologists across the world.

In 2019, ProInvent acted as pioneers by developing a production system that is able to simultaneously inspect up to 400 small cartridges for medical drugs, for chips and cracks. These cartridges arrive from the glass manufacturers in standardised boxes on pallets, and the heavy and monotonous workflows is now switched from manual to robotized processes.

Today, the collaboration between humans and robots is typically that men performs the heaviest and most difficult tasks. But, in the cartridges project, robots collaborate with other robots in 3D coordinated movements, and vision guidance enables the robots to solve the tasks so that everything works fully automatically

Developing production droids

While other integrators and machine builders work to make new flexible robots that are able to collaborate with humans, ProInvent has increased its ambitions and focus on full automation - again as a pioneer in advanced robot technology, this time with 3D coordinated movements at two armed robots. Leif Dalum points out, that even complex and challenging tasks which are difficult to automate, ProInvent is now able to automate. This is possible using multi-armed robots, equipped with advanced vision systems and tactile sensors. The robots are vision guided and have auto-calibration systems. This enables them to work with great precision and accuracy in repetition.

Leif Dalum refers to these robots as "production droids", developed by ProInvent for the pharmaceutical industry.

As Leif Dalum sees it as, the need for human input mainly lies in the development of products and production systems, as well as in maintenance.

ProInvent has 62 employees, growing and is now a one-stop-shop providing both product development and production lines for leading Danish and foreign companies. ProInvent's competitors are primarily large progressive German machine developers and robot integrators.

Yet, ProInvent sees itself as an important member of the Danish robotics cluster which in Leif Dalum's opinion, should aim specifically to meet the innovation and automation needs of major leading players in the production industry.

www.proinvent.dk

Picca

Picca is an automation company headquartered in Søborg near Copenhagen with branches throughout Denmark. Picca develops automation management software for a wide range of processing and production companies within the energy, pharmaceutical, industrial and food sectors. The company was founded in 1988 and today has 100 employees.

www.picca.dk

Vision technology from Trivision halves food waste in production, helping to fulfill the UN's global goal of reducing food waste from farm to table. Trivision's technology saves around 10,000 tons of food waste globally each year, across 25 countries. Vision technology captures and analyzes images based on predetermined characteristics, so that food, packaging or label defects are detected immediately and production can be rectified immediately. This means significantly less food waste, and expensive recalls are avoided. At the same time, the technology collects data, which allows food companies to optimize production and make it far more sustainable.

TriVision works with camera-based quality control

TriVision A/S is an industrial software company that develops and delivers camera-based quality control solutions.

TriVision has many years of experience working with technology at an advanced level. Their expertise has been gained by completing a large number of advanced installations at large Danish companies. The company, founded in 1999, has attracted venture capital to develop and market a number of standard-based camera solutions globally.

www.TriVision.dk

Technicon Grows by Making Itself Superfluous

New Danish integrator focuses on robotic cells, where production lines are replaced by flexible module-based production.

Can you imagine an integrator and machine builder who sees it as its purpose to make itself superfluous?

Founder and CEO in the Danish automation company Technicon, civil engineer Casper Hansen, can.

He actually sees it as his ultimate goal.

Together with his business partner, Jakob Goul Rømsgaard, he founded Technicon in 2014. Today they employ more than 30 people and supply flexible automation and robotic solutions for some of the country's largest companies, plus many of the smaller ones.

Hansen points to a study by the Danish Engineers' Association which shows that if all projects were automated in Denmark, which would have a payback time (ROI) of two years or less, one would create a societal gain of \$10 billion.

The Danish integrators and machine builders currently represent revenues totaling almost \$750 million, according to Hansen.

"We will not get out of the bottleneck, worth \$9.25 billion, if we do not push the companies to make the integrations through modules and flexible automation," says CEO Hansen.

"Technologies are becoming more democratized. Ten years ago, you could not get your smartphone repaired at an IT service center. You don't do that anymore. Also, you do not call the software engineer to make the app on the phone work. We must make it as easy for an operator to enrich his work with a robot as it is for him to start Spotify when he comes home and wants to listen to music," CEO Hansen explains further.

Machines must be as adaptable as humans

Hansen points to the young generation and their intuitive approach to technology:

"The ones that show up in production today have been able to make 3D models on their iPad before they could spell their own name. They can find Pokémon by walking around with a phone camera. They solve a task in a fundamentally different way. Machine builders and integrators have to as well. We demand from people, that they must constantly be ready to adapt, but we must also demand that from the machines."

For Hansen, the answer to the challenges is flexible production in modules.

In reality, this happens by building production cells that can be moved around the factory floor according to where they are needed.

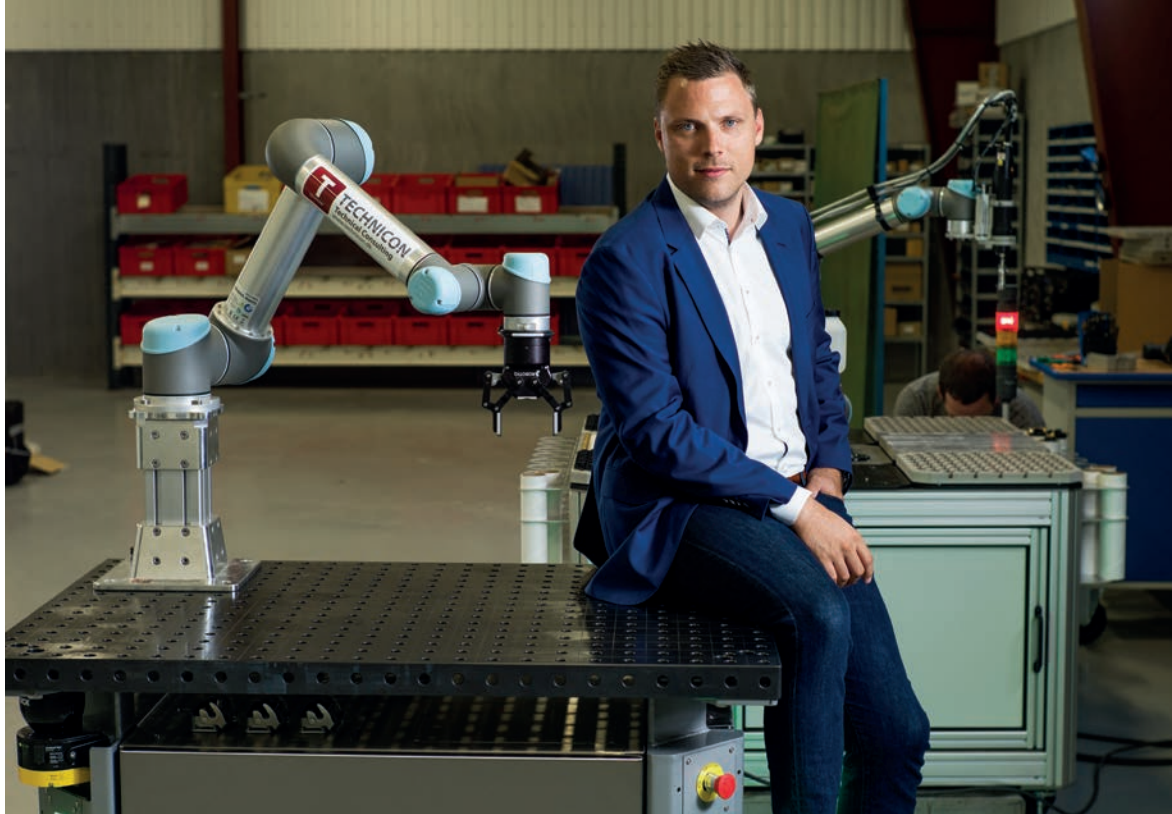


Photo: Bo Amstrup/Ritzau Scanpix

Casper Hansen, CEO, Technicon: "We require people to be flexible and adaptable. Machines should be too."

Together with other companies in the partnership MADE, Technicon has, among others, developed a new flexible robot cell, which is easily configured in four different ways, allowing it to switch between performing four different processes in productions, depending on what is needed.

This cell, consisting of a platform and a UR-branded robot, has so far been used in large Danish industrial companies, which have automated processes where the batch number was previously too low to make automation profitable. But the concept can also be useful in smaller companies that produce small batches of many variants.

The production cells are put together as production islands, where the fabricated subcomponents are transported between each island of mobile robots.

"You have to imagine that the islands of production cells stand up against the wall of the factory floor in the morning when you meet. Then the islands are pieced together according to what you need to produce that day," says Hansen.

www.technicon.dk



In 2011, Gibotech began to introduce robotics technology to the hospitals' sterile workflow. By implementing robotics technology the hospitals can increase their productivity with the same amount of employees while increasing capacity outside normal working hours.

Photo: Gibotech

Gibotech A/S Automates Hospital Logistics

Danish integrator is a world leader in automated sterilization centers for hospitals.

Just north of Copenhagen, at Gentofte Hospital, medical staff perform up to 100 operations per day. It is critically important that doctors and nurses can quickly gather all the instruments they need for their life-saving work.

By pressing a few computer keys, staff members receive a complete set of operation-specific instruments from robots that pick them up in the

hospital's fully automated sterilization center. After use, the instruments are retrieved and sterilized in washing machines before the robots properly store them away for when they will be needed again.

The fully automated sterilization centers were developed jointly by Gentofte Hospital and the Danish machine builder and integrator company Gibotech, which focuses on sterilization centers and automation of hospital logistics.

"Sterilization centers are in demand all over the world. It is difficult for hospitals to hire staff for hospital logistics, as it is very tedious work. And the more human hands there are, the less sterile it gets," says CEO of Gibotech, Henrik Anker.

The first center at Gentofte Hospital was completed in 2011. It was a major and decisive leap for Gibotech. The development task was demanding, and the project did not turn a profit for Gibotech, but it did become the foundation for a transformation of the business.

"During the project at Gentofte Hospital, we learned the industry and its requirements. We had setbacks along the way, but we also created a script to create the logistics solutions that hospitals demand, which we have since developed," says Anker.

From distributor to project company

For many years, Gibotech was a distributor of automation equipment and robots. The timber industry was its original target market. Gibotech installed machines and robots in production lines, but with minimal profit and the sourcing was very local.

Henrik Anker, CEO, Gibotech. Logistkløsninger til hospitaler har skabt et gennembrud for Gibotech.



Photo: Gibotech

Henrik Anker and his colleague, sales engineer Mikkel Bjerregaard, were the driving forces in the development of the sterilization center. In 2013, they acquired Gibotech in a generational succession. In Anker and Bjerregaard's hands, Gibotech went from being a reseller to a project business. The company today employ 106, 40 of whom are engineers.

The number of projects, both in sterilization and on industrial production lines, has grown dramatically since then.

"We design what customers need. There is no standard project. We design and produce everything ourselves, just as we supply power boards and controls. The rest we outsource. We deliver projects as far away as Australia," says Anker.

On the industrial side, Gibotech has made its customer segments narrower and deeper.

The goal in 2019 was to double revenue within three to five years. This explosive growth requires new standardized processes. It is not enough to automate for customers. Gibotech also automates itself.

www.gibotech.dk

BILA A/S Finds Industry's Untapped Productivity

Danish automation company aims at further global expansion.

Despite a positive attitude towards robots and automation and elevated adoption rates among Danish companies, the potential for automation in the Danish industry remains high, according to an analysis by the Danish automation firm BILA A/S. Using big data through its proprietary product – BILA Data Power – the company maps out possibilities to optimize production through automation.

One company that was quick to realize the potential of automation was the actuator manufacturer Linak. They methodically screened their production lines and analyzed processes before preparing a technology roadmap and investment plan. Their focus on implementing automation has led to success and ensured continuous expansion of production capacity in Denmark and abroad.

Photo: BILA



"Once the untapped automation potential is found, it needs to be realized. This doesn't happen in all Danish companies. Some companies are drowning in resource-intensive procedures and bidding requirements. The hectic, day-to-day pressures compel many to act very shortsighted or result in failed projects. It is so unfortunate to see when only a tenth of a company's potential is actually realized," states Jan Bisgaard, CEO of BILA A/S.

Founded as a project workshop in 1988, BILA A/S has since provided 2,000 automation solutions to the European and American markets in various industries. The company sells and installs Kawasaki robots, Universal Robots cobots, self-propelled trucks, automated pallet trucks and sells automation, production optimization and technical services to a wide range of industries.

BILA A/S employs nearly 400 employees in multiple locations in Denmark as well as Norway and Sweden. The automation company also serves Denmark's international conglomerates on several continents, and most recently, the company has set an ambitious international expansion strategy.

BILA A/S is both an integrator and a distributor. In recent years, BILA A/S has started to rent out automation equipment and this has created a new dynamic in the market.

The company is today run by Jan Bisgaard Sørensen, whose brother, Per Bisgaard, originally founded it with Jørn Larsen.

www.bila-automation.com



Egateg's focus is on improving working conditions. They deliver this exoskeleton, MATE, which enables an employee to perform repetitive tasks with less fatigue and strain. The exoskeleton helps to distribute weight from arms to the pelvis during heavy and repetitive tasks.

Photo: Egateg

Egateg abolishes one-sided repetitive work

Egateg A/S is an engineering company specializing in the development, production and integration of customized automation and robotics solutions. They provide solutions to the food industry, pharmaceutical industry and other sectors, and have clients that include large Danish companies such as Arla (dairy products) and Velux (windows).

The company has delivered more than 300 different projects to the industry – from simple automation systems to complete turnkey solutions. The letters EGA in Egateg stands for One-sided Repeated Work in Danish, which means that the company's automation solutions help to eliminate EGA – in other words, they abolish physically stressful, monotonous and manual work functions.

www.egateg.dk

The Growth Drivers

A groundswell of automation and robotics companies have grown in recent years. Some focus on cobot applications, but still more are coming out with new service robots.

Danish Robotics Companies are Rapidly Growing

The majority of Danish automation and robotics companies are small. Many of them have less than 10 employees, but in the past decade there has been an increasing number of fast-moving operations requiring a surge in personnel.

There is especially high growth in companies near the larger Danish university cities such as Copenhagen, Odense, Aarhus, Aalborg and Sønderborg, where a number of business ideas take root in their learning environments.

Other new robotics companies have been founded by robotics and automation experts, who have worked in major Danish automation companies and had new ideas that they want to try out.


Some operate in industrial automation, where applications by UR's cobots and MiR's mobile robots have created a foundation for new businesses.

Other entrepreneurs focus on developing service robots that solve needs outside of the factory floor.

Others still are concerned with how drones can be developed for inspection purposes. They can be used in agriculture, where crop development needs to be monitored. And they can be used for environmental studies and water level measurements and many other purposes.

Denmark has an advanced and mechanized agricultural industry, as well as a mature industry in the manufacture of agricultural implements and animal stables.





Danish agriculture has a high demand for new automation solutions, and several new companies have popped up to fill this need with agricultural robots. In addition, many new digital solutions are being developed – primarily software robots and apps.

Some of the newer Danish companies matured in Odense Robotics StartUp Hub located at the Danish Technological Institute in Odense, where there is currently room for eight companies.

The companies are at the hub for 12-18 months, and they are assisted with technical development, business models and capital injection. After that, they are nudged out of the nest and must be ready to fly on their own.

The StartUp Hub screens approximately 100 robotics companies a year. The majority are Danish, but there are also some applicants from abroad. The only condition for a foreign robotics company to gain access to the StartUp Hub is that the company is located and registered in Denmark.

In the following pages, we will provide an overview of significant new, fast-growing Danish startups.

First, the two companies listed on the Danish growth exchange, First North. Then we'll look at non listed companies. The overview is divided geographically in relation to Denmark's five regions – the capital, Zealand, southern Denmark, central Jutland and northern Jutland.

Listed on Nasdaq First North

Scape Delivers Precision

Danish producer of bin-pickers for large car manufacturers.

If you ask CEO Søren Bøving what exactly his business sells, he is quick to answer.

"We know bin-picking inside and out. We have the full solution. Not only can we recognize objects in a box with a camera, we've also thought about how to design the gripper, how to handle the robot when it needs to go fast. After all, it is not just getting the object from A to B, but doing it accurately, every time," says Bøving.

SCAPE is an abbreviation for Smart Classifier and Pose Estimator. It is a piece of software that controls a camera that analyzes images so that, for example, you can determine the position of a component in a box of 800 pieces and have a gripper robot extract it and place it on a conveyor belt or precisely deliver it to a machine. It will run 24/7 at intervals of just a few seconds – and with no breakdowns.

This may sound simple, but it is actually very difficult. Each time the robot has retrieved a component and returned; it must move in a new trajectory. It requires intelligence, well-developed vision and good motor skills. People have all of these attributes, but it's a stretch for robots. Their cameras

are not as good as the human eye, and they do not think creatively every time they have to move.

The late Professor Ivar Balslev and Dr. Rene Dencker Eriksen from the University of Southern Denmark have been working on the problem since 2004 when they founded Scape Technologies. They were initially introduced to the task while working with other robotics experts automating shipbuilding in Odense in the 1990s.

Today, Scape Technologies is listed on the Danish stock exchange and its systems are in use in the automotive, hardware, home appliances and many other industries. Their solution integrates grip devices, sensors, cameras and proprietary software for fast, reliable and accurate collection, control and placement of subcomponents and items that are delivered unstructured in boxes. Scape's software can interface with all robotic brands' operating systems.

Listing to the stock exchange

In 2018, Scape went public on the Danish stock exchange, Nasdaq First North Growth Market, where anyone can buy the stock in hopes of a favorable return in the long term. They decided to go public to raise fresh capital for global expansion.

Scape was running at a deficit in 2019 as had been noted during its IPO. They are investing heavily

in a global reseller network with other integrators and continue to develop their systems. This all costs money. But profits are expected in the coming years.

Scape's expertise in bin-picking is, in part, because its employees have worked with the problem for 16 years.

"No one in Europe has implemented as many bin-picker installations as we have. For many years it was difficult. Out at the customers, we had to take responsibility, not just for bin-picking, but for the entire robot cell implementation. Now we have more standardized solutions for our partners to implement. We have made it simpler and more intuitive. And the market is starting to notice," explains Bøving.

Among Scape's competitors are Fanuc, which has its own bin-picker solutions, but otherwise its competitors consist of smaller companies like Scape itself.

"At any given trade fair, you will see many bin-pickers that can handle 95 percent of the workload. But it's the last five percent that are the hardest. And the most important. Production has to stop. We have a 99% uptime with major companies in Germany running 24 hours a day," says Bøving.

However, Scape's various solutions are also sold as far away as in China, where Scape has a Chinese partner who is also a shareholder. Scape's "mini-picker" is especially popular there.

A typical Scape customer is Hettich Holding, a global manufacturer of kitchen hinges in

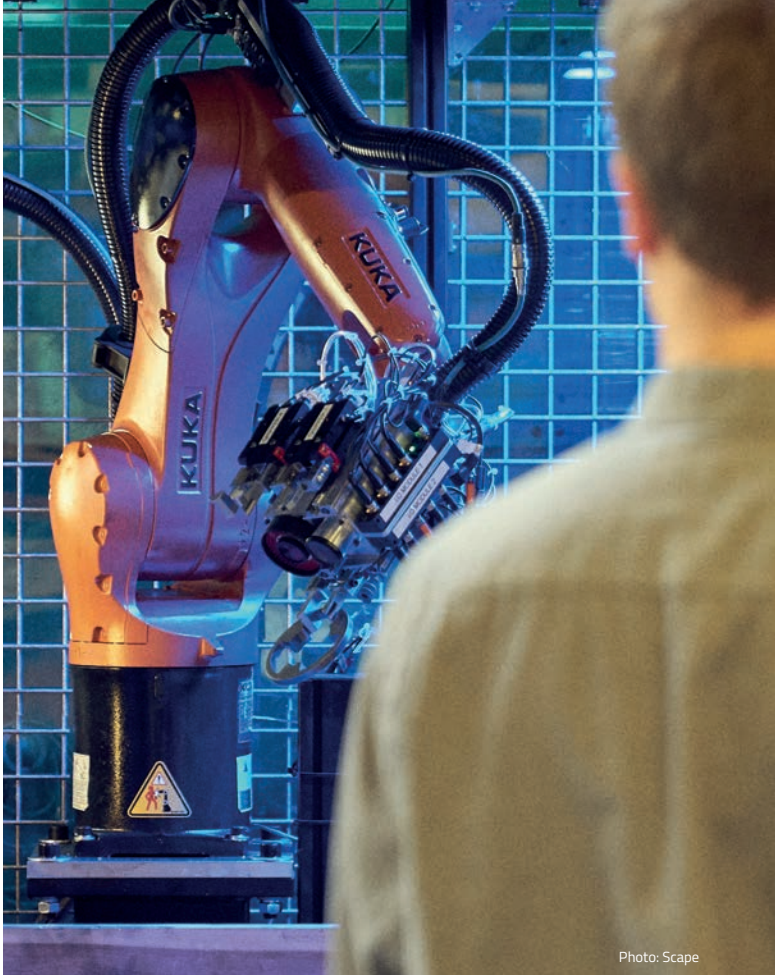


Photo: Scape

Scape bin-picking systems ensure a precise delivery.

Hannover, Germany. The company produces one million hinges and fittings daily.

The parts arrive from subcontractors in large containers, packed in no particular order. Scape replaces the labor-intensive (and expensive) sorters with automatic bin-picking.

www.scapetechnologies.com

Listed on Nasdaq First North

ODICO Aims to Revolutionize the Construction Industry

Custom-built robots make construction cheaper and more sustainable.

Perched in the fjord in the eastern Danish city of Vejle is "Fjord House." The 92 ft. tall building, which is the headquarters of a Danish family-owned venture capital fund, was designed by the world-famous Icelandic architect and designer Olafur Elisasson.

The Fjord House does not contain a single straight line. Cylindrical structures and complex geometrical shapes create an intersecting, curved building that was extremely difficult to construct.

The construction of the complicated structure was made possible in part because the Danish technology and robotics company Odico supplied 158,900 cubic feet of molds, which were cut by robots at the company's workshop in Odense.

Together with another world-renowned Nordic architect, Bjarke Ingels, Odico has set out to revolutionize the construction industry with the help of robots.

Their objective is, among other things, to encourage more wood usage in buildings, replacing

concrete, which is one of the world's largest contributors of CO2. Their robots produce advanced and currently time-consuming wooden structures based on the architects' drawings.

Odico was established in 2012 by mechanical engineer Anders Bundsgaard and architect Asbjørn Søndergaard. The company develops robotic solutions for the construction industry that can cut and mill different materials in three dimensions.

At the same time, the company has developed "Factory on the Fly," which is a mobile robot platform that can be easily brought to a construction site. It comes in a twenty-foot container.

The company was listed on the Danish growth exchange, Nasdaq First North, in July of 2018.

Big jobs in a conservative industry

"No two operations on a construction site are the same. So, what we are working on is creating a new interface between human requirements and industrial robots," explains CEO Anders Bundsgaard.

For example, ABB robots, which Odico has programmed, have enabled construction workers to cut tiles into round shapes, controlled from an iPad.

Fjord House, a 28 meter-high building located in Vejle, Denmark, was designed by architect Olafur Eliasson and built by Jorton. The Fjord House does not contain a single straight line.

This architectural tour de force was possible with the help of the robotics company Odico. Odico provided 4,500 square meters of molds, cut by its robots. The molds are put together like a jigsaw puzzle that is built into a formwork system so that it remains standing as the concrete is poured into the mold. Then the molds are peeled off and the house is walled up.

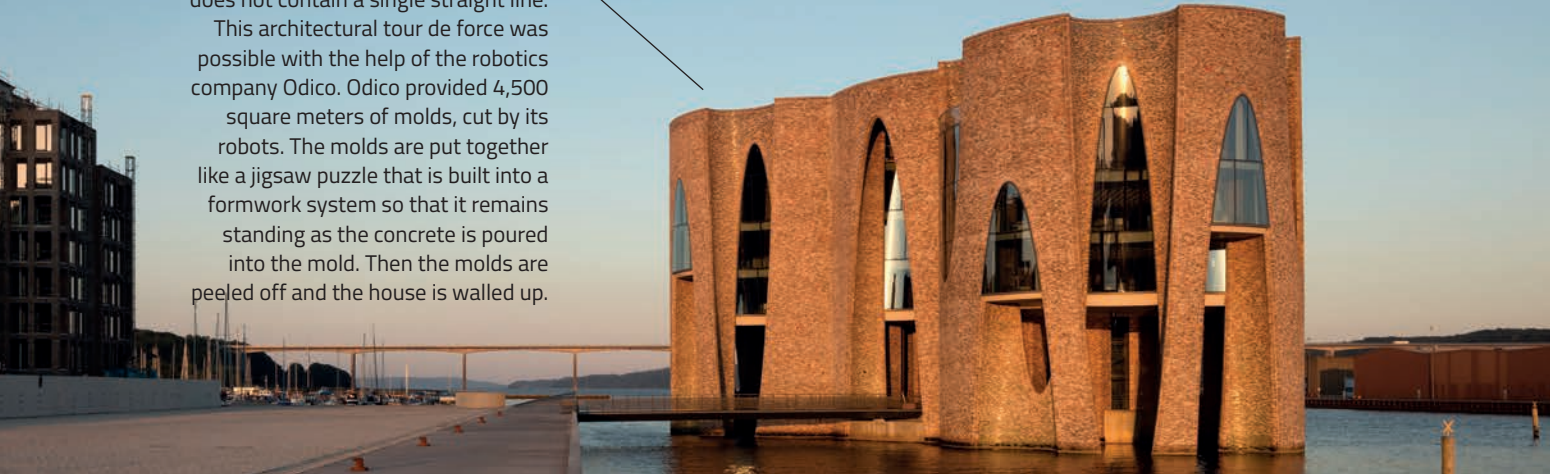


Photo: Anders Sune Berg

Odico consists of a development department that creates robotics solutions for the construction industry and an application department that handles tasks such as mold making for the spectacular headquarters in Vejle.

Bundsgaard notes that many architects would like to create innovative buildings with round shapes: "But builders and contractors are hesitant. The former because they think it is too expensive; the latter because they do not think it is possible. Our ambition is to be the one to contact when solutions for a demanding task need to be found."

It's a big ask. The construction industry is very conservative. It is one of the industries in the world where productivity has grown the least.

"We have solutions that can satisfy architects' wildest dreams. However, when an architect needs to sell their project to a developer, cost is a design parameter. When the builder goes to the contractor, they are told that if a wall is not curved but straight, they can build within the budget. In that game, it is difficult to come up with new technology if the contractor does not want to use it," says Bundsgaard.

What matters to builders is the bottom line. They would actually be happy to construct exciting buildings. Therefore, Odico's robotic solutions aim to make exciting buildings economically feasible.

www.odico.dk

CAPITAL REGION OF DENMARK

Kassow's Robots Rotate on Seven Axes

Cobot pioneer create new opportunities with a robot that works just as well as the human arm.

A typical collaborative robot arm has six rotating axes. It is in many ways similar to a human arm, but the axis that the elbow rotates around is missing.

This is not the case with the robots that Kristian Kassow, one of the original founders of Universal

Robots, produces at his company, Kassow Robots in Copenhagen. His cobot has seven axes.

"The competitive parameters of the old industrial robots were speed, lifting ability and range. When I decided to work with robotic arms again, I determined that collaborative robots could compete with the old industrial robots in terms of performance. That's why we had to make a cobot that was strong, fast and simple," says Kassow.

After a long and demanding development process, the result now comes in the form of a series of KR robots that Kassow Robots has marketed since 2018. The series consists of three robots that can carry a payload of up to 22 lbs. and a range of up to 6 feet. They weigh between 55 and 99 lbs.

Kristian Kassow (b. 1976), Managing Director, Kassow Robots

Kristian Kassow is a graduate of the Technical University of Denmark. Throughout his studies, he focused on robotics. Kassow became involved in research into the use of robots in the food industry in connection with his first job after studying at the University of Southern Denmark. He got the idea for small flexible robots and founded UR together with Esben Østergaard and Kasper Støy. He left UR in late 2009 to become a developer and team leader in NKT Flexibles. From 2013, as project manager for the French company Aldebaran, he helped develop a 4.5 ft. tall humanoid robot, called Romeo. Today, he is CEO and co-founder of the company Kassow Robots, which has developed and marketed a seven-axis cobot.



"I love making robots, so I really wanted to make a cool product," admits Kassow.

KR robots are intended for small and medium-sized companies working with smaller production runs and would like to automate their production with tools that can be used for a wide range of tasks – for example, bin-picking, machine feeding, painting, quality control, injection molding, packing, palletizing and many other tasks.

The robot can get around corners

"Our robot has some advantages that is obvious when, for example, used with a CNC (Computer numerical control) machine. One big advantage is that it can get around corners," explains Kassow.

Kassow Robots is currently working to build a reseller network. Europe is just about covered, and in the coming years they plan to establish a foothold in the U.S. market.

Distributors are typically machine builders who use the KR robots in their own solutions.

Like UR robots, KR robots are also easy and intuitive to program via a graphical user interface. They can also be considered as a competitor to UR's robot arms, which Kristian Kassow led the development of in collaboration with Esben Østergaard, before Kassow left Universal Robots at the end of 2009. Now he is working to help Kassow Robots carve out its own space in the cobot market.

www.kassowrobots.com



Photo: Cobod

COBOD has developed a "building printer".

COBOD / Copenhagen

In 2017, COBOD printed the first building in Europe – BOD (Building On Demand). Cobod demonstrated that it was possible to 3D print a building according to European building codes. Since then, they have developed a 2nd generation BOD printer – the modular printer BOD2.

German PERI Group, the world's largest manufacturer and supplier of formwork and scaffolding systems, acquired a significant share of COBOD in 2018.

Rapid growth continued in 2019. The new BOD2 printer is large enough to print three-story buildings with more than 300 square meters per floor. They are being sold to Saudi Arabian companies, along with others.

www.cobod.com



Cleaning with the Cargo Hold Robot replaces a conventional four-step cleaning process involving tons of chemicals and water with a one-step pure freshwater cleaning process. This cuts time spent on cargo hold cleaning by 50%.



Cliin / Copenhagen

High-pressure cleaners, chemicals, huge amounts of water and hours upon hours of demanding and sometimes dangerous work – that's the reality for crew on board bulk vessels around the world. Until now: Danish robot entrepreneur CLIIN wants to revolutionize the decade-old method for cleaning cargo holds with a remote-controlled robot designed particularly for the large dry cargo holds of bulk vessels.

According to Cliin CEO, Thomas Jørgensen, there is a large potential for roll-out to the global bulk fleet of app. 15,000 vessels. The hold of such vessels is typically cleaned five times a year before new cargos are loaded.

Only one person is needed for remote-controlling the robot. Magnetic belts enable the robot to climb the vertical walls of the hold. Generally, cargo hold cleaning requires significantly more manpower – typically a crew of 5-7 people. CLIIN robots have been developed in close cooperation with Danish shipping company J. Lauritzen.

Headquartered in Denmark, CLIIN's robot cargo hold cleaning technology has been successfully deployed to four of the world's leading shipowners: Lauritzen, Norden, Oldendorff, and Ultrabulk.

www.cliin.dk

Flow Robotics

/ Copenhagen

When a lab technician extracts fluid using a pipette and empties it again when dosing medication, it can wear out their arms, hands and wrists.

That's why the Danish company Flow Robotics, in collaboration with lab technicians, developed a patented cobot that can solve the problem. The robot costs roughly \$30,000. According to founder Kasper Støj, who, together with Kristian Kassow and Esben Østergaard, helped develop the first cobots at Universal Robots, the robot will pay for itself in six months. Støj is currently a professor at the IT University of Copenhagen, and the company is a spinoff from there.

The new robot can be used for many of the small pipetting tasks that fully automated pipetting robots costing \$250,000 are not able to do. The large robots must be programmed separately and that can take up to 12 months.

Flowbot ONE is as intuitive to operate as a smartphone. Using patented technology, live video from the robot is combined with a graphical user interface. This means that everyone is able to use the robot without any kind of programming expertise.

www.flow-robotics.com

Manual pipetting is a laborious task that can lead to injuries and attrition of laboratory staff. Therefore, automation is high on the priority list in the laboratory world. Flow Robotics has carefully developed a cobot that minimizes manual pipetting, making it a laboratory technician's best friend.



Photo: Flow Robotics



Robotize / Copenhagen

Robotize manufactures a mobile pallet robot, GoPal, which is installed in a large number of Danish industrial companies. GoPal operates from a number of stations where it picks up and places pallets. The company is owned by private investors.

www.robotize.com

Shape Robotics / Copenhagen/Farum

Fable is a modular robot building kit that allows anyone to create their own robots in minutes. Different modules can be clicked together in a myriad of ways to create the robot's body, sensors and movements. Fable is used in schools to teach children how to program, innovate and develop their skills in critical thinking and complex problem solving.

Fable is manufactured by Shape Robotics, a spinoff from the Technical University of Denmark (DTU). Behind Shape Robotics is Moises Pacheco and David Johan Christensen. Fable was developed at the Center for Playware, a division of DTU that is working on the interface between games, learning, robotics and artificial intelligence during a four-year research project with LEGO.

Fable robot systems have been at the top of Microsoft Education Apps list and have been launched with partners in the U.K., U.S., Russia, Italy, the Netherlands, Mexico and other countries. The teaching robots can be purchased or rented.

www.shaperobotics.com

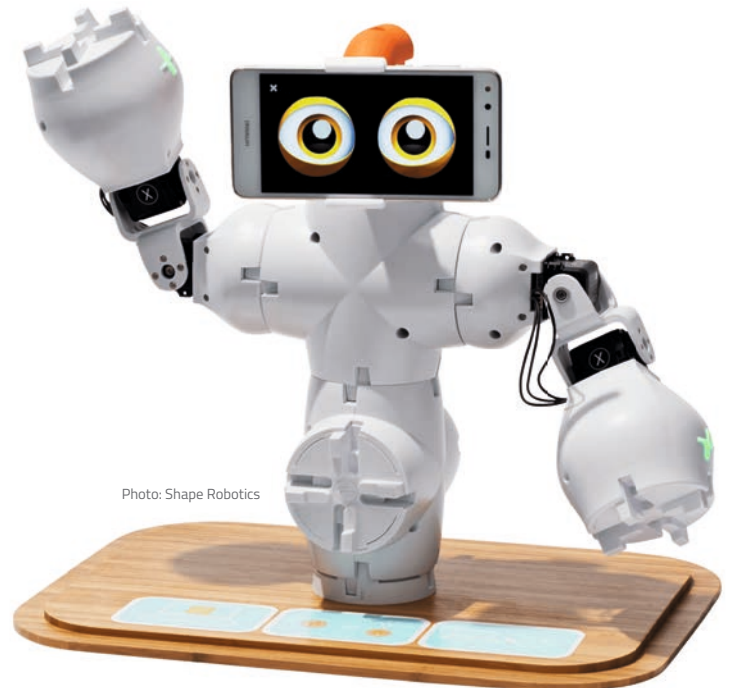




Photo: Cobot Lift

Dana Lim's factory in Køge produces more than 400 different types of glue and sealants. Cobot Lift developed a solution to place 30-45lbs sacks on pallets, totaling 250 tons per week.

REGION ZEALAND

Cobot Lift / Slagelse

Cobot Lift combines a vacuum lifter and robotic arm into a solution that increases a cobot's lifting capacity by a factor of 2.5. The more muscular robot can thus be deployed where normal UR robots must give up.

The idea is to make the well-known robot arm from UR far stronger than their present lifting maximum

of 35 lbs. By attaching the robot arm to a traditional vacuum lifter, the UR robot has been able to lift 55 lbs. Engineer and entrepreneur Flemming Bischoff Truelsen is behind the company.

www.cobotlift.com



Photo: Robot At Work

Robot At Work / Sorø

Robot At Work was founded in 2015 by Finn Christensen and Anders Geleff Martiny. Finn Christensen started taking an electrician education, but later became a carpenter and had his own contracting business until the financial crisis hit. Anders Geleff Martiny had an automation business.

Originally, Robot At Work used a robot arm from UR to make a construction robot mounted on a

platform. The robot could be used for exterior insulation where it could spray an insulation product on a facade. Furthermore, it could mill out joints, spray plaster and concrete, as well as paint. Now the robot arm itself has been dropped in favor of a frame solution where the robot can move freely over a larger area.

The robot is good at laborious, monotonous working conditions with large surfaces. Torben Frigaard Rasmussen, a well-known Danish angel investor, is the company's co-investor and chairman of the board.

www.robotatwork.com

REGION OF SOUTHERN DENMARK

AIM Robotics

/ Copenhagen / Odense

AIM Robotics supplies a range of dispensing heads that can be mounted on automated robots to ensure accurate delivery of high viscosity fluids. Once connected, they do not require time or technical expertise to install, according to the company.

All dispenser solutions are designed in Denmark and can be adapted for use with any robotic solution. The company originates from the Technical University of Denmark in Copenhagen.

www.aim-robotcs.com

Creative Sight / Odense

Up in the clouds and down to earth is the best description of Creative Sight. The company was founded by the pilots Sebastian Duus and Benjamin Mejnertz. Including pilots and other specialists, the company today has eight employees.

Creative Sight is a drone-consulting firm specializing in inspection and thermography for energy companies and construction sites as well as video creation for film companies and commercial advertising.

www.creativesight.eu

Photo: Creative Sight

EasyRobotics / Sønderborg

EasyRobotics started as Per Lachenmeier's graduate project at SDU, Sønderborg. He founded the company in 2015 with Syddansk Innovation. The company specializes in making robotic cells that are used to automate industrial processes.

EasyRobotics has built several robotic cells in which robots feed objects into CNC machines. The robotic cell has a tray located on a mover, which contains components to be machined.



When machining is complete, the parts are transported from the robotic cell and replaced with a new tray full of unprocessed parts. The company's modular robot cell, ProFeeder, can be built in three stages, depending on the customer's needs and project complexity. EasyRobotics has sold more than 400 robotic cells to 37 countries and has more than 70 partners.

www.easyrobotics.biz

EffiMat Storage Technology / Odense

EffiMat produces and supplies automation solutions for handling, picking and storing items. The company's name is derived from their main product, the storage robot EffiMat. EffiMat Storage Technology was founded in 2011. Its current management consists of Jørgen Flemming Ladefoged, founder and CEO, as well as Karl Hvingelby, director and CFO. The company is owned by its management, the Danish state's Growth Fund and Danfoss shareholder, Peter Mads Clausen.

EffiMat Storage Technology has developed several warehouse robots and sold systems to large customers such as Audi, Airbus and Novo Nordisk. The company today employs 40 people.

www.ffmpegat.dk



Photo: EffiMat Storage Technology

EffiMat's solutions are used both in warehouses and on assembly lines as well as in auto workshops and in retail outlets of web shops.



FarmDroid / Rødding

Farmdroid is a self-propelled lightweight robot for use in agriculture that automates seeding and weeding. Farmers using the robot can grow organic crops and, because the robot is lightweight, it is CO₂-neutral and does not destroy the structure of microorganisms in the soil. Farmdroid was

founded by brothers Jens and Kristian Warming. Among its investors is Esben Østergaard, founder of Universal Robots.

www.farmdroid.dk

Photo: FarmDroid

Fishi Robotics / Odense

The booming Danish robotics network has become a significant player globally and has attracted international entrepreneurs. Australian Carl Chatfield from Fishi Robotics is one such example. He moved the company from Silicon Valley to Odense to participate in Odense Robotics StartUp Hub, which provides companies with a platform to accelerate their growth for 12 months.

Chatfield is developing an underwater drone that can monitor and report on the condition of ships or offshore wind turbines below sea level, which previously had not been possible. He is financing the development of the company on his own.

www.fishirobotics.com



Photo: Fishi Robotics

Inrotech / Odense

Automated welding robots from the now defunct Odense Steel Shipyard were the starting point for Inrotech, which was founded in 2010, but has grown rapidly in recent years. The company was established by engineer Flemming Jørgensen, who worked with welding robots in the shipyard in the 1990's. The company was co-founded by his brother, Gert Jørgensen, who had worked for the Maersk shipping companies in the production of containers. Gert Jørgensen is now the managing director of the company.

Inrotech manufactures four different types of automated welding robots as well as customized solu-

tions that can work on everything from shipbuilding at shipyards and wind turbine foundations for the oil and gas industry to bridges and energy plants. The robots are developed together with the company's customers.

Among their investors is Peter Mads Clausen, part of the dynasty behind the Danish energy technology company, Danfoss.

The company is expanding rapidly globally with automated welding robots for heavy industry.

www.inrotech.com

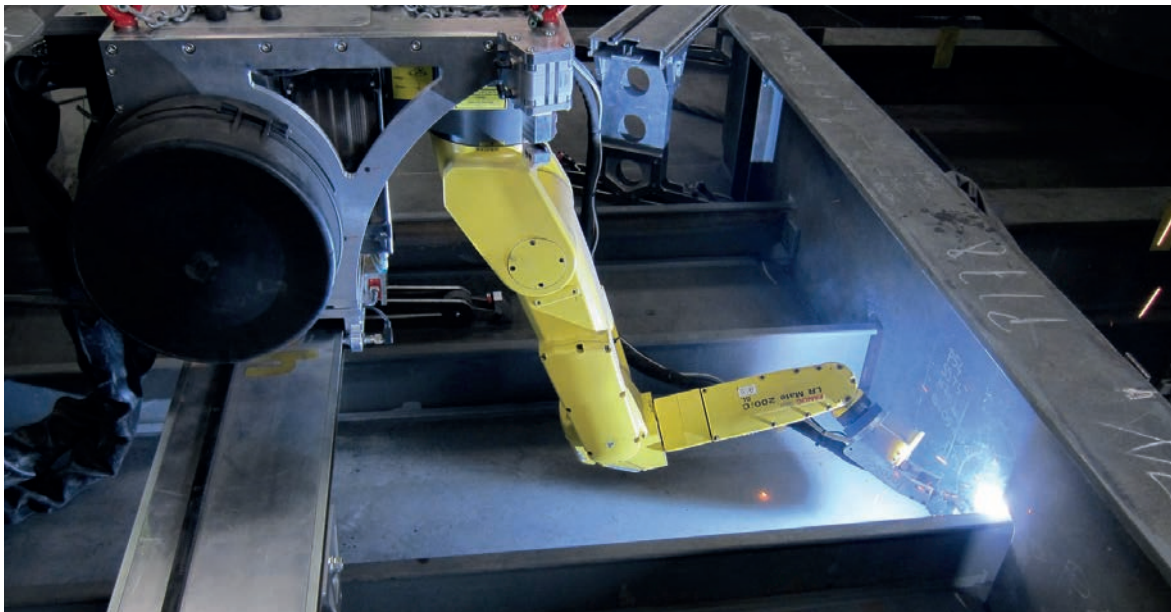
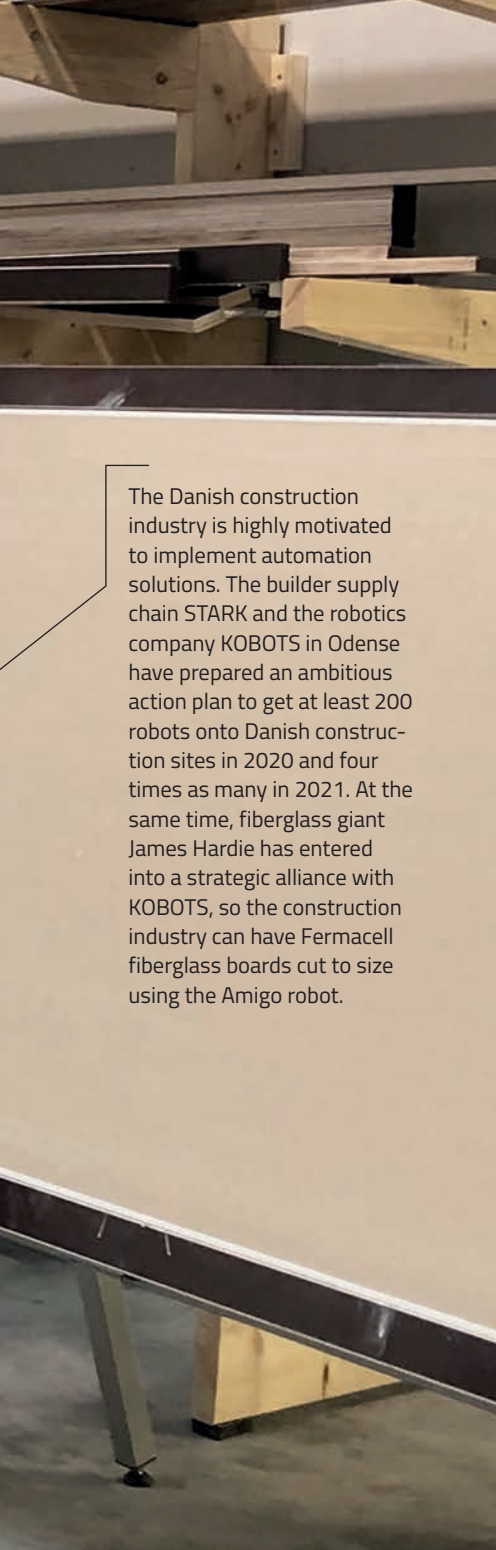


Photo: Inrotech





The Danish construction industry is highly motivated to implement automation solutions. The builder supply chain STARK and the robotics company KOBOTS in Odense have prepared an ambitious action plan to get at least 200 robots onto Danish construction sites in 2020 and four times as many in 2021. At the same time, fiberglass giant James Hardie has entered into a strategic alliance with KOBOTS, so the construction industry can have Fermacell fiberglass boards cut to size using the Amigo robot.

KOBOTS – Voice Responsive Robots / Odense

The work environment in the construction industry is in desperate need of improvement. Productivity and efficiency gains in the industry are modest at best, and worksite injuries that lead to early exits from the labor market cost society dearly. Automation can help. One of the ways to do that is through an automatic saw that can cut anything from drywall to tile. These are the exact specifications of KOBOTS' Amigo, a voice-controlled cutting robot.

"In addition to making work processes up to three times faster, it also reduces the negative effects of dust exposure, noise and poor posture. Amigo collects all data from its jobs and records materials that can be recycled. It is good for the economy and the environment. KOBOT's intelligent software can even point out that, for example, the plasterboard you need could be cut from a remnant and tell you its exact location in a pile of cutouts," explains CEO Peter Hartvigsen.

Other backers of the company include the founder of Mobile Industry Robots, Niels Jul Jacobsen and his wife, Charlotte Hybschmann Jacobsen, who together run the venture capital company Hybsch Connect Holding.

Amigo consists of a mobile frame and a tool adapter for different types of power tools such as grinders, cutters and circular saws, and advanced speech recognition and rendering software.

On a job site, a carpenter can talk to the robot in the same way he would a coworker. This means that he has his hands free for other tasks, such as measuring and mounting. Amigo continuously asks for the information it needs. For example, it may ask; "Where do you want to cut the board? The side? Top? Bottom?" Or it may say; "Set target," when the carpenter controls the robot with verbal instructions.

www.kobots.dk



The educational robot KUBO gives children a very concrete understanding of programming.

Photo: KUBO

KUBO / Odense

The educational robot KUBO helps children aged 5-11 learn how to program. Using puzzle pieces, the child compiles a sequence that the robot then runs. The robot's head can be replaced for use for various activities. For example, for spelling skills, the robot examines lettered tiles, but stops and glows red if it encounters the wrong letter.

KUBO was founded in 2014 by Tommy Otzen and Daniel Lindegaard. Among its investors is the Danish state's Growth Fund. Its management is composed of a former LEGO executive and a former director from a large Danish electronics corporation. They have invested millions of dollars in sales and marketing of the robot, which has won multiple startup prizes.

www.kubo.education

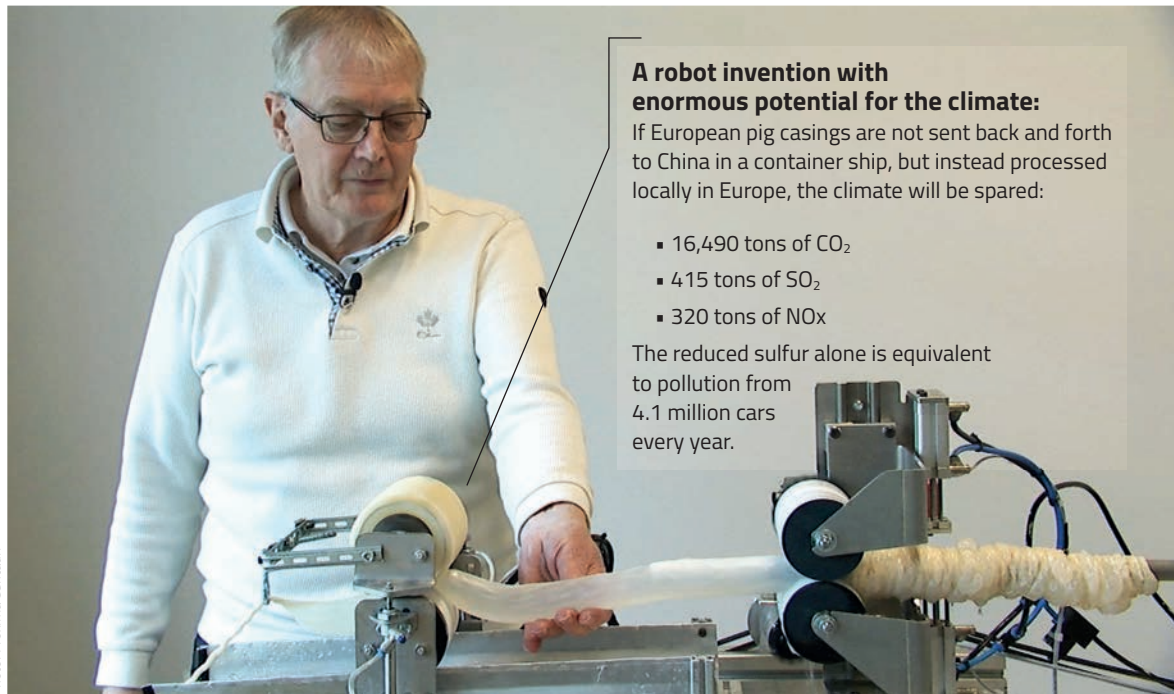
Proxima Centauri / Odense

Proxima Centauri's patented machines are designed to automate the sorting of natural casings for sausage production. Intestines used as casings need to be sorted by size and this has been done manually. The task is too labor intensive in Europe to be profitable, and therefore the intestines are transported to low-wage countries and back again. This transport represents an annual environmental impact equivalent to the pollution from four million cars. Proxima Centauri's technology makes it pos-

sible to solve the sorting task locally in Europe 65-78% cheaper and with only one machine operator rather than 16 employees.

Jan Pedersen, a 73-year-old retired slaughterhouse director, is behind the invention. His company provided the first sorting machines for the butcher industry in 2019.

www.proxima-centauri.dk



A robot invention with enormous potential for the climate:

If European pig casings are not sent back and forth to China in a container ship, but instead processed locally in Europe, the climate will be spared:

- 16,490 tons of CO₂
- 415 tons of SO₂
- 320 tons of NO_x

The reduced sulfur alone is equivalent to pollution from 4.1 million cars every year.

Photo: Proxima Centauri

Source: The University of Southern Denmark for Proxima Centauri.



Photo: QuadSAT

QuadSAT / Odense

The maritime and aviation industries rely on proper and fast satellite communications to operate optimally. QuadSAT is working on a new technology that can reduce interference from satellites in navigation systems found in aircraft, ships and cars.

QuadSAT's technology makes it possible to use drones to test and calibrate antennas for satellite communications autonomously, ensuring a consistent high-speed internet connection.

The Danish state's Growth Fund is among QuadSAT's investors.

www.quadsat.com

Nordbo Robotics / Odense

Nordbo Robotics, which was founded in 2015, supplies software, sensors and tools for robotics companies. Their core competency is application software for industrial robots and advanced computer vision technology. CEO and co-founder Leo Zhou has studied at the Mærsk Mc-Kinney Møller Institute in Odense. Nordbo Robotics is especially focused on the Chinese market, where there is high demand for automation solutions. The company has also gained Chinese shareholders.

www.nordbo-robotics.com



Photo: Nordbo Robotics

Tendo / Odense

Tendo is behind a robotic glove for people who have reduced strength in their fingers and hands caused by, among other things, brain hemorrhages, accidents and arthritis. The glove has reached the third stage of development - the fourth will be close to the final version, which will be ready in 2020.

Tendo was founded by three Swedish entrepreneurs with CEO Sofie Woge at the head. They work partly from Odense and partly from Lund in Sweden.

www.tendoforpeople.se





Photo: ROEQ

ROEQ / Vissenbjerg

ROEQ develops equipment for mobile robots that effectively build a bridge between warehouses and production lines, enabling industries to achieve fully automated internal logistics. The robotics company started in 2017, and is 100% Danish-owned, with most components supplied by Danish companies. ROEQ develops, manufactures and sells its products in 28 countries through 76 distributors. ROEQ's range of modules and cart solutions enable, for example, a MiR robot to pick up and deliver trolleys or pallets to a conveyor belt without human involvement. Users of ROEQ's equipment can be found in both manufacturing and the logistics industry, as well as the health care sector. Customers include Velux and the University Hospital of Zealand in Denmark, as well as international giants such as Visteon, Google, Toyota, Procter & Gamble, Stryker, Unilever, Faurecia, British Aerospace, Repsol and Volvo.

www.roeq.dk

CENTRAL DENMARK REGION

Agrointelli / Aarhus

Agrointelli is a Danish development company that creates sustainable automation technologies and products for plant cultivation. The company combines the latest technical research in sensors, data collection, intelligent automated data processing, decision support systems and automation with specialized agronomic knowledge in plant cultivation, soil and ecosystems.

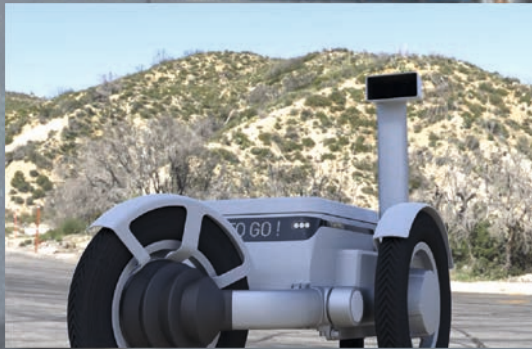
The company, which has 26 employees, was founded in 2015 by Aarhus University professor Ole Green and the agricultural machinery company Kongskilde. A number of private investors now owns the company. Agrointelli is based in Agro Food Park near Denmark's second largest city, Aarhus. Agrointelli has developed "Robotti" which is designed with a standard three-point suspension, so most types of implements can be mounted between two-wheel modules.

Robotti uses four-wheel drive and has a speed of up to five mph. It is designed to run on electricity. Robotti can be controlled from a smartphone or tablet.

www.agrointelli.com



Photo: Agrointelli



Capra Robotics has created a fast, agile mobile robot with low energy consumption that can easily overcome obstacles. It can navigate terrain much better than other mobile robots typically can.

Photo: Capra Robotics

Capra Robotics / Aarhus

Most mobile robots are equipped with differential control, which controls direction by differentiating the speed and direction of the wheels. This can create problems when, for example, a mobile robot has to move quickly on slippery or uneven surfaces.

Capra Robotics has developed a patented platform for mobile robots so they can operate inside and outdoors, without the robot stopping at obstacles such as wires, curbs, smaller stairs and doorframes. The new platform can drive over obstacles that are up to 40 percent of the height of its wheels. Most robots today can only manage 10-12 percent.

The platform was created by civil engineer Mads Bendt, who was confined to a wheelchair after an accident. He developed his own wheelchair, and his experience has been used to develop the new platform. Capra expects to deliver the first mobile platform to customers in early 2020. Investors in Capra include Niels Jul Jacobsen, founder of MiR, and his wife Charlotte Hybschmann Jacobsen, who operate a venture capital company investing in mobile robots.

www.capra.ooo



Photo: Turf Tank

There are literally millions of sports facilities in the world that Turf Tank can mark out. This is the massive automation potential for the world's first precision robot with millimeter accuracy. The solution frees up time and ensures that the lines of sports facilities are sharp and accurate every time a game is played.

THE NORTH DENMARK REGION

Turf Tank / Hjørring

It takes two men 2.5 hours to mark a football field manually. Now, that task can be done in just 20 minutes using a robot. The operator simply has to input the pattern in a tablet and the robot does the rest.

The robot was invented by Turf Tank, founded by Anders Ulrik Sørensen and Andreas Ydesen. The company has now been taken over by private investors who have set out to automate the billion-dollar global market for sports facilities, which are currently being marked out manually.

The company has attracted well-known Danish angel investors and, in 2019, established a new 33,000 sq. ft. headquarters. The company expects to invest \$15 million in marketing and sales. Turf Tank is already represented on three continents, but focuses especially on the United States, where the NFL teams New England Patriots and Tampa Bay Buccaneers are among its largest customers.

www.turftank.com



Photo: Life Science Robotics

Life Science Robotics / Aalborg

The rehabilitation robot ROBERT's purpose is to reduce complications for patients, so their time in hospital and subsequent rehabilitation are shorter.

The robot can perform passive and active training and works by having the staff first show the robot how to train the individual patient. The robot then repeats the desired movement in exactly the same way. When it receives the slightest resistance from a patient, the robot immediately stops. This frees up time for therapists to talk to patients or to train other patients in the same room. Similarly, the therapist can let the robot do heavy and repetitive movements and then focus on tasks that are more complex. The robot can also measure several specific parameters, including a patient's leg strength.

This enables the patient's strength to be accurately measured and reported.

Life Science Robotics is behind the rehabilitation robot, and has distributors in Europe, the United States and Korea. Among its investors is Søren Juul Jørgensen, who was among the first to invest in MiR.

www.lifescience-robotics.com


Robotto / Aalborg

Robotto has developed drones that can monitor and analyze forest fires. The company originated from a project at Aalborg University.

www.robottodk.dk



Illustration: Robotto



In 2019, the University of Southern Denmark (SDU) inaugurated the world's most advanced research infrastructure for the development of robotics technology and automation. It includes an Industry 4.0 lab. SDU plans to invest \$20 million over the next five years in the lab, which will be the most advanced in the Nordic countries.

A Strong Ecosystem Supports the Cluster

Application-oriented research, new educational opportunities, network collaboration and easy access to capital have been crucial to the growth of the Danish robotics cluster.

The major robotics companies, integrators and startups, as well as the fiery souls who created them, have been fundamental to the development of the Danish automation and robotics cluster.

However, the external ecosystem also plays a crucial role. This includes the research institutions, industry networks, educational institutions, investors and the availability of a competent, educated and experienced workforce. Without this strong ecosystem, there would be no cluster.

Research in automation and robotics takes place at the Technical University of Denmark (DTU) in Copenhagen, Copenhagen IT University, University of Southern Denmark (SDU) at Odense and Sønderborg, Aalborg University (AAU) and Aarhus University. In addition, the Danish Technological Institute (DTI), Denmark's version of the German Fraunhofer, provides extensive assistance in how companies put new automation technology to use. In 2019, DTI opened a dedicated cobot lab in Odense.

Danish research institutions have published a total of 441 scientific articles related to robotics in recognized international journals from 2014 to 2018. In the area of robots, robotics and manipulators, which includes computer technology, robotics and physics, Danish educational institutions are strongly represented with an impressive 221 articles published during that period.

These articles are quoted one and a half times above the average quotation rate worldwide. Measured in relation to the number of inhabitants, the Danish number of research articles on robots and automation is highest among the industrialized countries during the period.

Long traditions of working with companies on automation

At the Technical University of Denmark, the oldest Danish technical institution, there is a long tradition of researching and collaborating with Danish companies on automation and management.



Kasper Hallenborg (b. 1976), Department Head, Mærsk McKinney Møller Institute

Kasper Hallenborg is a Master of Science in Engineering, MSc. and associate professor at the Mærsk McKinney Møller Institute, which he has headed since 2014. Among other things, he has worked intensively on pervasive computing and multi-agent systems. Under Hallenborg's leadership, the institute has grown significantly in terms of both research and the number of employees, students and graduates.

Research has concentrated on three areas:

- Condition monitoring of decision support and safety-critical systems
- Reconfigurable and self-learning systems
- Perception and situational awareness under uncertainty

The common thread for DTU's modern research is autonomous systems. In 2020, DTU will open the Center for Collaborative Autonomous Systems, CCAS. The idea is to draw from the many competencies that exist at the university with the aim of developing intelligent autonomous systems that can collaborate with people.

At the center of this lies DTU's institutes: Compute, Space, Management, Engineering and Electrical. They also have a new test arena for drones and underwater robots. The new arena helps make DTU more attractive when it comes to searching for national and international research grant pools.

One example of the research conducted at DTU concerns autonomous ships. DTU envisions building ships that could sail for long periods unmanned, or in special cases – without a navigator on board. This can only be done when you have computer algorithms as skilled as an experienced ship captain.

The effort to bring the algorithms to the level of experienced captains is based on the ships' electronic surveillance system. Cameras and radar devices monitor the ship's surroundings. Through

information on markings and water depths, the computer will predict how close other vessels or other obstructions are. Based on this, the computer assesses the risks of collision or grounding, which it avoids by planning and performing its own maneuvers. One of the complications is that, for a computer, it can be very difficult to tell the difference between, for example, a sea marker and a kayak.

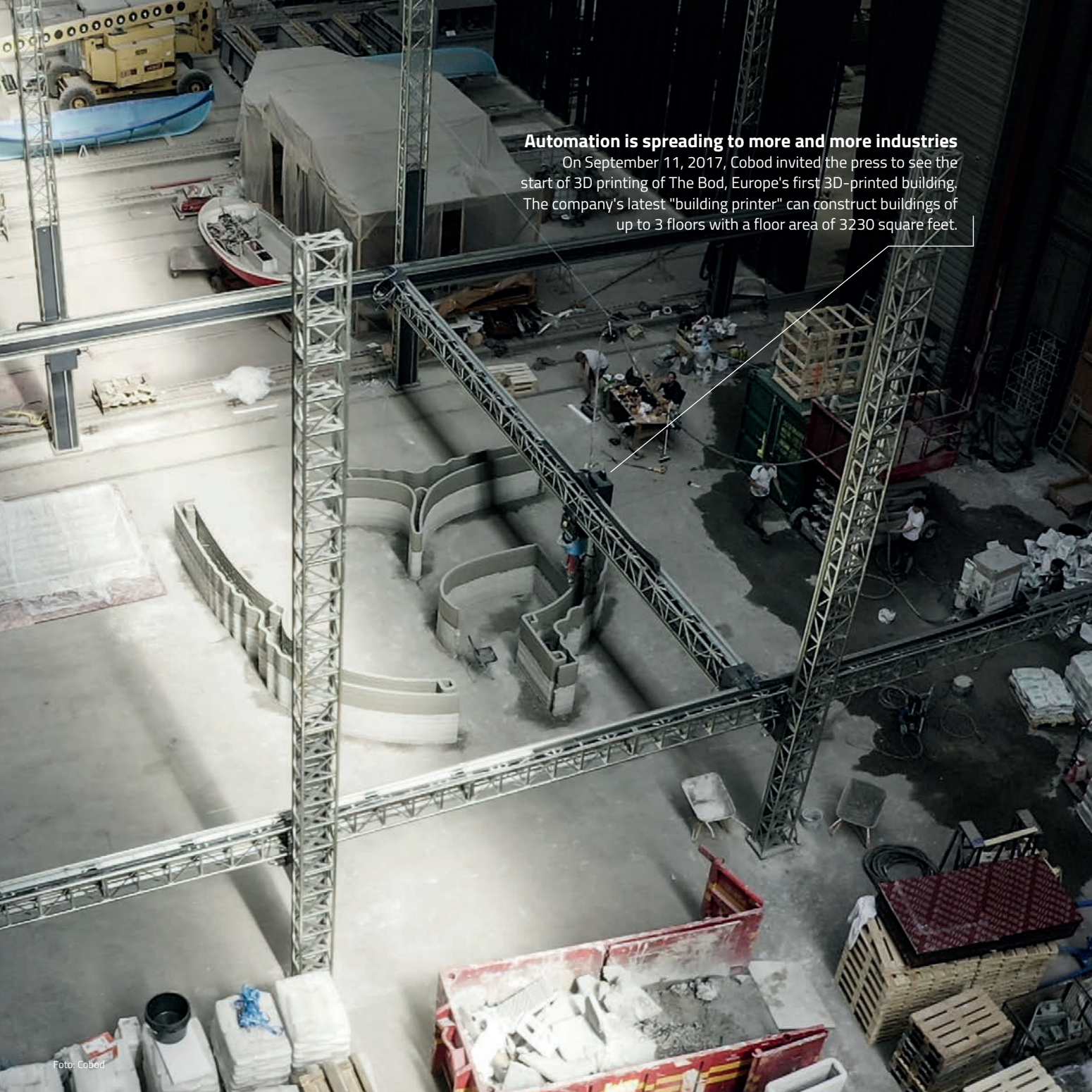
The research will focus on influencing international standards so that it will be possible for Danish suppliers to bid on specialized subsystems, certify these and secure the opportunity to export solutions to the rest of the world.

The project is being implemented together with the Danish maritime industry, a natural fit because the country has the world's largest shipping company in A. P. Møller Maersk.

At DTU, several Ph.D. projects in robotics technology have been conducted. One example is researching how a robot can control the de-icing machines used in airports. Another is from the company Cliin, which has developed a ship-cleaning robot that can help make a notoriously dirty industry significantly greener and healthier for workers.

Brand new research infrastructure at SDU

In 2019, the University of Southern Denmark (SDU) inaugurated the world's most advanced research infrastructure for the development of robotics technology and automation. It includes an Industry 4.0 lab. SDU plans to invest \$20 million over the next five years in the lab, which will be the most advanced in the Nordic countries.

An aerial view of a large industrial 3D printer, a long gantry system with two vertical towers, printing a large, curved concrete structure in a warehouse. The printer is positioned over a large, curved concrete structure. The warehouse floor is cluttered with various materials, including pallets, bags of cement, and a red container. In the background, a yellow crane and a blue boat are visible. The scene is brightly lit, and the overall atmosphere is one of industrial activity.

Automation is spreading to more and more industries

On September 11, 2017, Cobod invited the press to see the start of 3D printing of The Bod, Europe's first 3D-printed building. The company's latest "building printer" can construct buildings of up to 3 floors with a floor area of 3230 square feet.

This will allow researchers and students to work with some of the market's latest and most advanced flexible robot and automation solutions. They will also work with the technologies in a virtual manner: in a digital design lab with virtual reality and augmented reality equipment.

In addition, there will be a new research center focused on soft robotics technologies. Typically, robots work with hard materials, but there is an increasing demand for automation solutions that can handle soft things, such as food, textiles, or other soft materials.

The research in automation and robotics is concentrated at the Mærsk Mc-Kinney Møller Institute, MMMI, which was established in 1997 as part of the science department at the University of Southern Denmark. In 1999, the institute moved into a new building donated by the A.P. Møller and Chastine

Mc-Kinney Møller Foundation. In 2019, the foundation donated an additional \$14.5 million to expand the institute with a new building, and the institute has held the global leadership position in robotics for more than two decades.

The institute was among the first to start robotics research in Denmark and is closely associated with robotics companies on Funen, including Universal Robots (UR) and Mobile Industrial Robots (MiR), both founded by employees at the institute while they were still employed there.

Based on MMMI's efforts in robotics and software, it has also been possible to create research centers in related fields such as artificial intelligence, health and energy informatics. In recent years, drone research was included in the Institute's development footprint, as was robotics inspired by the anatomy of insects.

Henrik Gordon Petersen (b. 1960), Professor of robotics, Section manager, PhD, Mærsk McKinney Møller Institute, SDU Robotics

Henrik Gordon Petersen wrote his PhD under the guidance of John Perram. He quickly became a driving force at the Mærsk McKinney Møller Institute, where he later became a professor of robotics. He wrote several of the algorithms on which the new robotic technologies in the Danish robotics cluster are based, and he has trained many of its engineers. Petersen was a co-investor and actively involved in AMROSE. In 2015, he received the Grundfos Award of \$150,000 for his many years of research in robotics. He was also actively involved in the establishment of the Mærsk McKinney Møller Institute's new Industry 4.0 lab, which opened in 2019.

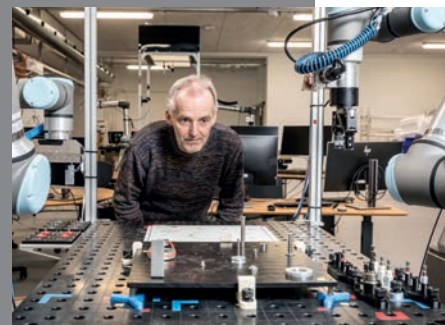


Photo: SDU

According to MMMI's director, Kasper Hallenborg, the purpose of the new Industry 4.0 laboratory is to work with flexible module-based production and automation.

"We are not just looking at a single area for a robot to work in; we are looking at the whole production system. We're working on modularization to meet the increasing demand for customer customization in modern production," explains Hallenborg.

Henrik Gordon Pedersen, a professor at the institute, adds that the institute can now try things in a business environment without having to interfere with production.

"Today, the industry does not have all the technology that is needed, but here we can test new things which we know will become commonplace in companies in the future," says Pedersen.

SDU is best known for working with application-oriented technologies, but at the same time, it seeks to travel to new frontiers, such as soft robotics technologies.

A prime example of a soft robotics project is SDU's partnership with the Danish aerospace producer Terma, a significant supplier to Lockheed Martin's F-35 fighter jets.

For years, various attempts have been made in vain to develop technological solutions that can reduce production costs by ensuring that composite layers of fiber mats are placed correctly and quickly in aircraft. Now, a breakthrough in automation has solved this complicated challenge. An experiment

was carried out in SDU's laboratories demonstrating that it is possible to fully automate the production of composite components for the aviation industry. Previously, the expensive composite layers had to be added manually.

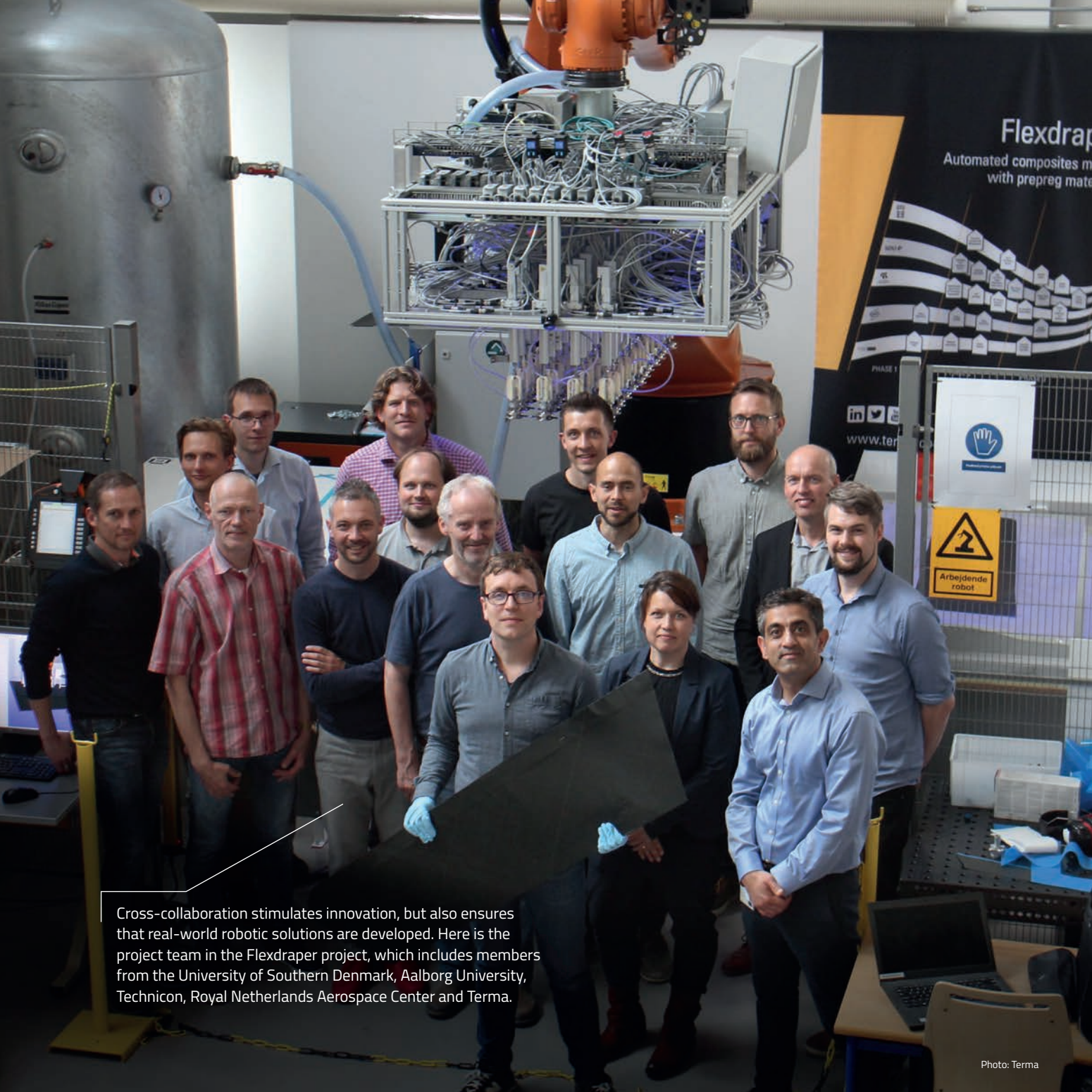
The FlexDraper, as the solution is called, is a single robot with sophisticated software. The FlexDraper has 120 suction cups that can be controlled individually and ensures that the fiber mats are placed correctly on the molds.

This project has attracted international attention, including that of two aircraft manufacturers, Airbus and Boeing, both of which are interested in the possibilities of using the new production technology.

The goal of the new soft robotics institute is to develop new ways of handling materials, for example, by simulating muscle structures. In addition, research infrastructure must be built within active and intelligent material types, so SDU will investigate how electricity make these materials active.

Another new development is happening in the southern Danish city of Sønderborg, where SDU has its Center for Industrial Electronics. This center includes researchers and developers from universities and companies on both sides of the Danish-German border. It works in close interaction with large Danish companies such as Danfoss, the world-renowned producer of thermostats and Linak, which produces electric actuators and lifting columns.

SDU is also actively working with service robots, such as nursing robots. According to Norbert



Cross-collaboration stimulates innovation, but also ensures that real-world robotic solutions are developed. Here is the project team in the Flexdraper project, which includes members from the University of Southern Denmark, Aalborg University, Technicon, Royal Netherlands Aerospace Center and Terma.

Krüger, professor of robotics at SDU, these robots are not intended to look like humans, but to handle simple tasks so that there is more time for real human contact. He is working on a team to develop a service robot for nursing homes.

No, this is not the classic cartoon The Jetsons. Instead, imagine a robot escorting the elderly to lunch, serving water and transporting laundry and garbage. The robot must learn to conduct short conversations and be able to perceive when elderly people are tired or thirsty.

"The biggest challenge when developing nursing robots is to get the human-robot interaction in place. We need to create models for how people act and react," explains Norbert Krüger.

"Little Helper" is in full swing at AAU

Aalborg University (AAU) in the northern part of Denmark is also active on the research front.

At the university, robotics research is taking place at a number of different institutes spread over all the faculties of the university. In 2007, a robotic center was established to coordinate the research. Today, Aalborg U Robotics, as the center is called, consists of more than 70 researchers who come from a number of different institutes.

Many of the researchers work with reinforcement learning. With this process, you give the system a problem that it must try to solve. Along the way, the system tests various ways it can solve the problem and is rewarded depending on how well it performs the task.

Reinforcement learning is typically used for tasks where robots need to interact with the real world. For example, it can be a process in which the robot explores how fast a screw is to be screwed in and tries until it has found the right pace and strength.

Like the University of Southern Denmark, Aalborg University has an interdisciplinary and application-oriented approach with robot technology and automation. Students spend half their time on projects in companies.

This connection to business can be seen in several of AAU's projects. One example is the "Little Helper" project, which was inspired by the Disney figure Gyro Gearloose's trusty assistant. AAU has been working with Little Helper since 2006, and several different versions have been developed that have been tested in various contexts. The latest Little Helper is almost entirely Danish. It consists of a MiR robot platform on which a UR5 robot is mounted. In addition, the robot is equipped with a gripper and a number of cameras.

This type of robot is indicative of the future of robot technology. It is mobile and can navigate around without any lines or magnetic paths in the floor. It can be used for a variety of tasks, as it is easy to reprogram. In addition, it is modular so it can be quickly reconfigured, and it can operate without a grid. There is a wide variety of applications for such a robot, for example to feed items into machines, assemble simple items or retrieve objects for an operator.

Another project is about making Industry 4.0 accessible to smaller businesses. The project is called Innovation Factory North. The project aims

Innovation Factory North at Aalborg University works within three main areas:

- Awareness: What technologies are there and how can companies leverage them?
- Demonstrations: Together with partners, suppliers and production companies, demonstrations of new solutions are being built.
- Anchoring: Moving innovations back to the original manufacturers and building companies' competence to translate innovations to new potential.



Photo: Factory North

to help manufacturing companies utilize smarter production techniques. It includes mapping, testing, competence development and the implementation of many technologies available now but may be difficult to put into use on a production line. The project involves 10 technology companies and 60 suppliers.

It consists of three main activities:

- Awareness: What technologies are there and how can companies leverage them?
- Demonstrations: Together with partners, suppliers and production companies, demonstrations of new solutions are being built.
- Anchoring: Moving innovations back to the original manufacturers and to building companies' competence to translate innovations to new potential.

A third area of focus is exoskeletons. These portable, mobile machines are powered by a combination of technologies that allow human limbs to move with increased strength and endurance. There is a great need for devices capable of relieving the work force with things such as lifting heavy objects and thereby reducing the risk of injuries. AAU research on exoskeletons has been a constant focus for the past decade. The current models are mechanical and thus “stupid,” but AAU is working

to build intelligent customized exoskeletons. They use algorithms to measure movements and are figuring out how the movements can be controlled and strengthened.

Through its research and projects, Aalborg University is paying particular attention to understanding more fully the processes that can be turned into an action a robot can understand and respond to.

AU focuses on classic engineering disciplines

In the second-largest city in Denmark lies the University of Aarhus (AU). Within the school's classical engineering disciplines, including mechanics, electronics and IT, there are many research and development activities that are relevant for automation. There are also many graduates within these disciplines with knowledge of robotics and automation technology.

Their focus is on general robot programming, robot kinematics, autonomous mobile robots, vision technology, motion planning and navigation. Students collaborate with companies to work with enterprise hosts to develop robot manipulators for telemedicine solutions and drones for monitoring the power grid.

Robots are at the forefront of the Danish Fraunhofer

In many ways, it has been crucial for the development of robotics technology in Denmark that the Danish Technological Institute (DTI), a counterpart to the German research institute Fraunhofer-Gesellschaft, established its own robotics center in 2007.

Kurt Nielsen, head of the Technological Institute's Robotics Technology Center.



Photo: DTI

DTI is among the largest institutions in Europe working with robot technology and automation. DTI's robotics department in Odense has around 50 robotics specialists who find new ways to automate and help companies solve automation tasks that cannot be solved by integrators and other commercial automation providers.

DTI's robotics department has testing and development facilities of 32,291 square feet, 50 robots and has 500 contract customers. DTI has been involved in about 60 development projects.

DTI has a number of focus areas. Kurt Nielsen, head of the Technological Institute's Robotics Technology Center, points to computer vision, artificial intelligence (AI) and robotic security as some of the essentials.

"We use cameras to control many processes – for example gluing, welding and quality control, but there are many unsolved problems. We know this from the many companies seeking specialty solutions in the area. Robot safety is equally a challenge. The collaborative robots, which the Danish robotics cluster is particularly strong in, should not be confined to work in one spot. However, robots must be safe when moving between people."

"If we are to have more robots outside the factory floor, it is crucial that the robots become more intelligent by utilizing artificial intelligence, which enables them to adapt to the uncertainties they face outside the factory floor. At the same time, we also need to find the right ways to provide security," says Nielsen.

In addition, DTI is host for eight startup companies in a robot incubator, Odense Robotics Startup Hub. The new young robotics companies have free access to all DTI's equipment and to the on-site consulting and expertise.

Several companies have since achieved great success and have been sold to new investors who are taking them to the next level in the value chain.

DTI also drives the DIRA robotics and automation network, with more than 200 member companies. DIRA works purposefully to improve the competitiveness of Danish companies in international markets through the introduction of automation and robotics. The network has a history that stretches back to 1982. Every year, the institute recognizes leading companies with an automation award.

The network is a good characterization of the approach that Danish companies and research institutions take to automation and robotics.

The MADE network introduces new technologies

One of the newest and most important networks in this area is MADE, the Manufacturing Academy of Denmark, which was launched in 2014. Following the outsourcing wave that Danish industrial companies had been through in the 1990s and 2000s,

universities, research facilities tech companies and others banded together to create an alliance to make Denmark one of the leading producers in the world.

By the end of 2019, MADE had well over 180 members, including institutions and companies.

The three main challenges that MADE addresses are how quickly you can introduce new products and equipment in the industry, how to optimize production with digital simulations, and how to handle the complexity that characterizes production companies today.

This must be done, among other things, by leveraging the advantages that Denmark has through its culture of collaboration and practical approach across companies and knowledge institutions.

These challenges provided the foundation for the research platforms MADE SPIR and MADE DIGITAL. In MADE, small and large companies come together with educational institutions in so-called work packages. The intention is to develop new methods and production forms and solve the problems that arise in production. The end product is communicated widely to producers throughout Denmark. In 2019, there were nine work packages in MADE, with projects typically lasting for several years.

One example is object-feeding (Picture page 135). The goal is to move objects to and through a robot as cheaply and flexibly as possible. Feeding a robot with objects in the right way is a difficult task.

The classic solution to this problem has been so-called vibratory bowl feeders. These feeders rely

It can be difficult to make robotic component feeders both flexible and profitable. It is even more so for small and medium-sized companies that produce small series with high variations. That's why MADE has looked at how to easily and quickly build different vibration bowl feeders.

In his Ph.D., MADE researcher Simon Mathiesen investigated whether using advanced computer simulation could speed up and lower the price of developing bowl feeders.

- There is a positive economic potential if you can use a computer to develop vibration bowl feeders cheaper and easier using CAD models and 3Dprint. Then you do not have to justify that they are not used 24 hours a day when you have bought one, says Simon Mathiesen.

Photo: MADE



on the mechanical behavior of a part, such as when gently shaken down a conveyor chute that is specifically shaped to fit the part, they will gradually be shaken so that they are all aligned. This results in objects leaving the feeder's conveyor one-by-one, all in the same orientation.

Along the way, mechanical rejection mechanisms are used to ensure that the items only reach a certain point on the bowl if are oriented in the right way.

This can ensure that a screw only reaches a robot in a position where it can properly grasp it and attach it to another item or product.

Workers dedicated to this solution is expensive. It takes time to develop each container system, which can basically only be used for one purpose. Using computer simulations that take into account the dynamics of a process – for example, friction between subjects – you can measure and forecast quite precisely how good a solution will be. In

this way, you make all the adjustments as a digital simulation until you have a solution that is worth moving from concept to the production line. This makes the development of a vibratory bowl feeder less expensive, so that they do not have to be used 24 hours a day to give a return on the investment.

Electronics manufacturer Danfoss participated in this project. They provided use cases for different objects and continuously tested and provided feedback on the software and hardware the researchers developed.

The ultimate goal is for a company to only be required to come up with a precise CAD model of an item, press a key on a computer, and the same day get the finished design for a vibratory bowl feeder, which could potentially be 3-D printed.

Nigel Edmondson, Director of MADE, explains the type of collaboration like this:

"We often try to bring researchers together with application companies, machine manufacturers and subcontractors. This creates a space for developing new products with minimal risk. The larger companies want a solution. The smaller ones are interested in developing and selling it. The large companies provide financial backing and the small companies invest their time. Half of the companies working on the research platforms are small and medium-sized."

Edmondson adds that in smaller companies, the owner or director often work closely with the researchers and gets to know them. This makes it easier to make strategic decisions – for example, whether to invest more in automation and robotic solutions.

The key to successful work packages and projects, which MADE is conducting, is thorough project management and alignment of interests and expectations among the participating parties.



Photo: MADE

Nigel Edmondson (b. 1974), Director of MADE

Nigel Edmondson is Director of MADE – Manufacturing Academy of Denmark. He has a PhD in robotics from Loughborough University in England, where he worked with Grundfos. Nigel worked for eight years at Grundfos and seven years at Maersk, both places with leading positions in areas such as quality assurance and process optimization. He has been the driving force in building the MADE network and worked to make the association useful for both small and large companies as well as educational institutions.

This is relatively easy in Denmark, where most large companies work in niches and where few companies compete directly with each other.

The task is also simplified, according to Edmondson, because of the Danish education system, where group work and collaborative exams are common. In his native England, students take exams individually and often compete intensely with one another.

"In the Nordic countries, people are better at creative thinking and learn to question almost everything. This promotes innovation," he says.

Edmondson punctuates this point, noting that, "Analysis now shows that the socio-economic gains of the production solutions launched via MADE have a value of around \$1 billion in cost savings in companies."

AutomationsBoost is preparing companies for the future

The southern Danish innovation program AutomationsBoost expects to create 66 new jobs, increase revenues by \$24.5 million and increase exports \$5 million in the span of just five years.

Through Automation Boost, RoboCluster and Southern Jutland Businesscenter, in partnership with researchers and others have boosted several smaller companies' exciting automation solutions so they are ready for the future.

An example of a small company that has been successfully boosted by automation is AmiNIC. They have developed a new meter that captures food spoilage more accurately than ever before. It builds

on nanotechnology and in a matter of seconds, measures the precise freshness of fish and meat, and gives an exact shelf life. The sensor is based on patented technology, developed in collaboration with several of the country's largest universities and has a very promising future.

"AmiNIC's solution will change quality control throughout the food industry value chain and pave the way for future distribution and processing of fresh foods," said Jens Peter Klausen, CEO of fish producer J.P. Klausen.

More skilled labor on the way

It is, of course, significant that research and development collaboration is taking place between research institutes and companies throughout Denmark. It is equally critical that the educational institutions provide the qualified workforce that the sector needs. In general, there is an increasing number of students joining programs relevant for robotics. In 2019, a new master's degree program in autonomous systems was established at the Technical University of Denmark (DTU) and almost three dozen students were just enrolled. People with different bachelor's degrees, such as electronics, mechanics and software are the key demographic for admittance. Of note is that DTU already graduates about 70 engineers annually with degrees relevant to robotics technology.

At the University of Southern Denmark (SDU), civil engineering and an engineering degree in robotics have been offered for years. The latter degree program can be achieved on a compressed timeline, but requires an internship at a company allowing software engineers to be trained in the field.

In total, approximately 300 students a year are admitted to robotics-relevant educational fields. In 2019, SDU graduated 110 engineers with robotics-relevant graduate degrees.

At Aalborg University (AU), a master's degree in robotics was started in 2019 and they have had a bachelor program in robot technology for the past five years. Between 60 and 70 students are admitted each year.

However, it is not just engineers and other highly skilled specialists who are in demand in the robot industry. Industrial technicians, electricians and other skilled workers are also in demand.

This has been considered at the Southern Denmark Business School in Odense. A few years ago, the school inaugurated a new center for automation and robotics. The center is a collaboration between three business schools on the island of Funen and has an ambition to train apprentices from all of the country's business schools as the future work force for the robotic industry.

"So far, most people may have had a notion that the robotics industry is primarily made up of PhDs and engineers, but robots must also be built. Skilled craftsmen are required, and we would like to supply them," says Lars Bregnehøj, director of the Southern Denmark Business School.

With the prospect of an increase in the number of employees in the Danish robotics cluster to 17,000 within the next five years, the output from the higher education institutions and business schools doesn't come close.

That is why Danish robotics companies are also increasingly recruiting abroad as companies become more global.

Easy access to capital

The final, key factor for the development of the automation and robotics cluster is access to venture capital. Over the past five years, the Danish cluster of robotic companies have added more than \$1 billion in fresh capital. The money has come from private investors such as the American company

Ole Ravn (b. 1959), Professor, Group leader, DTU

Ole Ravn is a professor of intelligent robotics and has been a group leader at the Technical University of Denmark, Automation and Control. Originally trained as a civil engineer in electronics, he has extensive teaching and research experience in the field.

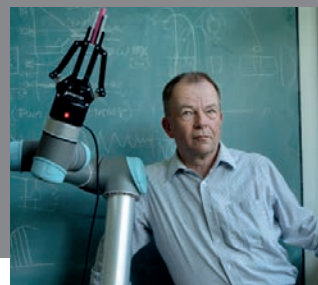


Photo: Mikal Schüssler

Teradyne, Danish and foreign capital and venture funds, such as American Summit Partners and the Danish venture fund Nordic Eye.

In addition, the Danish Growth Fund, which operates on the state's behalf to invest in growth companies, has played a decisive role throughout the years.

In the mid-2000s, the Growth Fund (www.vf.dk) and a local public-owned venture company helped UR get on its feet. The company was later sold to Teradyne for \$2.3 billion.

The Growth Fund has recently invested in end-of-arm supplier OnRobot, which, like UR, has global ambitions.

The fund makes risky investments together with private players and has invested in numerous other companies.

One example is Kubo, which manufactures a learning robot that teaches students to code. QuadSat, which helps calibrate ships' satellite reception, is another example. A final example is EffiMat Storage Technology, which produces warehouse robots. The Growth Fund invested in EffiMat together with the owners of the Danish thermostat manufacturer, Danfoss.

Lars Rønn, partner in the Growth Fund's direct investment department, VF Venture, explains that there is no longer a need for the fund to be a pioneer in investing in the robotics and automation industry.

"Our task is not to fight for every project. We have to be where there is high risk, but also high potential. Robotics have been pretty hot. If the price gets too high, we pull out – we've played our part," he says, pointing out the increasing number of deals that now go to venture capital funds and angel investors.

He explains that angel investors are now very interested in the pre-industry.

Several of the other players in the Danish robotics industry have established their own venture companies that invest in robotics.

For example, the founder of MiR, Niels Jul Jacobsen, together with his wife Charlotte Hybschmann-Jacobsen, invests through the company Hybsch Connect Holding, and UR founder Esben Østergaard invests via ReInvest Robotics.

Søren Bøving, Managing Director of Scape Technologies, a publicly traded Danish manufacturer of tie-picker systems points out that some robotics companies have an opportunity to go public.

"A listing on the stock exchange acts as a stamp of approval internationally. As a small business, it is easier to earn the trust of customers when they see that investors are willing to back our business," he says.

Angel Investors Bet on Danish Robotics Technology



Photo: PR-photo

Torben Frigaard Rasmussen has created an entrepreneurial environment where the companies he has invested in are based.

Torben Frigaard Rasmussen is an entrepreneur and angel investor. At the epicenter of the Danish robotics cluster, Odense, he has created his own entrepreneurial environment in his former bank building, where 10 of the companies, he has invested in, are housed.

For several years, Torben Frigaard Rasmussen has been the director of the ERP company, E-conomic, which in 2013 was sold to a capital fund for just over \$110 million. In addition, Torben Frigaard Rasmussen was a co-investor in an early phase of MiR, which was later sold to Teradyne for \$250 million. His portfolio of growth companies includes "Robot at Work."

In addition, Torben Frigaard Rasmussen, together with the Danish state's Growth Fund, invests in the fund's European Angel Fund Denmark (EAF Denmark), where the fund doubles the investments made by private investors.

His expertise does not necessarily relate to robotic concepts, but in turn, he can help with scaling and making the right decisions on their corporate growth journey.

Torben Frigaard Rasmussen points out that many decisions in a growth phase are important because they cannot be reversed. This applies, for example, to platforms, software language and standards. He draws on his experience from E-conomic, which today is an ERP system with a strong global position among smaller companies.

Torben Frigaard Rasmussen was the CEO of E-conomic in 2008 when the financial crisis came and swept the carpet out from under many companies.

"Suddenly, customers would not spend \$ 5,500 on installing an ERP system. That is why we introduced Software as a Service, where software could be rented. It turned out to be the right model," he says.

Torben Frigaard Rasmussen, who in 2018 was named "Angel Investor of the Year" in Denmark, sees it as an advantage to bring together the companies he invests in under the same roof.

He points out that it is important for small businesses to be in an environment they can be inspired and inspire others. Again, he draws on his E-economic time, where he merged the company's many different branches into headquarters in Copenhagen. It created a completely new creative dynamic.



The Major Role of Industrial Policy

The fear that robots will completely take over our jobs is groundless. In Denmark, trade unions are asking for more robots. Businesses and the Danish government have answered by playing an active role in developing the robotics cluster.

How has the automation and robotics industry achieved so much success in Denmark and attracted international attention with the promise of continued strong growth?

First and foremost, the industry owes its success to several talented and passionate individuals and entrepreneurs who created the innovative companies in the cluster. Without their decisive efforts, the robotics and automation industry in Denmark may have simply fizzled out.

But for a cluster to grow and thrive, the conditions must be right. A framework of specific initiatives and broad societal conditions are the foundations upon which the companies flourish.

For example, there needs to be a fair legal system, fiscally responsible startup costs, reasonable administrative burdens, financial and political stability, a functioning labor market with well-educated candidates, unfettered access to broadband and consistent regulations.

Most of these factors are determined by the overall policy of a country and are largely the realm of macroeconomics, while the specifics of companies are about microeconomics and industrial policy.

Consensus on fiscal policy

Denmark's governments switch between center-right and center-left, but there is a consensus that the private sector must have favorable business conditions to compete globally and provide the foundation of the Danish welfare model.

In the Nordic region, there is an export-oriented, efficient private sector and a well-functioning public sector. The public sector establishes a framework for the workforce that guarantees low prices for childcare, free education, and health care. The two sectors are not at odds, but rather act in support of each other. A relatively high tax rate has not prevented Denmark from being named as one of the countries in the world where it is easiest to operate as a business.

According to the World Bank's annual Doing Business report, Denmark is the third-best country in which to start a business. The report ranks countries by how easy it is to operate a business in terms of taxation, ability to secure loans, qualified labor, access to electricity, cross-border access as well as several other parameters.

At the same time, there is a longstanding practice in Denmark that employers and employees, without the burden of governmental involvement, negotiate to settle disagreements on pay and working conditions. The overall agreements are negotiated nationally every three years, but they are adapted to local business conditions. Consequently, there are rarely conflicts in the Danish labor market.

No need to fear a jobless future

As in many other countries, Danes love to discuss whether automation and robots will take over most work functions and cause widespread unemployment. However, unlike in other countries, fear of robots is not a pervasive sentiment in Denmark.

Denmark: Open for Business

Accolades and awards for the Danish Business climate.

Denmark boasts a large number of entrepreneurs and serial entrepreneurs for such a small country. This has created a unique culture of mutual support among Danish entrepreneurs.

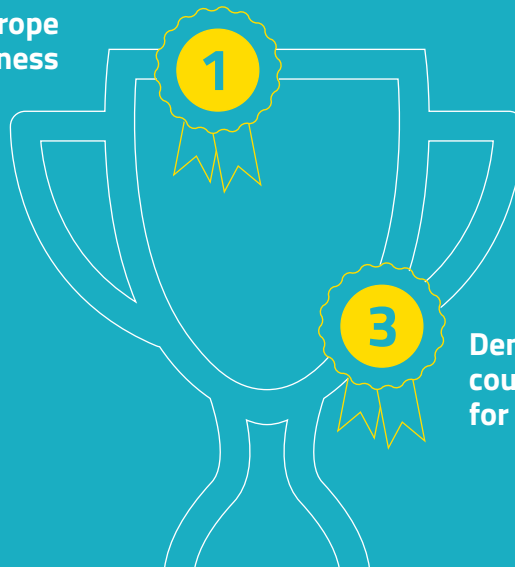
High ICT adoption makes the Danish population among the most digital in the world. Technological readiness is driven by world-class R&D and an adaptive workforce.

Denmark boasts of the highest number of companies with scalable potential per capita in Europe.

Denmark has the 5th most well-functioning labor market in the world. Denmark is a pioneer of the flexicurity model. The Danish workforce ranks as one of the most productive workforces among the OECD countries.

- ✓ Most flexible hiring and firing legislation in the EU.
IMD, World Competitiveness Yearbook 2016
- ✓ 10th most competitive business climate, measured by the institutions, politics and factors that determine the level of productivity.
World Economic Forum, The Global Competitiveness Report 2018
- ✓ In 2018, the UN named Denmark a world leader in public digitalisation.
- ✓ Copenhagen ranks as one of the most liveable cities in the world.
CNN Travel 2018

**Denmark is the number 1
country in Europe
for doing business**



**Denmark is the 3rd best
country in the world
for doing business**



In 2017, the consultancy firm McKinsey analyzed what work functions could be automated around the world. Denmark ranked among countries where the fewest job functions – around 40 percent – could be automated with known technologies. In other European countries, the percentage was closer to 60 percent.

The primary reason for this is that automation is not as fully entrenched in other countries as it already is in Denmark. And while 40 percent of work functions can, in principle, be automated, Denmark experienced full employment in 2019.

In the years following the financial crisis, the private sector expanded and created many new jobs despite the fact that automation was already occurring with considerable intensity in the Danish industry.

The American author, Martin Ford, who wrote the book *The Rise of the Robot*, has predicted that robots and automation will eliminate jobs to such an extent that citizens will need to be given special

Treatments with the robot ROBERT contribute to the rehabilitation of patients and prevent stiff joints, ligaments, muscle breakdown and other injuries. At the same time, ROBERT reduces the amount of strenuous work required by therapists and nursing staff. The idea for the rehabilitation robot came from a Danish nurse who, in his daily work, could see that patients often did not receive sufficient rehabilitation.

loans and other measures would need to be introduced to ensure stable incomes.

But this scenario does not carry much weight in Denmark, even though the idea of jobless societies, where robots solve all tasks, is at once daunting and fascinating.

Denmark has made significant progress in digitizing the country's large public sector. It did not happen without errors and carried significant costs, but digitization has also created many jobs in the companies that have developed the systems.

Another consideration is the fact that, although some things may be technically feasible, it does not always make good sense economically.

An example of this is the Concorde passenger jet, which could travel from Europe to the United States in less than three hours. But the aircraft was never a commercial success and did not replace the more traditional, but slower, aircraft types such as the Boeing 747.

Robots open the way for more employees

Automation can help companies a great deal. However, full automation, where the last 20 percent of tasks are also performed by automatic systems, is not always profitable.

History has shown that new technology has probably replaced job functions in certain industries but triggered more employment in others. This is how it has been since the birth of industrialization some 200 years ago.



In Denmark and especially on the island of Funen near the “robot capital” Odense, there is a thriving new industry in the production of medical cannabis. Automation plays a key role. Already, with its cool northern European climate, the agricultural country has a strong tradition for horticultural industries, so it makes sense to combine with Denmark’s strength in the development of automation and robotics.

Photo: Spectrum Therapeutics, Canopy Growth Denmark

Esben Østergaard, founder of Universal Robots (UR), refers to the fact that many of the companies that have bought UR’s cobots over time actually hire even more employees.

Industry 4.0 focuses on optimization, error reduction and cost reduction. This can save 10 to 20 percent on production costs, which is significant, for example, at a car factory.

However, according to Østergaard, consumers today want individualized products, and they are willing to pay more for them. “We do not want the same doormat as our neighbor. We want our coffee cups, furniture and cutlery to be special.”

“If you can make the product worth five times more by producing what consumers demand, then it has a completely different value. But you can’t create

this value through automation – the more you automate in Industry 4.0, the more you kill creativity,” he says.

Østergaard further believes that what he calls Industry 5.0 will trigger new jobs and new functions. This will involve consumers creating their own individual product together with an expert. For this purpose, a wide range of competencies is needed. Knowledge of materials, processes and a flexible production apparatus will be required to deliver distinctive products to the consumer. There will need to be a person close to the machines who understands what the customer wants. This flexible automation with cobots will give power back to those working on the factory floor.

“With flexible automation, there is no longer the need for a metal worker to stand for five hours and

drill holes in something. This is taken care of by a robot. Instead, there is a need for his experience, knowledge and insight,” Østergaard opines. “If a customer does not like a certain finish of a product, an expert craftsman will experiment with his CNC (computer numerical control) machine and perhaps use a different cutting oil or something to achieve the finish that the customer is willing to pay for.”

Trade unions call for more robots

The flexible automation approach is completely in line with the Danish trade union movement.

The Danish Union of Metal Workers drafted an opinion in 2019 arguing that automation rates in Danish companies, especially smaller ones, should increase to ensure their competitiveness.

Tax incentives that provide favorable conditions are noted to stimulate companies' investments in automation. In addition, the public sector could create robotics libraries to give smaller companies access to knowledge about automation. There is also a need for more governmental consultants and private organizations that can help smaller companies get started with automation.

“Danish companies need to compete internationally to build the foundation on which the Danish welfare model is based. This will require further automation. We are not worried about the jobs. Historically, new technology triggers new jobs. Those who were producing oil lanterns when electricity was introduced were obviously hit. But electricity created a lot of other jobs,” explains Thomas Søby, Chief Economist at Dansk Metal.

He notes that the Danish labor market model protects the worker, not the jobs. It is easy to fire and hire in Denmark. On the other hand, workers are guaranteed relatively high unemployment benefits and access to continuing education, so that the skills demanded in the labor market can be met. This model is widely known as flexicurity.

Many continuing education courses and certifications are investments borne by employers. However, Søby recognizes that not all Danish employers are willing to pay for certifications because in the long run they risk losing some employees.

“But the converse of that,” Søby explains, “is that it is not in the employers' interest that all employees just stay put.” The workforce must be renewed on an ongoing basis if the company wants to be innovative and efficient.

The fact that wages continue to increase in Denmark is another indication that Danish workers employed in jobs that could, in principle, be automated, have so far not experienced a negative effect.

A study conducted by the Danish think tank DEA, which deals with education and research, shows that taking a nontechnical approach to education does not mean being pushed out or down in pay. In fact, between 2010 and 2015, more than two out of three skilled graduates experienced positive wage or employment development, while half of the less skilled graduates experienced positive wage or employment development.

A study conducted by Anders Humlum, a Danish PhD student at Princeton University New Jersey,

USA, has further shown that Danish companies that installed industrial robots have, on average, increased their employment by eight percent between 1990 to 2019. In the same time period, companies with industrial robots increased their overall average wages by 0.5 to 1 percent.

Industrial policy plays a vital role

Just as macro-economic policy is important for the Danish automation and robotics industry, the industrial policy is also of great importance.

Industrial policy involves laying out a set of parameters within which business is conducted. It encompasses regulations as well as initiatives by

the state and public sector to strengthen business development and foster job creation.

Danish industrial policy consists of national strategies on cross-functional areas such as digitalization. In addition, specific initiatives are designed for areas in which Danish companies hold internationally recognized positions of strength, such as agriculture, biotech, and environmental technology. Efforts are based on recommendations from industry growth teams.

In addition, the Danish industrial policy guides various institutions and programs that support the policies, strategies and focus areas.



Photo: The Growth Fund

Christian Motzfeldt (b. 1957), former CEO of the Growth Fund

The Danish State's Growth Fund and its management under Christian Motzfeldt from 2002 to 2019 have played a crucial role in the development of the Danish robotics and automation cluster. The fund invested in Universal Robots at a time when no one else would. Without the fund's investment, UR would not have likely existed today and achieved its successful exit. The Growth Fund has since strengthened its focus on industrial automation and, among other things, invested a significant amount in OnRobot, which aims to become a global leader in applications and tools for robots. Motzfeldt is a trained economist and, prior to his role as CEO of the Growth Fund, he held management positions in, among others, Denmark's National bank, the European Commission, Danske Bank and the Ministry of Commerce.

For example, the state-owned Growth Fund works to strengthen Danish companies' access to venture capital so that they can create innovation, growth, and jobs.

In addition, there is the Innovation Fund, which co-finance the development of new technology. There are also several programs in which companies can receive grants for specific initiatives, such as export promotions, as well as state-funded technology institutions and innovation networks.

One policy that spans multiple functional areas is the national digital growth strategy. This includes robot technology, artificial intelligence (AI), and IT security.

The strategy plays out in many ways. For example, there is a digital hub with a research center for AI and big data. Another initiative is a national platform where companies, entrepreneurs and educational institutions can share skills and knowledge. There is also a program that gives companies free access to data from public authorities such as the Danish Meteorological Institute and Statistics Denmark.

In addition, programs are being launched to help small and medium-sized enterprises with digitalization, as well as programs to improve the digital curriculum throughout the Danish educational system.

Denmark also has a national drone strategy, which is now being followed by a national strategy for automation and robot technology.

Resources are dedicated to research into drone technology at three universities in Denmark, and test flight facilities are being improved. They are

also promoting the use of drones in the public sector. For example, drones are being tested to transport blood samples between hospitals. Courses have been established for people to earn drone pilot certificates. And on the research front, the ties between Danish and international drone research facilities are continually being strengthened.

State actors are investing when the market hesitates

For years, state actors such as the Growth Fund and the Innovation Fund have been supporting and developing the automation industry in Denmark.

In 2008, the Growth Fund invested in the startup company UR, which was established by entrepreneurs in 2005 with seed investments from a small publicly-owned local venture company. The fund earned \$120 million when UR was sold in 2015.

Since then, the Growth Fund invested in OnRobot, a multimillion-dollar company which develops and manufactures applications for cobots of all kinds. Together with private investors and an American venture company, the Growth Fund has invested millions in this business.

The Growth Fund's goal is to initiate investments in areas where there is potential for Danish companies, but where the development horizon is too far and the risk too great for private investors to provide all of necessary capital.

Today, the Growth Fund is profitable and pays dividends to the state, but this situation did not materialize until several years after the financial crisis.

During the crisis, the Fund managed to hold on to its most promising assets, including investments in the robotic companies.

The Growth Fund's financial stake within robotics and automation has been followed by significant private investors from venture capital and angel investors. The Fund paves the way for the private market and contributes to the establishment and cultivation of Danish positions of strength. As an area develops and emerging companies begin to create value, private speculators become increasingly active and comprise a growing share of the necessary seed money.

The importance of soft financing

Robotics and innovation accounts for a significant portion of all the soft financing which the Innovation Fund provides for companies and educational institutions to research and develop new products.

For example, the Innovation Fund, together with Siemens and Danish research institutes, have developed an autonomous 3-D robot scanner system for inspecting wind turbine blade surfaces. The robot can adapt to an individual blade without pre-programming. It determines on its own what to measure and then adapts its algorithms as necessary. It gathers data from multiple sources, including from images of the leading edge of the blades, which are important for aerodynamics. The data is then used to assess the need for maintenance. The same technology can also be used to inspect bridges and pipe structures, for example.

The Innovation Fund's predecessor, the High Technology Fund, which was established in 2005, has

also played a major role in the development of the robotics industry in Denmark.

The High Technology Fund actively contributed to the financing and creation of research consortia in the automation field. Several companies in the Danish robotics cluster participated in and benefited from the Fund's projects.

One example is the Handyman Project, which had a total budget of \$4.5 million. The University of Southern Denmark joined forces with several companies in their efforts to further develop gripper robots so that they became more flexible, user-friendly and cost-effective for small businesses. The project greatly benefited both researchers and private companies, including UR.

Projects such as these have greatly helped the small startup companies that participated in them. In fact, they have helped many of them survive, by providing new knowledge and technology, as well as financial support in the form of payment for the time and materials used in the projects.

New strategies on the way

In early March 2020, the government released an update on Denmark's national robotics strategy. The strategy emphasizes the potential of the robot industry for contributing to sustainability and focuses in particular on promoting the use of robots and automation in small and medium-sized companies (SMEs).

The strategy is important for two reasons: it includes legislation and framework conditions, and it legitimizes government support for research and devel-

opment in the field and government co-financing of company establishment in a hesitant market.

Historically, on a regional and local level industrial policy has also contributed to the emergence of an automation and robot cluster in Denmark. As interest in automation waned at the end of the 90's, where major parts of the Danish manufacturing industry moved to low-wage countries, Danish regions and municipalities supported the creation of networks and centers of competence, which helped to retain robotic experts and skills in Denmark.

According to IRIS Group analysts, Denmark continues to show major growth potential within the robotics area due to our clear commercial and competence strength position with strong business units and knowledge environments. Further scaling of the sale of robots to global SME is possible, and the development of new application areas and applications may increase demand among new and existing customer segments in the global market. In addition, the Danish robotics industry will be able to gain an increasing share of the growth in the budding and growing markets for professional service robots within, for example, health and welfare, agriculture and drones if the strong technical and commercial competences that already exist in Denmark can be utilized in depth and extended to these areas.

In 2008, the founders of Universal Robots developed the company's first robotic arm. Product development also built on knowledge from several research consortia within the automation field. Pictured here are Esben Østergaard and Kristian Kassow.



About the authors



Carsten Steno, born in 1951, is one of Denmark's most experienced business journalists. In the 1970s, he was a business journalist at the Ritzaus Bureau. In the 1980s, he was a correspondent in New York and later was the editorial director at Dagbladet Børsen. In the 1990s, he worked as a business editor at Berlingske Tidende.

From 2001 to 2008, he was editor-in-chief at ErhvervsBladet. From 2009 to 2015, he was a senior journalist at Berlingske. Since then he has worked as an author and freelance business journalist.

He has previously written the following books:

The real heroes - a portrait of the owner-manager culture, Gyldendal 2011

Made in Denmark - is it still possible?, CEPOS 2013

A cluster that works - Universal Robots and the Danish robot environment, 1986 to 2016

Where the market hesitates - The Growth Fund 1992-2017



Malene Grouleff, born in 1973, has worked for more than a decade sharing knowledge of automation and robotics. She founded a specialized media company in 2004 with the Danish robotics industry quickly becoming the focal point. Among other things, she put the concept of the cobots - collaborative robots - on the agenda in Danish and global industries.

Prior to founding her specialized communications business, Malene Grouleff was employed as an editor and journalist in the Danish media industry, including at the Danish public broadcaster, DR, and at Computerworld, as well as serving as an associate professor at the Danish School of Media and Journalism, DMJX. Malene is also a sought after speaker in Scandinavia on Denmark as a robotics nation.

She has previously contributed to the books:

Almost Happy in Nerdland by Dorte Toft

Become Visible in the Media:
This Is How You Tell Good Stories



Thanks to all
contributors of information
and photo material.

The background of the entire page is a dense, repeating pattern of stylized robot icons. These icons are rendered in two colors: a vibrant cyan and a bright yellow. They include various types of robots, such as articulated arms, mobile bases, and humanoid figures, all depicted in a simplified, line-art style. The icons are scattered across the entire surface, creating a textured, high-tech aesthetic.

Denmark and the Robots

In the last 10 years, Denmark has built up a successful robotics and automation industry that has caught the attention of global markets. In a short time, the country has become a powerhouse for robotics development and automation innovations.

But how did a small country with just six million inhabitants achieve this? What do Danish companies know about robotics that sets them apart? What is unique about the ecosystem they operate in and how are they organized? How do Danish companies compare to their peers around the world? And what does the future hold for the Danish robotics industry? These are the questions the authors of this book will attempt to answer.