

A hand holding a gear next to a robotic gripper. The background is a solid green color with a faint, semi-transparent image of a hand holding a gear and a robotic gripper. The text 'Robotics in Healthcare' is overlaid in white.

Robotics in Healthcare



Healthcare
DENMARK



Foreword

As a result of more than a decade of public–private collaboration on innovation, Denmark has created a modern healthcare system that keeps the patient in focus while looking out for the health professionals and hospital staff.

The increasingly ageing population and the growing number of chronic patients mean that more people are going to need healthcare in the future. Combined with the expected shortage of skilled labour, innovative technology solutions will be essential in delivering healthcare more efficiently. As new approaches are called for, the opportunities offered by robotic technology become increasingly interesting to the healthcare sector.

Denmark is a frontrunner in the development and use of robotics in healthcare, and robots are already playing a vital role in the day-to-day operation of Danish hospitals. Through research and hands-on experience, the Danish regions are engaged in projects to develop and implement technologies that offer the highest quality of treatment for patients. At the same time, this ensures healthy working environments that protect our healthcare staff from the physical harms of repetitive and monotonous work tasks.



Both large- and small-scale investors and national and regional policymakers are aware of Denmark's stronghold in robot technology. Our world-class healthcare system and strong tradition for public–private partnerships and innovation create opportunities for propelling healthcare robotics forward with novel solutions for Danish patients, while our companies are given export opportunities – a clear win-win for all.

With this publication about the use of robots in the Danish healthcare sector, Danish Regions hope to further the dialogue on the future role of robot technology in healthcare. Some of the robotic projects described here are already deployed, while others are still under development.

Anders Kühnau

President of the Danish Regions

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Danish healthcare robots are handling tasks such as:

- Assisting in surgeries
- Disinfecting rooms
- Transporting medical equipment and pharmaceuticals
- Dispensing medications
- Lifting patients
- Coordinating tasks
- Enabling remote patients to talk to healthcare professionals via telepresence

Introduction

Robotics in healthcare is a rapidly developing field. Healthcare robots ensure a high level of patient care, efficient clinical processes and a safe environment for both patients and health workers.

While there are considerable advantages in rethinking the distribution of tasks among healthcare workers and robots, the concern expressed by patients and healthcare workers that robots will “take over” seems unjustified. Robots are mainly

being used for monotonous tasks and administrative routines, enabling healthcare workers and medical professionals to devote their time to the care of patients. At a time when human contact is more important than ever, we should use technology to compensate for the present manpower scarcity while at the same time easing the physical strain on healthcare workers.

With its highly digitalised healthcare system, Denmark is in the global top ten of countries as far as automation is concerned. The key role of technology is evident in the daily routines of all healthcare professionals, whether they work in hospitals, general practice, nursing homes or take care of people in their homes.

Still, manual or administrative tasks occupy much of the skilled hospital personnel’s valuable time and expertise. We must therefore take advantage of the already available technology to make the most of our resources.

The establishment of a strong national robot and drone cluster in Odense, Denmark’s third city, has played a vital role in securing Denmark’s leading position in health robotics. Developing innovative technology is costly and time-consuming, but Odense Robotics is spearheading a nationwide effort for innovation and growth by providing support and expertise to companies at every stage of the development process. The involved companies are invited to collaborate with some of our universities’ leading researchers, resulting in acceleration and improvement of their innovation level.

Denmark: a nationwide robot cluster

Although Denmark's robotics cluster originated in the Odense area, strongholds for innovation on collaborative and mobile robots are found across the country. While robots are used extensively in industry, their easy programmability and safety for patients and staff promise great benefits for the healthcare sector.

The University of Southern Denmark and Odense University Hospital have jointly established the Centre for Clinical Robotics, which aims to facilitate contact between companies and research environments for the implementation of new robot technology in hospitals.

A unique ecosystem

Several circumstances have contributed to Denmark's stronghold in robotics:

- The comprehensive programmes established at Danish universities. They are crucial to ensuring relevant competences and sustaining innovation across Denmark.
- Investors' willingness to take a risk with future technologies, whether via reinvestment of exit capital or new investments from national and international venture funds. Such investments are instrumental in facilitating new technical developments and enabling robotic startups and high-growth companies to fuel their expansion.
- The presence of Odense Robotics, Europe's only gold-certified robotics cluster. Supported by the municipality and its cluster management team, the cluster's startup hub offers prime conditions for growth and innovation in startups and other budding entrepreneurs in robotics.

World-leading test market

Denmark hosts a range of test sites for drone and robot applications in healthcare, agriculture and manufacturing. This enables testing of robots and welfare technology with real end users in full-scale environments, such as nursing homes, living labs and a full-scale airport dedicated to drone technology. Precision application tracks with vibration and auto steering test facilities are also available at independent facilities.



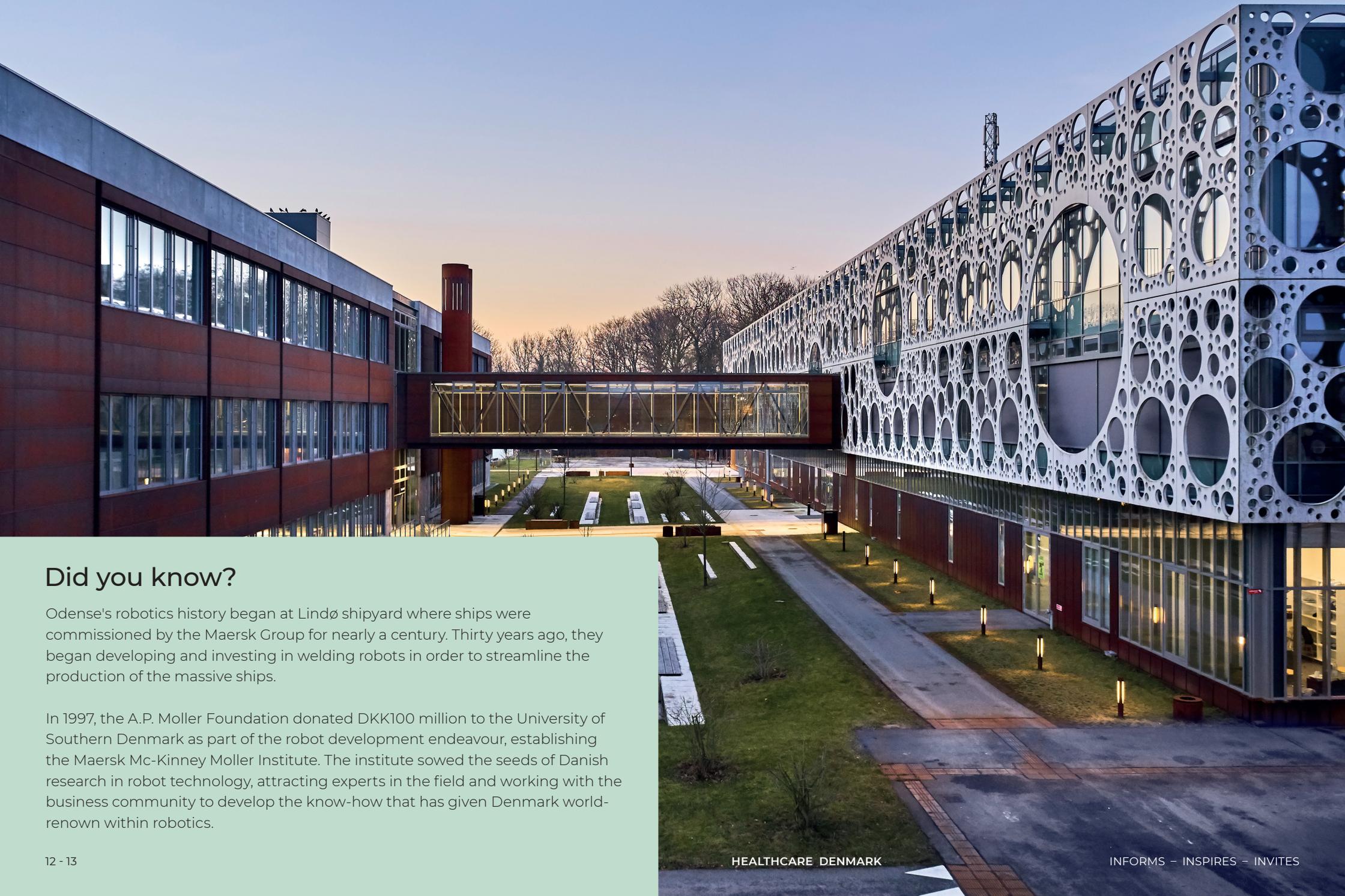


Odense's decade-long history of public-private collaboration

Odense University Hospital and the University of Southern Denmark have a strong tradition for collaboration, knowledge-sharing and innovation. By matching the healthcare sector's needs with the latest research, the partnership has resulted in new competitive solutions for the benefit of companies, healthcare workers, authorities and patients alike.

The Odense area provides numerous examples of close public-private collaboration involving companies with expertise in collaborative and mobile robotics, the healthcare sector and internationally leading research environments:

- **Odense Robotics, Health Innovation Centre of Southern Denmark and Danish Life Science Cluster** involve healthcare authorities, companies and research environments in knowledge-sharing and matchmaking regarding mobile robotics.
- **Centre for Innovative Medical Technology** is a research and innovation collaboration between Odense University Hospital and University of Southern Denmark. By bringing hospitals and universities together, the centre has pioneered solutions in telemedicine, video consultations, drone aviation and the reporting of patient outcomes. Camera pills and apps have also been developed at the centre.



Did you know?

Odense's robotics history began at Lindø shipyard where ships were commissioned by the Maersk Group for nearly a century. Thirty years ago, they began developing and investing in welding robots in order to streamline the production of the massive ships.

In 1997, the A.P. Moller Foundation donated DKK100 million to the University of Southern Denmark as part of the robot development endeavour, establishing the Maersk Mc-Kinney Moller Institute. The institute sowed the seeds of Danish research in robot technology, attracting experts in the field and working with the business community to develop the know-how that has given Denmark world-renown within robotics.

Modern workflow **robots relieve** strained hospital **staff**

To ensure consistent processes in the hospitals, service robots are now being used to streamline routine tasks such as procurement and inventory tracking, so that supplies, equipment and medications are available where and when needed.

Automated disinfection robots take care of efficient sanitising of patient wards and operation theatres. Robots are also used for heavy lifts of patients and when moving beds to reduce the physical strain on staff – ultimately providing a better working environment and more efficient hospitals.

Manual routines and simple administrative tasks still occupy much of the skilled hospital staff's time and expertise. By letting workflow engines handle time-consuming trivial tasks, healthcare workers' valuable time can be spent solving vital tasks for the benefit of patients while the risk of error is significantly reduced.

The following pages describe a selection of innovative Danish solutions that have streamlined procedures in the day-to-day operation of modern hospitals.



Optimising hospital intralogistics with mobile robots

Five hospital departments at Zealand University Hospital receive their deliveries from its central sterilisation centre. Mobile Industrial Robots (MiR) is helping achieve the goal of flexible and automated logistics throughout the planned 190,000 square meter “superhospital”.

Covering more than one hundred kilometres per week, the hospital's 10 carts are piloted by autonomous mobile robots (AMRs) to improve services, optimise storage capacity and prevent shortages.

Improved workflows

AMRs' key tasks in hospitals include the transportation of

- Waste bins and trolleys
- Linen
- Meals from kitchen to wards
- Sterile supplies
- Pharmaceuticals, care supplies, laboratory tests, etc.



"One big advantage is that MiR robots are designed to run exactly in the same areas as humans, so there's no need to change the existing facility. The robots can use the lifts, drive in the hallways alongside staff and patients, avoid obstacles and even open doors autonomously."

Johnny Hansen, Operations Manager for Zealand University Hospital.

UV-C radiation for secure automated room disinfection in hospitals

Hospital-acquired infections are among the major causes of complications during hospitalisation, with serious human and economic consequences. But automated robots with high-intensity ultraviolet light for disinfection have ensured significantly improved environmental hygiene in hospitals. UV radiation provides an almost bacteria-free environment while mitigating the load on personnel and securing a safe environment for patients and staff.



The safety of patients and healthcare workers is a growing concern for administrators worldwide. The use of personal protective equipment, improved hand hygiene and antimicrobial stewardship programmes have recently been supplemented by the introduction of disinfection robots to limit the risk of transmission of pathogenic microorganisms.

While short-wave UV-C irradiation for disinfection is nothing new, UVD Robots have pioneered the implementation of robots for autonomous disinfection in order to ensure efficient whole-room distribution of the light rays. Utilising ultraviolet germicidal irradiation, UVD Robots complement existing cleaning and disinfection practices by deactivating pathogens on both high- and low-touch surfaces in the hospital environment.

"The robot kills 99.99 percent of viruses, bacteria and fungal spores."

According to Dr C. Huscher, head of oncological surgery robotics and new technologies at the Italian Policlinico Abano hospital chain, the robot "... kills 99.99 percent of viruses, bacteria and fungal spores. We've had no coronavirus cases among nurses, doctors or patients since we started using the robots." Dr C. Huscher expects the robots to eventually become mandatory at hospitals.

In the course of 2021, the European Commission has donated 305 UVD robots across the EU. The robots were deployed not only to assist in battling Covid-19 but also to help deactivate environmentally transmitted pathogens.

Communicating with robots and humans: allocating tasks to the less busy resource

The introduction of automated processes in modern hospitals confronts staff with new challenges, such as learning to operate a joint platform for task requisition. A platform developed by Systematic enables clinicians to request assistance not only from porters, cleaners and other staff groups but also from robots.

When a task has been registered in the Columna Flow Task Management system, its rule engine allocates the task to either a human colleague or the AMR, according to how busy they are. The system may also be customised to send all urgent tasks directly to the staff, whereas non-urgent tasks are allocated to an AMR. By relieving the healthcare workers of the decision process, valuable time is freed up and waiting times are reduced. This enables departments to keep on schedule for surgeries, consultations and procedures such as X-raying and diagnostic imaging.

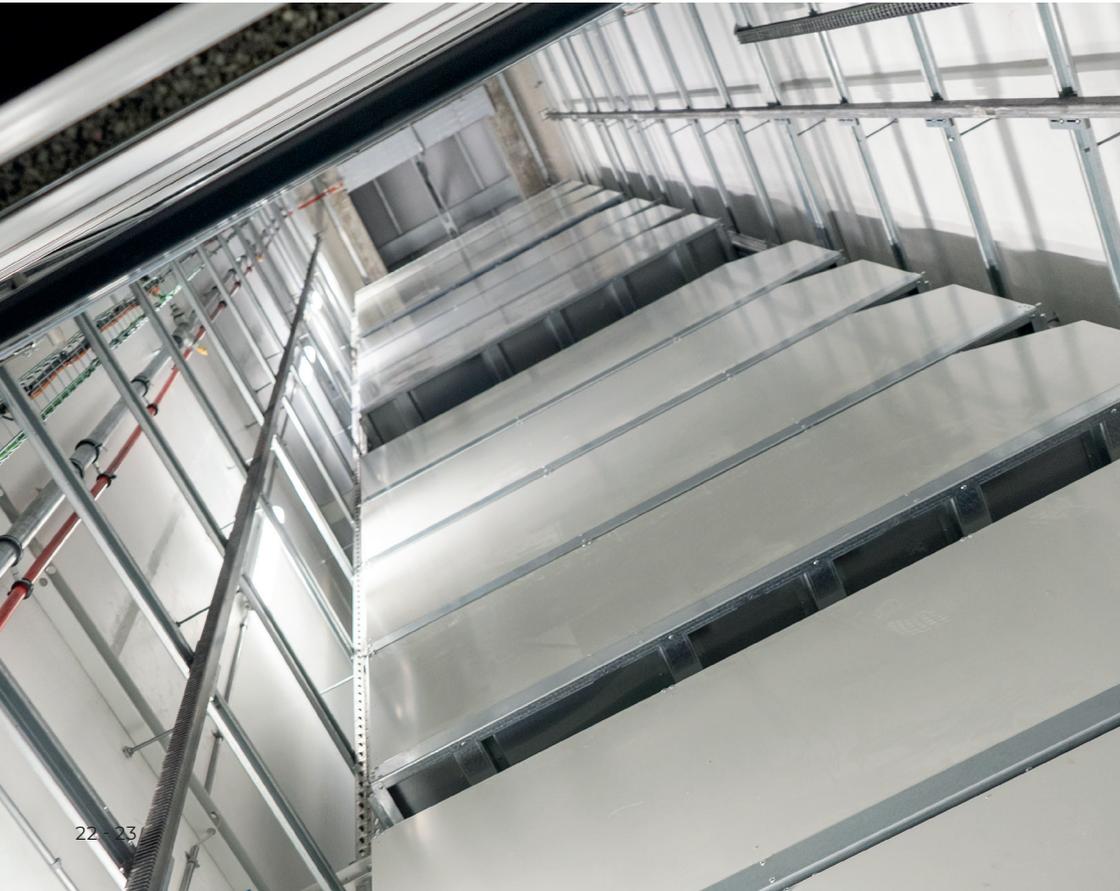
The traditional way of outsourcing tasks directly to a specific staff member tends to create bottlenecks. Waiting times go up and workloads increase for some staff members, while colleagues may be unoccupied. The digital system solves such problems by ensuring that a task reaches the less busy resource, whether human or robotic.

The task system becomes the clinicians' shared communication platform, freeing up time for the primary task of taking care of patients.



Intelligent bed storage and handling increases efficiency and safety

Vertical handling and storage of hospital equipment ensure smarter utilisation of hospital capacity, reduce space requirements and support healthcare workers' ergonomic working practices.



Stavanger University Hospital plans to implement robots for the vertical storage of hospital beds, medical devices and other supplies to reduce the cost of healthcare for the region's population.

From its start the Stavanger logistics project was premised by three conditions:

1. Zero growth in personnel costs.
2. Increased patient capacity.
3. Improved flow and logistics.

The HospiMat storage solution will enable handling and vertical storage of beds, making them accessible where and when needed while saving porters from long walks. At present the beds are stored in four towers, varying from 26 to 40 meters in height. Where a traditional vertical lift module needs 23 minutes to pick 25 items from three different levels, it will take just 7 minutes for one EffiMat tower of 38.5 meters to handle 75 items.

The various departments at Stavanger will be serviced by six EffiMat supply towers, directly replenished from the main warehouse on the hospital's lower floor.

Taking care of the carers

Workers' skills are critical to the day-to-day operation of nursing homes, hospitals and other healthcare institutions. The introduction of robots to aid with everyday activities supports staff safety and well-being, allowing workers to concentrate on delivering high-quality care rather than on the numerous time-consuming manual tasks. Inefficient workflows often result in poor working environments that benefit neither citizens nor patients. Time and expertise may be spent considerably more efficiently on tasks that add

job satisfaction for the healthcare workers, giving them more time with the patients, who also gain from the increasing use of robots in treatment and post-hospital rehabilitation, where early mobilisation is essential.

The cases described below show how robots can assist with archiving, heavy lifting and patient transfer to minimise the physical challenges confronting healthcare workers. A healthier working environment for all personnel ultimately leads to a stronger and more efficient healthcare system.



Flexible and safe patient handling takes the load off workers and patients

There are countless situations calling for patient transfers: from bed to wheelchair, from wheelchair to toilet or shower chair or from ambulance stretcher to hospital bed. Emergencies caused by accidental falls also occur, and robots can offer vital help to carers. Robotic assistance in rehabilitation is equally important for patients' self-reliance in gait training after stroke, where support of the body weight can be regulated.

A physiotherapist at Zealand University Hospital Køge said,

"I remember my surprise at how easy it was to operate the robot. At first sight, it seems quite a whopper, but driving it around you don't sense that. It takes you very smoothly in any direction you want – you just have to touch the joystick."

Working with patient repositioning, transfers and rehabilitation is associated with serious health hazards for caregivers. The physical strain, particularly on the neck, back and shoulders, may lead to acute-onset injuries and general overload. Securing safe patient transfers with robotic technology increases patients' experience of quality while resources are released for other patients at Zealand University Hospital, where serious staff shortages are foreseen as the population is getting older.



Wishing to create a flexible tool for more efficient work routines and a safer working environment, Zealand University Hospital Køge and Blue Ocean Robotics joined forces in developing the PTR robot. Offloading the heavy lifting by handling patients up to 250 kg (550 lbs), it frees up healthcare workers' time for responsive patient care.

- As a Class I medical device the PTR robot features safety measures, such as obstacle detection, automatic wheel lock and panel control access code.
- Zealand University Hospital Køge is currently implementing the PTR Robots in their existing buildings while preparing to move to the new "super hospital" starting summer 2022.

Innovative robots in lower extremity rehabilitation

A new rehabilitation robot relieves healthcare workers of the physical strain of repetitive exercises while improving their patients' rehabilitation.

Rehabilitation training is an intrinsic part of the treatment after, for example, stroke, cancer or spinal cord injury. Mobilisation and repetition are crucial to regaining function in the lower extremities, in particular for geriatric patients. The rehabilitation robot relieves physiotherapists by repeating many of the mobility exercises that their patients need to perform to activate an injured hip, knee or other joints and muscles.

Designed to empower the patient to self-train a customised exercise programme, the robot bypasses the practical limitations of exercising for extended periods. The patients are able to improve their neuroplasticity, maintain or increase their muscle mass and expand their range of motion. The healthcare professional can check on the patient's progress via a data monitor.

Physiotherapist Stine Hansen, Neurology Centre Østerskoven, finds that *"... the robot is a great support in training the patient's paretic side, where the many repetitions and heavy lifts are extremely taxing for me and my colleagues. When we're doing exercises with a wide movement path that requires leaning over the hip, we really see the unique support given by this solution."*

Bedridden patients receive early mobilisation training while the healthcare professional's physical burdens are alleviated as the robot carries the patient's weight. Taking only two minutes to set up, the professional is able to concentrate on more complex tasks.

The robot was developed by Life Science Robotics in consultation with North Denmark Region's Neurology Unit North, Neuro Rehab Aalborg and the Spinal Cord Injury Centre of Western Denmark.



The rehabilitation robot has been implemented in numerous healthcare facilities in Europe, Asia and the U.S., where patients praise its importance for their self-reliance.

Relieving staff with a pathology slide archive system

The digitisation of routines in the Department of Pathology at Odense University Hospital has led to significant improvements in workflows and procedures. Physicians and laboratory staff have seen their time released for other urgent tasks.

The pathology department provides analyses of tissue samples for a wide range of diagnoses to hospitals in the Region of Southern Denmark. The time-consuming tasks of manually registering, archiving and retrieving the tissue samples to and from a huge library of pathology samples cultivated on thin glass sheets increase the workload at a time of skilled staff shortages. To relieve the lab technicians, the department developed an automated system for the storing, retrieval and, ultimately, disposal of up to 30,000 glass slides at any given time. Within seconds, the new automation system indexes the glass slides based on their QR codes and deposits them in an empty slot in the archive. Similarly, the retrieval of glass slides happens almost instantaneously.

In addition to freeing up time for other lab tasks, the archive system has had an indirect impact on productivity in the various clinical departments serviced by the pathology archive in the form of faster replies to requisitions. Another benefit of the automation is improved working conditions in the lab.



The glass slide archive system was developed in collaboration with the Danish company KILDE Automation A/S, with financial support from Innovation Fund Denmark.

The archive system is 4 metres across and 2 metres deep.

Budding technologies

Healthcare authorities and companies in Denmark are continually exploring the possibilities that advanced robot technology can offer its citizens, patients and healthcare professionals.

The perspectives are illustrated by two ground-breaking innovations capable of early detection of rheumatoid arthritis and increasing the self-reliance of persons with severe disability:

- Combining artificial intelligence and robot technology, a unique automated ultrasound scanner evaluates disease activity in direct interaction with the patient.
- A human–robot interface enables paraplegic persons to perform complicated actions via muscle, tongue and brain signalling.

Such solutions will be playing an increasingly larger role in healthcare systems as well as in the homes. Persons with physical or mental disabilities strengthen their self-reliance by utilising a wide range of robots to perform household chores such as cleaning and lawn-mowing.

In the Danish healthcare sector, the increasing use of robot technology signifies a break with many traditional notions of healthcare. As the demand for more efficient workflows and automated processes grows, the road is paved for self-optimising robots that can communicate with other machines.



Fast and reliable automated ultrasound scanning of rheumatoid arthritis patients

A user-friendly automatic ultrasound scanner using advanced robotic technology and AI speeds up diagnostics while providing more reliable monitoring of rheumatoid arthritis patients.

ROPCA has developed a fully automated ultrasound scanning system for diagnosing patients with rheumatoid arthritis (RA). ARTHUR, as the system is nicknamed, is the first to interact directly with RA patients, without staff support. The patients are placed at the centre of disease monitoring, enabling them to receive an objective disease assessment on demand. For the clinicians, the robot has reduced waiting times and expenses by providing fast, reliable and uniform decision support for diagnostics and monitoring.

When the robot's interface was tested for usability in a clinical trial, the participants found that the procedure was comparable to scanning by an experienced rheumatologist. More than 90 percent of the participants said they would welcome ARTHUR as a part of their RA monitoring.

Designed as a plug-and-play system, the robot is compatible with the ultrasound machines already used in the clinics. While automatically grading images using its built-in AI algorithms, the quality of the ultrasound images is on a par with the standard delivered by experienced physicians.



The robot's user-friendly graphical interface guides the patient from ID registration to placing their hand on the touchscreen display to performing the ultrasound scanning as the robot moves the ultrasound probe from one finger joint to the next. Each ultrasound image is scored using an AI algorithm that evaluates disease activity.

The data is stored in the patient's records, enabling the robot to track disease progression for the clinician. ARTHUR's objective assessment is crucial for close patient monitoring while saving physicians' time. This secures the correct administration of immunosuppressive medication of critical importance to both the patient and society.

Tongue-controlled robot to empower severely disabled persons

The Centre for Rehabilitation Robotics at Aalborg University focuses on improving therapy and assistive technologies through user involvement and cross-disciplinary research and development. The goal is to empower people with neurologically based physical disabilities, such as those caused by a spinal cord injury, stroke or amyotrophic lateral sclerosis.

The interdisciplinary centre's extensive national and international network is instrumental to its activities. The researchers collaborate with users, clinicians, businesses and scientists from various fields to improve the quality of life for individuals with severe disabilities through the development of human-robot interfaces based on muscle, tongue and brain signals. The daunting complexity of this task is illustrated by the fact that both arms and legs of the user may be completely paralysed.

The Itongue project is one of many originating from the centre. In a collaboration with TKS company, the researchers are aiming to enable individuals who are completely paralysed but have retained control of the tongue to operate their wheelchairs, TV sets, smartphones and similar. All users will benefit from the solution, as the control box will be compatible with all types of electric wheelchairs.

The centre is also involved in innovation and development of new robots and exoskeletons to improve neurorehabilitation therapy outcomes while reducing therapists' workload and risk of work-related injuries. As a result, the centre contributes to mitigating the impact of demographic challenges, such as the growing labour shortage in the healthcare sector.

"Being able to do something independently is life-defining."

Danish Spinal Cord Injuries Association



The EXOTIC exoskeleton developed at the Centre for Rehabilitation Robotics is the world's first tongue-controlled full arm/hand exoskeleton to empower individuals who are completely paralysed from the neck down to drink and eat on their own.

The technology underwent testing by users with spinal cord injuries in 2021 and is ready to enter an innovation process, after which it is expected to mature for production within 1-2 years. The project is currently open for interested investors. Further research aims at integrating brain-based control of the EXOTIC.

The centre is supported by Aage and Johanne Louis-Hansen's Foundation and Aalborg University.

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