Special Feature Articles:

A study on robot applications in manufacturing industry with special focus on the successful cluster in Odense, Denmark

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Abstract

Over the last three decades robots have changed how manufacturing processes are being planned and executed. Substituting many manual work processes with robots have reduced one-sided and sometimes debilitating work. Increased efficiency due to possible operation of 24 hours a day with same level of quality has given the companies ability to increase effectiveness and quality and at the same time offer their workers a better work environment and change the role of the worker to become more a checker and planner of the processes. During the last decade we have seen collaborative robots (cobots) implemented on the shop floor. The Cobot is a real co-worker, easy to program, flexible, cheap, and able to work together with the operator without shield.

Robots have also intervened into the service sector and health care. As in the manufacturing industry they will transform the work environment in a positive way for the staff and influence planning of infra -structure as well as physical facilities.

The last development has been mobile robots and flying drones, which gives the robots more degrees of freedom and incredible options for the future.

The appearance of new advanced technologies like Artificial Intelligence, Virtual Reality and big data will give us yet unknown benefits. But also threats, which must be taken into account. An important discussion going on between industries, universities and authorities is, how to regulate this new technology in order to make it safe to use and keep it to serve the human being instead of overruling us. Ethical discussions , in this regard, are also a hot and much debated topic.

This paper will describe the evolution of these technologies and how it has been implemented in society and business regarding how it gives new vitality to Business-Process - and Product Innovation and fits into Industry 4.0.

The paper has used a real case study from a very successful Danish Robot Cluster, which during two decades have grown up to be one of the world´s most dynamic business environment with great impact on the society, the business practices and the university in the region.

Keywords *- Robots, Cobots, Drones, Innovation and new technology, Industry 4.0, Successful Clusters*

Background

Robots

The word “robot” comes from the Czech word “robota” which means slave. It was the Czech writer Karel capek, who used the word first time in 1920 in the theatre play, Rossum´s Universal Robots. The play was about the future creation of robot-workers, who finally surpass man in skills and end up eradicating the genus.

Today,100 years later, the scientists are discussing how man can control the future development of robots that possess artificial intelligence and can learn from experience.

Originally, the phenomena robot is defined as a programmable machine, which can execute multiple tasks by autonomic interaction with its environments. It has more degrees of freedoms and consists of actuators, interfaces like grapples, sensors and programmable controllers.

The first real robot was implemented in 1962 in USA, welding parts together in the automotive industry. Afterwards industrial robots have been implemented in industries all over the world, most intensively in countries with automotive industries. Until today these robots are typically fixed in place, performing the same tasks day after day. They are typically heavy, expensive in implementation, quite complex to program, require shielding around the working station, but are very reliable and can deliver high quality and precision work and also apparently difficult and adverse work environment. In the manufacturing industry they are typically used for welding, painting, polishing, grinding and handling of items in manufacturing processes including assembling. During the last decade smaller and more flexible robots have been developed and implemented in the industries. Mainly in medium size and bigger companies, and in almost all branches.

Denmark is among the countries, which mostly use robots. Only four countries have more robots per 1000 employees than in Denmark in manufacturing industries, and they are all big automotive and steel manufacturers, which first of all implemented robots in their automated production lines.

South Korea	61 robots per 1000 employees
Japan	29 do
Germany	27
Sweden	24
Denmark	22
USA	20
Belgiche	18
Italy	17
Netherlands	16
Austria	16

Table 1: Ranking of countries using robots (Damvad Analytics &IFR(2018) OECD)

The main drivers behind Denmark’s remarkable ranking could be strong requirements for work environment, high degree of flexible production and a high cost level regarding wages for workers. And therefore a high demand for robot technology has given robot developers a room for developing and testing new applications. Also a high level of education and in

service training has an impact on company's ability to implement new automation technologies.

In accordance to Damvad Analytics &IFR(2018), the global market for industrial robots including services and software is expected to grow from 47billion dollar in 2018 to 101 billion dollar in 2025. Especially the market for Collaborative Robots (Cobots) is expected to have a huge contribution to this growth due to opening of a new market for cheaper and more flexible robots.

Branch/industries	**Have robots**	**Expect to have**
Food,drinking,tobacco	23%	27%
Textile , leather	15%	40%
Wood,cardboard,graphics	38%	28%
Chemicals,Plastic	59%	28%
Stone,clay,glass	47%	20%
Steel and metals	54%	22%
Machines	35%	25%
Furniture	38%	28%

Table 2 Expectations about robots in Danish Production:
(Danish Technological Institute 2018.)

Number of employees	**Have robots**	**Expect to have**
10-19	24%	20%
20-49	42%	26%
50-99	46%	26%
100 -250	69%	20%
> 250	80%	15%

Table 3 Big companies have robots (Danish Technological Institute 2018.)

The companies have following priorities to new robots: The criteria considered important by the industries for engaging robots to replace the traditional work practices.

1. Flexibility - easily be transformed to new tasks
2. Simplicity - easy to operate
3. Short pay-back time
4. Should have higher productivity than manual operation
5. Reliable
6. Security
7. Usable for complex operations

(Danish Technological Institute 2018)

Cobots - A new radical innovation in robot technology applications

Collaborative robots (cobots) are a real radical innovation. They are small in size, they don't need to be enclosed in shielding but can work side by side with the operator. They have embedded sensors, which avoid the robot to hurt the person beside them. They are easy to program thanks' to new graphical user interfaces and other interactive user interfaces. They are cheaper and many users demonstrate a pay back time less than one year. It's easy to move the robot to another work place to start up the new operation. The man has got a real co-worker, which improves the capability to produce products in small series with quick shift to the next variant. A wide range of tools to be mounted on the cobot arm have been developed the last years by smart integrators, enabling the cobot to substitute manual operation in many useful ways.

Damvig Analytic, IFR & Loup claim that the world market for collaborative robots in 2016 was 0,8 billion dollars. The Danish start up company Universal Robot, recently sold to the American company Teradyne, counts for 50 % of that market. In 2025 they assume the total global market of cobots to be 27 billion dollar, 27% of the total global industrial robot market.

Cobots have really enlarged the market for robots, and we have not yet seen the full impact from it.

Under all circumstances huge growth rates will give a tough competition among producers. The first movers like Universal Robot, which in a few years have realized huge growth rates will in the future compete not only on technological innovation but also on tuning their business model and organization.

Drones and mobile robots - a rising application of new technology

Drones are in fact flying mobile robots with special embedded functions. There are many different types from many manufacturers. But the technology has in a short time reached a technical mature level, regarding speed, maneuverability, and stability in positioning and time in air. The prices of the smallest ones are very low and there is a huge private market as well as a professional market. They are used for military purposes, farming, police and rescue purposes, housing and property registration, and delivery of goods and as private toy.

Universities have established research and education in drones, e.g. SDU (university of Southern Denmark) who have established laboratories for testing drones and has been driving force in establishing a full scale-testing center at the former Hans Christian Andersen Airport close to Odense city.

There is a need for rules and legislation in order to regulate the use of drones. There have already been cases where drones have penetrated the airport space. The radiated noise is still at a problematic level and risk for falling drones may cause injuries to persons and goods.

Also there are ethical questions and issues, e.g. how will use of drones for any purpose impact the right for personal integrity and peace?

Universities make research in how developers can embody Value sensitive design (VSD) into the development process.

See e.g. Dylan Cawthorne. Ethical by Design: A Review of Value Sensitive Embodiment in Civil Drones. 2018. **url: https://www.dylancawthorne.com .**

Autonomous mobile robots are invading the factory shop floor by automating transportation of pallets and heavy loads. They can move around without any exterior safety measures, by help of advanced sensors, scanners and computer controls. Advanced technology and software enable the robot to navigate autonomously and choose the most effective route to its

destination. As an example, the robot Mir 1000 from the Danish company Mobile Industrial Robots, can be controlled via smart phone, tablet or computer using a intuitive interface which do not require special programming skills. Depending of the requirements the top modules can easily be changed with e.g. pallet lifts, conveyor belts, a robot arm or other applications. The robot can be integrated into the ERP system for fully automated solutions. **See mobile -industrial-robots.com**

Other mobile robots are penetrating the market for service and hospital services. Handling and transporting goods from one point to another. Or like the UVD robot from the Danish company Blue Ocean Robotics, which is used for disinfecting and reducing the spread of infectious diseases in hospitals and pharmacy industries.

The drones and the autonomous mobile robots have extended the mobility of cobots to all three dimensions in space and will definitely become a greatly increasing market in the future.

Driving forces and success factors behind the successful robot cluster in Odense, Denmark

In the middle of Denmark, a remarkable change in the industrial development has occurred during the last ten years. Around the regional main city Odense, with around hundred eighty thousand inhabitants, one of the most powerful robot clusters in the world has grown up and new high tech startup's are popping up with increasing speed and success.

The history behind this adventure was in short as follows. In the nineteen eighties and nineties Odense lost many work places in old traditional industries. The costs per working hour were too high in relation to the competitors primarily in the Far East.

The future did not look so good and even if the city had a good reputation among tourists as the lovely hometown of the world famous, adventure writer Hans Christian Andersen and housed renowned education institutions like a university and a university college of engineering, the mood among people was a little pessimistic and the economy was declining.

One of the most advanced shipyards, situated at Lindoe near Odense, was owned by the world's leading shipping company, Maersk Line. They realized that there was only one chance to let the shipyard survive, namely to automate the very complicated and comprehensive welding operations of ship sections. But there was no available technology for that purpose at that time. The CEO met a professor from the university of South Denmark(SDU), who made research in applied mathematics primarily for the growing molecular biological research and development at the university and new research park, where researchers could test research results in collaboration with the pharmaceutical industry. The Professor became interested in the problematic in developing software and mathematical models for complex robot control in welding processes and by the end the shipping company sponsored 70 million **DKr t**o build a new institute at the university as a part of the Faculty of Natural Science. The purpose of the new **Maersk Mc-Kinney Moller Institute(MMMI), f**ounded in 1998, was to make research the above-mentioned areas and to educate young researchers and engineers within the field in collaboration with Odense University College of Engineering. In 2006 the university and The University College of Engineering merged and they formed the new Faculty of Engineering at SDU (University of Southern Denmark). The Maersk Institute became a part of it and the graduates and researchers from the institute has from the very beginning obtained an outstanding reputation as innovators in the field of software design and robot development. Not only education programs at the Maersk Institute focused on robot technology but also other engineering programs like Electronics, industrial design, mechanics and Product development and

innovation and included courses in robot applications, sensor technology, software design and architecture etc. that gave basis for collaborative project courses across the professional borderlines and learned the students to involve other competences in their projects. Many new student startups took advantage of this.

In 2011 was Lindoe Shipyard closed, the automation task was too overwhelming, but the basis was created for a new technological era in the region, and the area of the shipyard was transformed to a very successful new industrial area for heavy industries, e.g. wind power industries, steel construction plants, heavy laser welding service companies etc.

At present MMMI have approximately 160 employees and 1100 students. The research related to robots has diffused to other departments at SDU and has a wide academic foundation. The research areas are mathematical modeling, planning optimal robot trajectories, object recognition and pose estimation and collaborative robots.

The third important stakeholder in developing this new industrial power center was the city government in Odense. Odense robotic was formed as an umbrella organization for supporting the startup's originated from the incubator environment at the university. The startups can achieve support regarding financial issues and support, how to establish a valid business plan, how to organize and scale up the company, how to establish a sales and distribution channel and other business related issues. Further, it acted as coordinator of all relations and networks created in the environment. They organize a network of business angels and experienced business people, who can give advices or even go into the startups in the scaling up phase. Another player in the cluster was RoboCluster, a national network for automation and robot appliers and developers, which also is situated in Odense.

The Danish technological Institute (DTI) which support the Danish industry with all kind of technological knowledge in all branches was at that time present with a small department, but when the robotic development showed a sustainable growth, they decided to concentrate all activities in robotics in Odense in new buildings and laboratories, close to the university. Here DTI has recently created a laboratory for very early start ups. Entrepreneurs who have a proven and new innovative idea, which now should be concretized in a prototype in the laboratory can utilize these facilities and supports. Here they can obtain all kind of technical support and exchange knowledge and experience with their counterparts. DTI ´s focus is not only on industrial robots, but also on all kind of robots for the service and health sector.

The outcome of the cluster in Odense is quite impressive:

The two most valuable ones are:

Universal Robot (2006)

First mover in production of collaborative robots

Sold in 2015 to an American company Teradyne for around 300 million dollar. However the headquarter of the company remained in Odense to be in close proximity to the DTI , They also have strengthened theirs sales organization worldwide.

Universal Robots now have sold more than 37000 robots world wide

MIR (2013)

First mover in intelligent mobile industrial robots again sold in 2018 to Teradyne for 1,6 billion DKR.

Just now three Danish start up's are among the ten most promising robot startups in Europe ***(teknologisk.dk)***

And many others promising start up companies are disrupting different sectors worldwide just now. Most of them with many awards and prizes from startup competitions all over the world.

The robotics cluster in Odense area consists of robot and automation companies, suppliers, education and research institutions, investment capital and public bodies. The current cluster on robotics including research facilities operate in Odense is:
129 companies in automation and robotics (Odense Robotics)
3200 employees
40 education programs
10 research and education institutions
64 startups founded since 2010
In 2018 total investments in the cluster companies was 750 million Euros, 42% coming from investors rather than public funding and loans.
In 2017 the turnover was 763 million Euros and the export was 578 million Euros

Conclusions

The Odense area is the power center for Danish robot development. More than half of the activities in that sector are done in the Odense region which count for less than 10% of the Danish population.
The drivers behind that is a close collaboration between powerful business people, A university which dared to get out of its ivory tower and meet the challenges of the society and a public government who understood their role in supporting the innovation process.
Today the Cluster is known as one of the most prospective clusters in the world.
UR-CEO Jurgen von Hollen presented recently on behalf of 68 robot companies a vision for 2025. 25000 employees in the robot industry with a total turn over of 52 billion DKR (7 billion Euro). The impact on the industry implementing the robots and on the sub suppliers will count for another 30 Billion DKR.
There are still many challenges to be overcome and these include:

- Access to qualified work force
- Investment in research and development
- Increased focus by the public institutions
- Coordination of the sectors global marketing activities

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