ROBOTICS

Solutions for Support, Assistance and Collaboration

Market overview and opportunities for Brabant

Business Development

Brabant Development Agency
BOM

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FOREWORD

Robots are set to change our world. Robotics will transform methods of mass production, transportation, agriculture and care provision. Robots will even change the way we keep ourselves entertained. Yet concerns have been raised in recent months about the threat posed by robotics, particularly with regard to employment opportunities for low and medium skilled workers.[1]

In this report the Brabant Development Agency (BOM) will demonstrate that the new generation of robots offers numerous opportunities for businesses and employees alike. The robots of the future will support our work, assist us and co-operate with us. They will take away some of the strain and enable us to concentrate on the tasks we have been trained for and in which we excel.

The Netherlands, particularly in the area of research, makes a substantial contribution to the rapidly expanding robotics market. This expansion brings with it a need for companies to develop and implement new applications. As a high-tech province, Brabant is exceptionally well positioned to seize these opportunities. The required knowledge and creativity for these opportunities is available in abundance within Brabant. You will see some examples of this later in this publication.

Robotics also offers indirect opportunities for many other Brabant businesses. By using robots, companies and organisations can increase productivity, improve quality, reduce costs and so boost their competitiveness. Robotics can provide a fresh impulse to Brabant's high-quality industries, but it also offers possibilities for innovation in other sectors, such as logistics, agrofood and care provision.

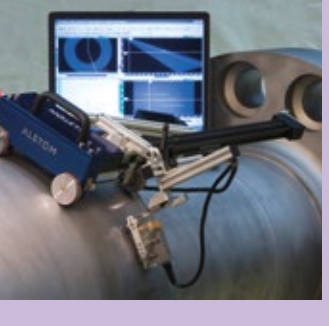
Working in partnership with our clients, BOM Business Development (BOM) can harness the opportunities provided by robotics. In our role as a developer and business incubator, we frequently act as initiators and process managers in matters of innovation. We bring together emerging SME companies, research institutions and government partners to help create opportunities for co-operation and innovation.

We invite you to work with us towards implementing an action plan to fully exploit the potential offered by the robotics market in Brabant.

Dick de Jager
Sector Manager for Business Development
Brabantse Ontwikkelings Maatschappij

[1] *See inter alia "The race against the machine" [Dutch title 'De race tegen de machine'], De Volkskrant, 22 February 2014 (http://www.volkskrant.nl/dossier-archief/de-race-tegen-de-machine~a3601545/).*


LELY VECTOR



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When examining the opportunities offered by the robotics market, we can distinguish between five market sectors:

1 **Industry** - The demand for classic robots continues to climb at an average of 12 per cent a year. The greatest opportunities in this market sector are for collaborative robots or 'cobots'. These robots can work alongside people and even collaborate with them. They take up little room, are easy to install and can rapidly learn new tasks. Cobots bring robotics solutions within the reach of medium and small enterprises.

2 **Healthcare** - The advanced service robots used by medical specialists to carry out minimally invasive eye operations represent a relatively small but lucrative market. The care robots currently under development at our universities are not yet ready for the market. In the care sector, the greatest opportunities are provided by solutions for people with physical impairments such as robot arms or exoskeletons and 'telepresence' applications that provide stimuli for impaired people.

The newest Care-O-bot of Fraunhofer (photo: Fraunhofer Institut)

MANAGEMENT SUMMARY

In the coming years, the robotics market is set to grow exponentially. This growth will be driven partly from the first generation of robots which, since the seventies, have been used in factories and warehouses due to their speed, precision and reliability. The fastest growth by far, however, will come from the new generation of robots and service robots which can support and assist people at work. This second generation of robots offers significant economic opportunities for The Netherlands, particularly in view of the low levels of robot utilisation in comparison with other European countries, such as Germany, Sweden, Denmark and Belgium.

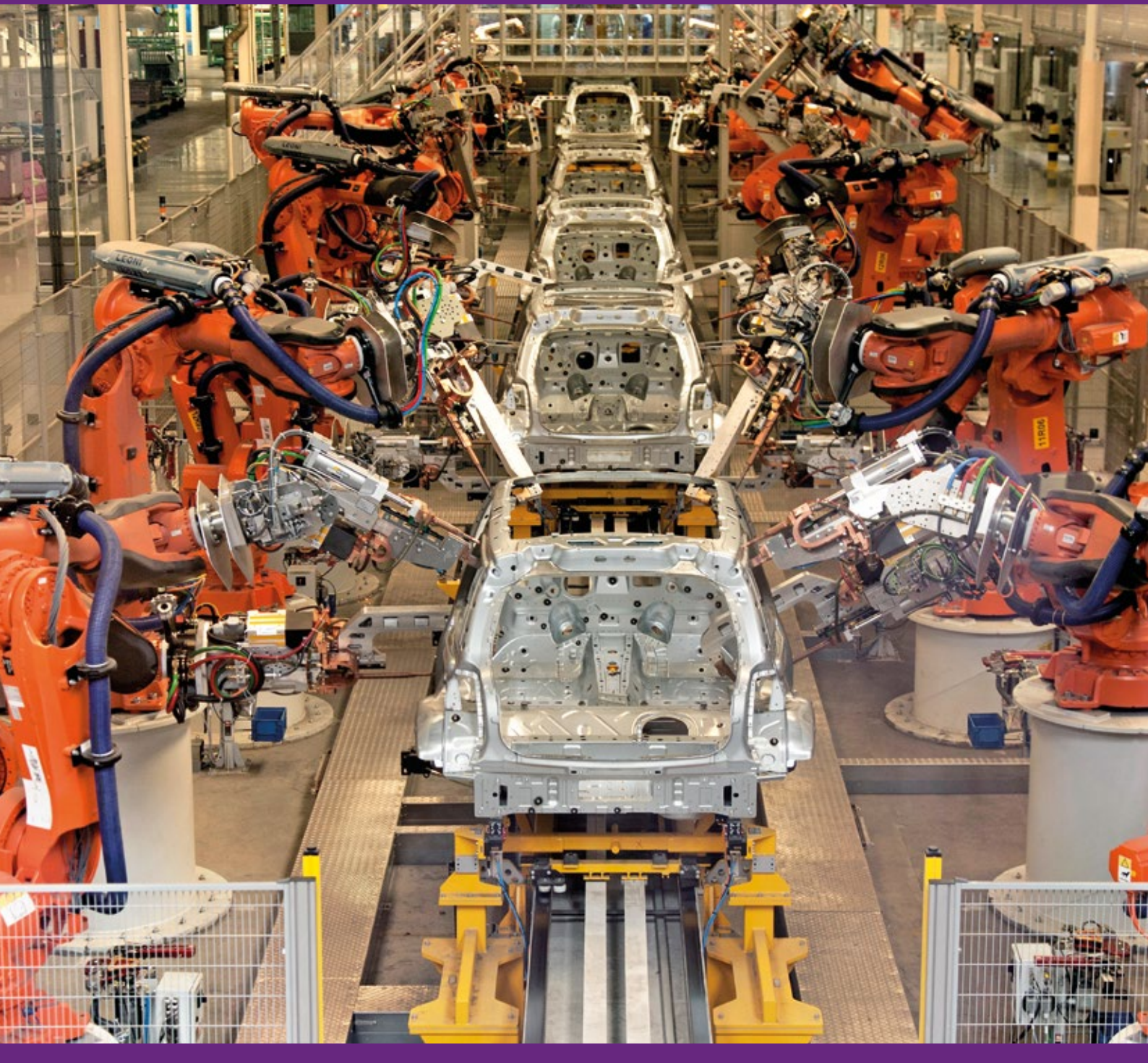
3 **Agrofood** - The combination of drones in the air and robots on the ground can enable farmers to make significant increases in productivity. Solutions are rapidly being developed to replace the labour-intensive harvesting of vegetables and fruit which, in combination with vision technology, will lead to better product quality. In addition, this sector has potential to provide specific solutions, such as milking or feeding robots.

4 **Maintenance and service** The characteristic of this sector is the development of very specific robots for inspection and maintenance in hard to access and often unsafe areas. Examples include robots for inspecting pipelines or the removal of paint from aircraft.

5 **Intralogistics** - It is possible, using small flexible robots, to automate the input and output of goods in distribution centres. With a new generation of automatically-guided vehicles, the automation of the internal transport of goods is becoming attractive.

What distinguishes the new generation of robots from previous ones is the highly-developed competencies in the fields of perception and navigation. This is what enables them to support, assist and work together with people. This survey shows that the new generation of robots offers significant business opportunities in all five market sectors under review.

Brabant is exceptionally well positioned to grasp these opportunities. Brabant excels in the field of mechatronics, possesses many system integrators with market experience and is home to companies specialising in the fields of vision and software. Furthermore, the province boasts a modern industry network - we perform well in the fields of agrofoods and logistics, invest in maintenance and service and are among the forerunners in new care concepts The challenge now is to convert these promising developments into market-ready solutions. The often contradictory concerns of the various elements of our industry network can slow the adaption of robot technology. To overcome this, we need to unite research establishments, companies from the robotics industry and companies from different market sectors to help integrate the available technologies and implement concrete measures to resolve these problems. In this context, BOM acts as a catalyst. ■



Car manufacturer VDL Nedcar in Born (photo: BMW)

1 Introduction

Robots have been extensively used in industry since the 1970s. Robots have found wide application in the automobile industry and other sectors with highly repetitive, often physically demanding tasks that require speed, precision and reliability. In spite of the advantages offered by industrial robots, the robotics market stagnated during the 1990s. In their efforts to reduce production costs, many companies opted to relocate their activities to low-wage economies instead of investing in automation.

Today there are increasing signs of a reversal of this trend, which means that an increasing number of companies are once again opting to locate their production facilities close to the markets they sell to. A number of developments have contributed to this, particularly the shift from "mass production" to "mass customisation". Thanks to new manufacturing technologies such as 3D-printing, it is becoming increasingly easy to make client-specific products on a large scale with rapid delivery times.

In addition, the manufacturing economy is increasingly moving from a linear to a circular model. Producers who take back their products after use and put them partially or wholly back into circulation after recycling, repair or refurbishment, will benefit from a location close to their user market. What's more, an increasing number of companies are finding that the reduced costs offered by low-wage economies simply do not outweigh the higher costs of transport, stocking, long lead times and reduced flexibility caused by the relocation of production.

The high degree of complexity in planning and process management fuelled by the need to accelerate innovation and shorten product life cycles presents further challenges. This renewed focus on production within Western Europe offers opportunities for the robotics market.

Other market sectors such as healthcare, agrofood and maintenance also have potential to harness the opportunities offered by robotics. Healthcare costs are constantly increasing, partly due to the aging of the population. Robots are not only able to keep healthcare costs at an affordable level but can also provide improvements in quality. The agrofood sector is under enormous pressure to feed increasing numbers of people, in spite of climate change. Robots can not only solve the problem of the lack of manpower in this sector but can also increase productivity. When it comes to maintenance and servicing, robots can carry out inspections and maintenance activities under dangerous conditions in locations where human operators cannot gain access.

This report identifies the opportunities offered by robotics for The Netherlands in general and for Brabant in particular. We begin with an overview of the market and the developments taking place in it. This market assessment then leads to a review of the opportunities that the robotics market offers for Brabant - including cross-sector collaboration. In conclusion, the report reveals how businesses in Brabant can exploit these opportunities.

2 The world market in focus

The robotics market can be divided into two main sectors: industrial robots and service robots (Figure 1). Industrial robots are typified by the classic "articulated robots" which have been used in industry and logistics since the 1970s. These robots are employed in controlled, protected environments in which they carry out a limited number of tasks with considerable speed, precision, regularity and reliability. Think about the welding or spraying of body panels in the automotive industry or the stacking of products on pallets at the end of a production line. Elsewhere, top-mounted 'SCARA' robots are used for precision applications including assembly operations in the electronics industry.

Another category of robots has been developed over the past fifteen years: service robots. These robots are employed for specific tasks, such as transport, inspection, care provision or entertainment. Well-known examples include the robot mowers which can be seen in an increasing number of gardens, the self-driving cars being developed by Google and the drones that are currently the subject of so much hype.

This category also includes robots that assist surgeons in operations and those used by market garden businesses to pick vegetables or fruit. These robots are differentiated from classic robots by the fact that they can work next to people in unstructured environments or even work together with them. These robots can even work fully autonomously.

Thanks to this new generation of robots, the robotics

WORLD OF ROBOTICS

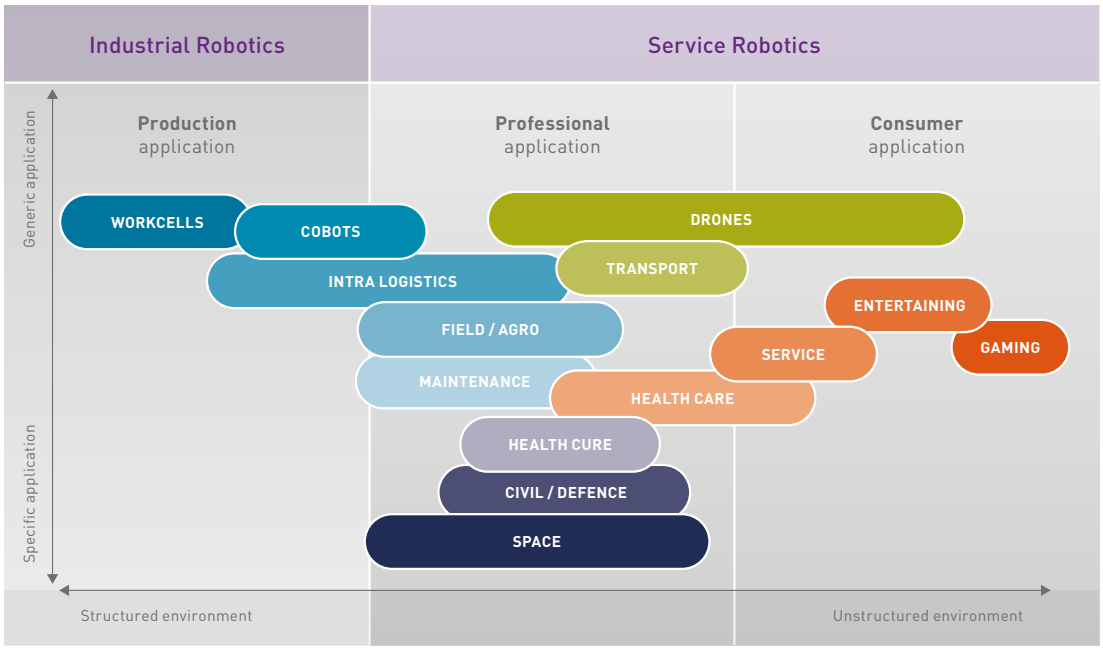


Figure 1 - Split of the robotics market
Source: BOM, 2014

market, after years of stagnation, is at last moving into exponential growth, which is expected to continue over the coming years (see Figure 2). Although the market for industrial robots continues to expand, the main driver of this growth is the increased demand for service robots. Whilst the turnover in the service robotics industry was negligible as recently as the year 2000, within ten years turnover should be several times greater than that for industrial robots.

The more developed countries in Southeast Asia are currently in the vanguard of robot applications. South Korea leads in terms of robot density with 437 industrial robots per 10,000 production workers. Within Europe, Germany leads with a density of 282 per 10,000 workers. The Netherlands lies behind in eighth place with a density of 93. This means there are plenty of opportunities for growth.

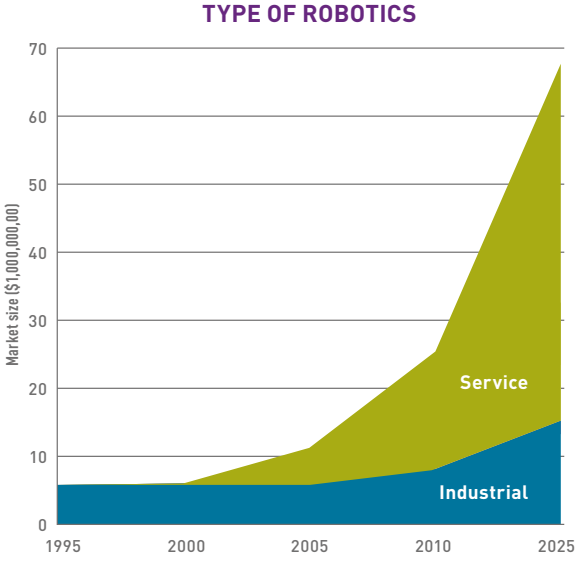


Figure 2 - Development of the robotics market (in billions of dollars)

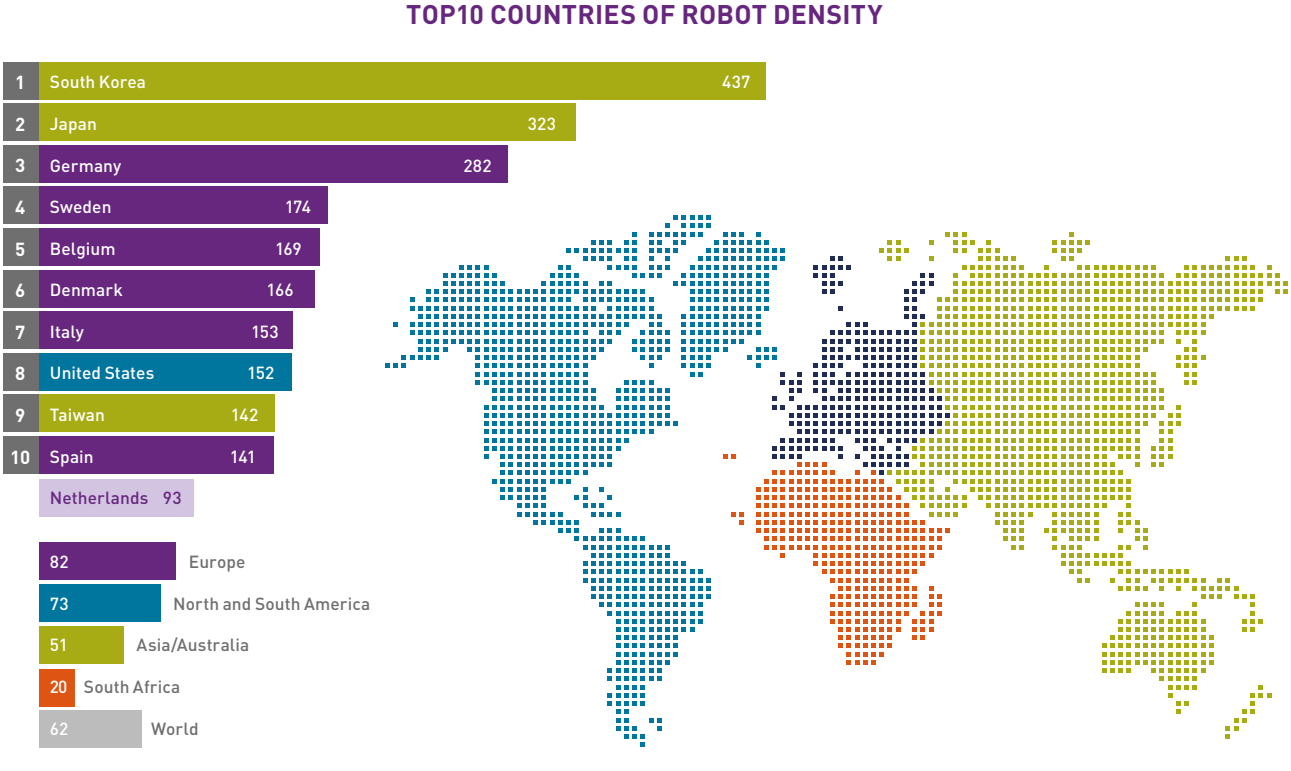


Figure 3 - Top ten countries with the greatest robot density (number of industrial robots per 10,000 production workers)
Source: IFR World Robotics 2014

The growing demand for industrial robots

Demand for industrial robots is beginning to grow again after years of stagnation, fuelled by an increasing focus on the automation of production and logistics processes. This focus on automation has been growing in The Netherlands as a result of the 'Industry 4.0' concept unveiled at the Hannover Trade Fair in 2011. The 'Industry 4.0' concept outlines a future where "smart factories" feature machines and systems that communicate with one another - and with people - in real time. Robots will play an important role in these factories, particularly the new generation of collaborative robots – or 'cobots' - that can operate alongside and with people.

The International Federation of Robotics highlights further trends that will promote increased sales of industrial robots, including increasing global competitiveness and growing consumption in developing markets, which will require modernisation and the spread of production facilities. Innovations are being rolled out with ever greater speed and product life cycles are shortening. This has triggered increased demand for flexible solutions in which robots can achieve more than the majority of conventional production methods. In addition, robots are becoming cheaper and ever more user-friendly, which means it is becoming more attractive for even small or medium-sized companies to invest in them.[2]

The expectation is that demand for industrial robots will rise at an annual rate of 12 per cent over the coming years. This means that annual sales will rise from 200,000 to almost 300,000 units over the next four years.[3] More than half of these units will be sold in Asia, where demand is growing particularly fast in China. A striking example is Foxconn, the contract manufacturer that provides jobs for more than a million people in China. Foxconn has announced that they want to install 10,000 robots, which can each assemble 30,000 iPhones per year.[4] Another example is the Chinese robot producer Siasun, which in a short period has developed a wide portfolio of robots within a mature market. The Chinese market is currently growing by about 40 per cent per year.

The market for industrial robotics bears all the signs of a mature market. Currently some 1.6 million robots are in use worldwide, of which 60 per cent are in the automotive and electronics industries. Almost three quarters of the global market dominated by the four major robot producers: ABB, Fanuc, Kuka and Yaskawa. The remainder of the market is mostly filled by robot producers from Japan and Germany.[5]

In Benelux, more than 1,900 robots were sold last year, of which 800 went to The Netherlands. Within The Netherlands, engineering and systems integration firms in the south of the country drove demand. Names that come to mind include VDL Steelweld, AWL, Robomotive, Duflex, Robot Solutions and Irmato in the field of industrial applications: CSi and Vanderlande in the field of logistics: and Focal Meditech within the medical sector.

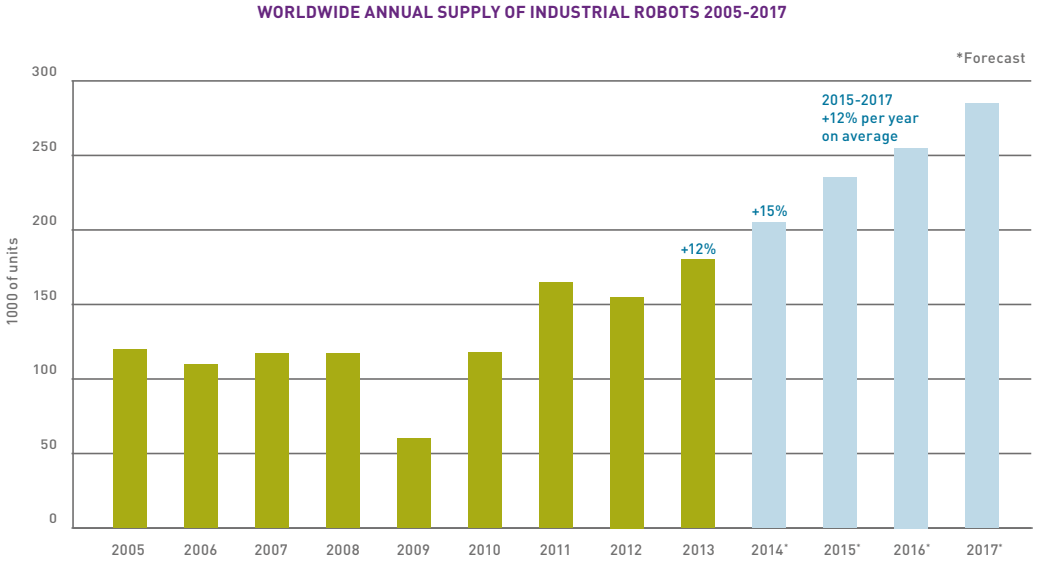
The rapid expansion of the service robot market

Unlike the industrial robotics market, the market for service robots is still very young and diverse, with no clear market leaders. This market has a value of USD 5.3 billion - still below that of the industrial robotics market, although it is expected to expand significantly over the next few years. This growth will occur in both the professional and consumer markets, which exhibit very distinct characteristics.[8] In absolute numbers, the professional market is relatively small, with 21,000 service robots, but represents a total value of approximately USD 3.6 billion. That is more than twice the value of the consumer market, which covers some four million robots. Over the next three years, it is estimated that demand for professional service robots will grow six-fold, with an eight-fold growth in the number of robots for personal use.[6]

Almost half of the professional service robots currently in use are for military applications, such as the drones used by the American Army patrolling over Iraq and Syria. A quarter of those in use are milking robots, a market dominated by the Dutch company Lely. Approximately 1,900 robots are used for logistics purposes, principally as automatic guided vehicles (AGVs). The medical sector is the most lucrative - the 1,300 robots in this sector represent a value of almost USD 1.45 billion Demand for consumer robotics is mostly driven by household applications, such as robot mowing machines or robot vacuum cleaners. It is expected that within three years some 24 million out of the 31 million robots produced will be employed in this market. The remaining seven million will be used for entertainment and leisure - one might think of drones and toys - while around 12,400 robots may be used in care provision for elderly or handicapped people.[7] ■

[2,3,5,6,7] *'World Robotics 2014; Service Robots', International Federation of Robotics, Statistical Department, 2014.*

[4] *'Foxconn's 'Foxbot' robots will assist human workers at major iPhone factory, report says', Appleinsider, 9 July 2014 (http://appleinsider.com/articles/14/07/09/foxconns-foxbot-robots-will-assist-human-workers-at-major-iphone-factory-report-says).*



Figue 4 - Market development for industrial robots (in thousands of robots) - Source: IFR World Robotics 2014

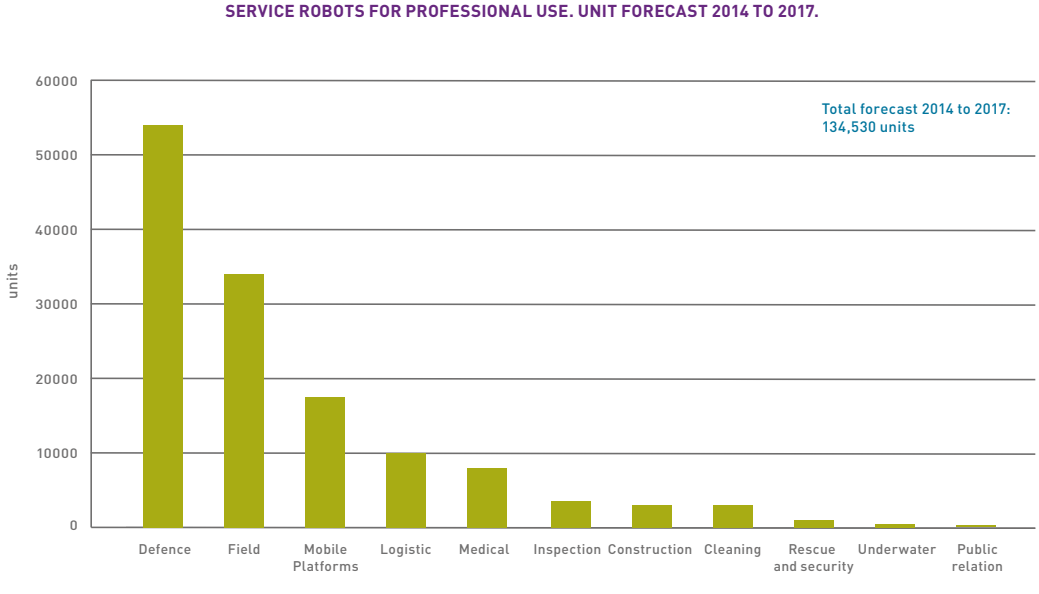


Figure 5 - Growth of professional service robots by application (in number of robots) - Source: IFR World Robotics 2014

INDUSTRIAL ROBOTICS MARKET	SERVICE ROBOTICS MARKET
→ $ 10 billion	≈ $ 5.3 billion
1.6 million robots	4.0 million robots
12% growth per year until 2017	Growth to 31.1 million robots by 2017
4 market leaders with 75% market share	Diversified market with many start-ups
60% automotive and electronics industries	70% defence and agriculture (professional robots)

Table 1 - Industrial robotics market versus service robotics market - Source: IFR World Robotics 2014

[8] *'The Next Generation Of Home Robots Will Be So Much More Than Vacuums', TechCrunch.com, 19 maart 2015'*

Cobot in action (photo: Universal Robots)

3 Market sectors

The rapid growth of the robotics market shows that opportunities exist - but precisely where? In this chapter we will investigate the opportunities in five market sectors: Industry; Care Provision; Agrofood; Maintenance and Service; and Intralogistics.

3.1 Industry

In 1961, the first industrial robot was put into service in a General Motors factory in New Jersey. Its job was to lift and stack hot components from an injection moulding machine. The big breakthrough for the robotics industry followed in the 1970s, when thousands of robots were installed in the automotive and electronics industries. Since then, the industrial robotics market has matured and is dominated by four major producers: ABB, Fanuc, Kuka and Yaskawa.

The success of 'classic' industrial robots can be attributed to four factors: carrying capacity, speed, accuracy and reliability. These robots are especially suited for repetitive tasks that demand a great deal of concentration or high physical effort when done by people. These robots operate in a controlled, protected and safe environment. The typical purchase cost of an industrial robot is around EUR 50,000. This sum typically needs to be supplemented by funds for programming, integrating and installing the robots on the shop floor.

Classic robots: total cost of ownership

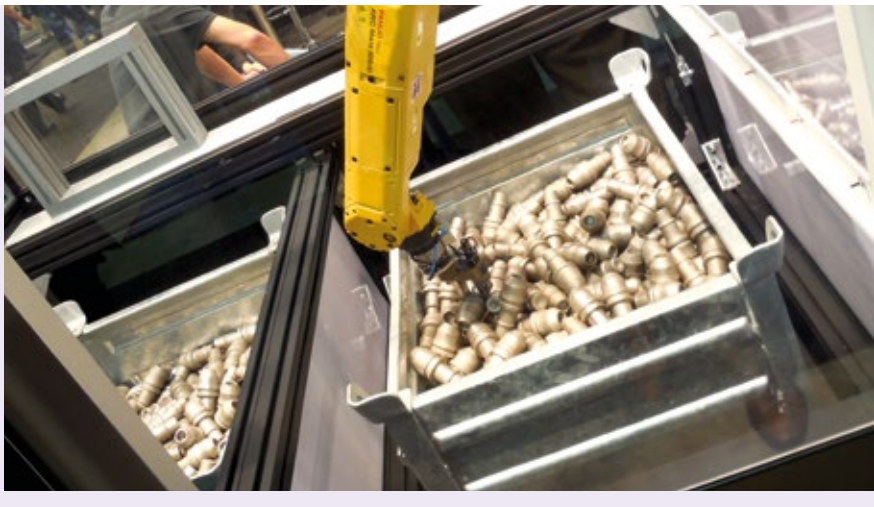
Current developments in the industrial robotics market focus on the "total cost of ownership". Robot manufacturers are trying to reduce the costs throughout the whole life cycle of a robot. This "total cost of ownerships" refers not only to the purchase and integration costs but also the costs of use and maintenance. In other words: robots are constantly using less energy, require less maintenance and are accordingly easier to install and reprogram.

Through cross-sector collaboration with vision technology specialists, new applications for classic industrial robots have been created over the last few

The Baxter robot
(photo: Rethink Robotics)

> *We are on the brink of introducing a new way of working with robotics into our factories. With a new class of smart robots we do not need to choose anymore between a fully manual or fully robotized processes. By collaborating with robots in a safe and smart way, new hybrid manufacturing processes are opening up. By strategically implementing this way of working we can enhance productivity and improve manufacturing processes. At MIT we are researching this new generation of robotics and hybrid processes creating safer and smarter robots.*

Julie Shah, Boeing assistant professor at Massachusetts Institute of Technology



Industrial robot for binpicking

years. The most important application is bin-picking: the picking of unsorted products from a container or box. Thanks to advanced vision technology and smart algorithms, robots are now able to recognise products and work out how they should be picked up, irrespective of how they are actually positioned in the container or box.

Another recent trend relates to safety. The traditional cages around robots are increasingly being replaced by electronic protection systems such as "proximity sensors", which directly detect an approaching employee. This means that the robot and the whole of the production process no longer needs to be halted immediately in the event of an emergency.

Collaborative robots: easy to train

In industrial robotics a new generation of robots is being developed with three important characteristics: they are cheap, easy to train and capable of interacting with people. These collaborative robots - 'cobots' for short - are bringing robotics within the grasp of small and medium-sized enterprises.

Two companies are at the forefront of this market: Universal Robots and Rethink Robotics. Since their market launch in 2009, Universal Robots has sold some 3,000 cobots. Thanks to sophisticated sensors and a new form of artificial intelligence, these robots are quickly able to learn new tasks. The robots are mainly used for bin-picking or the loading and unloading of machines. They are fitted with multi-functional grippers and are capable of picking up a large number of different products with which they have never previously been confronted.

In 2012, Rethink Robotics launched the Baxter - a two-armed robot that is mobile, can work between other people on a production line and quickly learn new tasks. Existing robot producers, such as ABB and Kuka have also developed the 'YuMi' and 'LBR iiwa' cobots, which can work alongside and together with people.

Cobots in the automotive and food industries

An outstanding example of the deployment of cobots is the Audi factory in Ingolstadt. The factory's 'PART4you' robots take components out of containers

Cobots hand over parts in the plant of Audi in Ingolstadt (photo: Audi)

and pass them in the correct sequence and at the right time to the people assembling them - all at the proper tempo for the production operators. Safety is ensured through the use of intelligent sensors and a soft protective covering over the robot arms. The cobots improve productivity and ergonomics, but Audi stresses that they do not cost any jobs. "The people remain necessary for making decisions about the progress of production,"[9] a spokesperson says.

In The Netherlands, goods importer Gibas has purchased some 150 cobots from Universal Robotics for loading and unloading machines. Machine supplier Van Wees Waalwijk has installed two mobile cobots inside a bakery in the north of the Netherlands. The first cobot automatically places baking tins and baking sheets onto the production line, whilst the second takes them off again, with the assistance of vision technology. Van Wees Waalwijk is exploring the possibilities for using these robots in other positions on the production line, such as decorating or injecting the products with whipped cream.

Lower purchasing and integration costs

The expansion of the market for cobots has made robotics accessible for an increasingly number of

Van Wees Waalwijk, pioneer in robotics

"We put the robots where the work is"

Van Wees Waalwijk is a 110-year old engineering works which, in the last few years, has completed fifteen robot projects. "For example, we have installed robot units for packing rolls of sweets and biscuits, but also for assembling heat exchangers and car seats. Working together with the development company Producon, we developed a robot unit which, in a patisserie, whips the tarts out of baking tins, lays them on a cooling belt and then brushes the baking tins off and stacks them", explains owner-director Andries van der Werf.

Van Wees Waalwijk and Producon have recently taken a completely new track. Instead of robots that are installed in isolation inside cages, the company has now implemented a project with a new type of robot that can literally move amongst the people. "It's no longer necessary to bring the work to the robot, we bring the robot to where the work is. So, this mobile robot becomes the ideal flexible employee for simple, repetitive and short-cycle activities."

companies - particularly SMEs - for whom classic robots do not represent an option. One significant reason is the dramatically reduced purchase cost. The Baxter from Rethink Robotics, for example, costs USD 25,000 - half the cost of a classic robot.

Integration costs for a cobot are also much lower. For a typical industrial robot, a large amount of space must be released on the shop floor, and the production line must be adapted in order to accommodate the robot. A cobot, by contrast, does not take up much space and can be employed on the existing production line. Expensive programming resources are not needed because a cobot can learn new tasks easily. A cobot is also more efficient as it can carry out different tasks at different locations.

A typical example of the advantages of cobots is provided by the international research project 'Factory-in-a-Day', led by the Robotics Institute at Delft University of Technology. The most important aim of this project is to make European SME enterprises more competitive by removing the most significant obstacle to the introduction of robots: the long installation time and the high integration costs. More than 140 research personnel are currently attempting to reduce the time needed for system integration to less than a day.

3.2 Healthcare

In the healthcare sector, we distinguish between two areas with different challenges: 'Cure' and 'Care'. The 'Cure' market is particularly lucrative - its 1,300 robots represent a market value of USD 1.5 billion.

> *With the fast progress of service robots, a lot of new applications are arising. Some others offer the possibility of re-shoring industries which have been lost to countries outside Europe, due to the productivity regained with service robots. We are still standing at the start of a curve that will rise steeply. What we need is knowledge and imagination. What is still missing is a supply chain with suppliers who can deliver components to robot producers, so this means that the present robots are still very expensive.*

Uwe Haass, Secretary General of euRobotics

[9] *Neue Mensch-Roboter-Kooperation in der Audi-Produktion', persbericht Audi, 12 februari 2015 (https://www.audi-mediaservices.com/publish/ms/content/de/public/pressemitteilungen/2015/02/12/neue_mensch-roboter-kooperation.html).*

"The robotics market has stood still for quite a time", observes Van der Werf. "The fact that developments are now proceeding so rapidly is, above all, due to the combination with other technologies such as vision systems and smart sensors, which are making new applications possible. The classic robot is not people-friendly, has a large footprint and is not suitable for working together with people in a small production space. In this respect we are now having to try out the changes, but there's still plenty of room for development." ■

Robot surgery: minimally invasive, high precision
A major player in this field is the American company Intuitive Surgical which, under the Da Vinci brand, develops surgical robots for treating different types of cancer and disorders of the kidney and urinary tract. A new entrant to the market is Medrobotics, who have developed a flexible technology for endoscopy.

Medical robots make minimally invasive surgery possible (photo: Intuitive Surgery)

The Netherlands is a leader in this specialist area. At Eindhoven University of Technology, researchers are working on robots for applications such as the sewing together of blood vessels, the insertion of electrodes into the brain and the machining away of bone in jaw operations. In partnership with the University of Twente, Enschede firm Demcon has developed a robot that allows a specialist to operate a flexible endoscope with one hand, freeing the other hand for carrying out the operation.

The most impressive example is Preceyes, a project from Eindhoven University of Technology which has developed a robot for eye surgery. Using technology also employed by ASML, this robot puts eye surgeons in a position to operate with ten or twenty times greater accuracy. The biggest challenge now is how to bring these innovations to market.

Care: from telepresence to exoskeleton
The most remarkable robots in the care sector are undoubtedly those currently under development in various research organisations. These robots are capable of enabling elderly or chronically sick people to live independently for longer periods. Robots being developed in this field include the 'Amigo' from Eindhoven University of Technology; the 'Leo' from Delft University of Technology; and the 'Rose' from the Delta project. The most recent robot to be developed is the 'Care-O-Bot' from the Fraunhofer Institute in Germany.

Beltech, specialists in vision-technology

"Companies wanted – for collaboration on innovations"

Beltech was created 28 years ago as a spin-off from Eindhoven University of Technology. The company develops vision technology, complete systems with cameras, lasers and software, for applications in industrial automation. The robotics market is a strategic market for Beltech. "We provide a robot with eyes, so that, for example, it can independently see and pick up products. So our technology is used for random bin picking and for loading and unloading machines, but it can also be adapted for a milking robot. Not long

Robot Rose - a prototype robot for home care developed in Brabant

These robots each beautifully demonstrate what is technically possible, but for the time being, they are still too expensive and their possibilities too limited to be used on a wide scale in the near future.

The take-up of robots without arms employed for 'telepresence' applications is more likely in the short-term. These robots can be used by doctors and care personnel to keep in touch with patients and elderly people in order to discuss their condition or check whether their medicine is working. One example is the solution from Double Robotics, which in fact is little more than an iPad on a Segway.

There is also potential in the market for robots used by people with physical limitations. Products here can include robotic arms for people with impaired hand functions. These robot arms can be mounted on electrically-driven wheelchairs. In Brabant, Focal Meditech supplies these arms, which have been developed by the Canadian company Kinova. Another example is the use of exoskeleton applications: robots which people can "put on" to support or strengthen certain physical functions. These are all solutions that are already being put into practice.

3.3 Agrofood

The agrofood sector offers opportunities for robotics throughout the entire production chain - from sowing and harvesting through to the processing, packaging and preparation of products. The combination of drones for measuring crop development with robots for working on the crops makes precision agriculture a tangible possibility. The potential of robotics could further strengthen the position of The Netherlands as the world's second-largest exporter of agricultural products and also provide a solution to the threat of food shortages.

ago, our technology was applied to a robot that inspects headlights in an automotive factory. People are just not capable of carrying out a consistently reliable inspection all day long, but this robot can", reports Richard Vialle, managing director of Beltech.

The way in which a robot can recognise products is changing fast. Normally, the image of an object is compared with a product template, but this doesn't work for cucumbers and tulips, where each one is different. "With the help of vision and smart algorithms, a robot can nevertheless recognize these products, pick them up and inspect them directly. This way, robots are more flexible because they need not be constantly changed over or reprogrammed. They can learn new tasks by themselves."

The developments in vision technology are often stated as one of the reasons for the rise of a new generation of robots. According to Vialle, this is nonsense. "The technology has proved itself all along, but the market had shown little interest in it for a long period. What we need is cross-pollination: SMEs who want to collaborate with one another in short-term projects for innovation, and who are willing to invest time and money in them. We are one such company." ■

The self-propelled tractor Conver (photo: Conver)

Drones and field robots promise higher productivity
Precision agriculture begins with the use of drones or robotic birds to map suitable agricultural land and measure crop development. By using smart cameras and sensors, these flying robots can generate accurate data about matters such as biomass distribution and the nitrogen or moisture content of a crop, linked with the GPS co-ordinates of the particular area.

This data can then be applied to allow intelligent field robots, fitted with vision technology and smart sensors, to provide each plant with precisely the correct quantity of water, fertilizer or plant protection product. The result is an optimal application per square metre which will have as small an impact as possible on the environment.

A new generation of agricultural robots is being developed as part of the international 'AgroBot' project. Applications include the installation of software to enable the supply of fertilizer to crops or clearing of weeds. The 'Robird' is also of interest - a robotic bird of prey developed at Twente University for scaring birds off farmland.

Brabant potato producer Van den Borne Aardappelen has, in the meantime, introduced precision agriculture on a practical basis. The company has the capability of planting, fertilizing and harvesting potatoes with one centimetre accuracy thanks to the use of robotics.

Harvesting with gripper and vision technology
Harvesting is a particular matter of concern in the agrofood sector. At the present time, harvesting remains a very labour-intensive and physically demanding activity, for which Western Europe mainly employs workers from Eastern Europe. The development of a new generation of grippers, boasting advanced vision technology, makes it possible to use robots for harvesting. These robots can see which peppers, cucumbers or apples are ripe, work out how best to approach the fruit and then pluck them without damage.

Two examples of these robotic 'grippers' have been produced by USA firm Righthand Robotics and Dutch robot manufacturer Lacquey, a spin-off from Delft University of Technology. The potential for these grippers is highlighted by the fact that machine manufacturer Food Technology Noord-Oost Nederland (FTNON) recently acquired a majority share in Lacquey. FTNON wants to use these grippers for sorting, processing and packaging vegetables and fruit.[10]

One recent research project is 'Sweeper', in which a robot was developed for harvesting peppers. Various partners, including Wageningen University, system integrator Irmato and pepper producer De Tuindershoek, are working together on this research project, subsidized by the European Union.

BoniRob, multifunctional open robot platform for agriculture (photo: Agrobot)

Specific applications

Apart from precision agriculture or the harvesting of vegetables and fruit, the agrofood sector uses robots in many other applications. In horticulture, there is great interest in the automation of the handling of pots and plants. The Belgian company Degramec has begun to develop a mobile pot-handling robot called 'Degraplace'.

The 'Greenbot' is a self-propelled tractor being developed by Giessen firm Conver. The robot tractor will store all the individual repetitive actions involved in a particular activity, such as steering and accelerating, for repeated use. In Canada, Clearpath Robotics is developing unmanned vehicles for applications in agriculture and other sectors.

In cattle rearing, robots are used not only for milking cows, but also for driving animals. Lely, in Maassluis, is one of the worldwide market leaders in this sector. The processing of meat and fish is also an area where robots are playing an increasingly important role.

The Province of Brabant is well positioned to drive growth in the development of robots in the agrofood sector. Brabant is where the ambitions for the high-tech and agrofood sectors meet, as can be seen from the agenda of, amongst others, Agrofood Capital, an initiative by entrepreneurs, public authorities and educational institutions for the purpose of making North-east Brabant a key player in the development of innovative products, technologies and concepts for the agrofood sector.[11]

"Agriculture is confronted with the enormous challenge of feeding some nine billion human beings by 2050. At the same time, water and fertilizers are becoming scarcer, and the participation of the population in agricultural work is reducing. Thanks to the ever-more intelligent algorithms that are able to crunch environmental data at lightning speed and react to them, we can increase agricultural productivity in a sustainable manner using robots in combination with vision technology, as in precision agriculture. The biggest challenge is making the business case. Solutions should not only be robust and accurate, but also be very attractively priced."

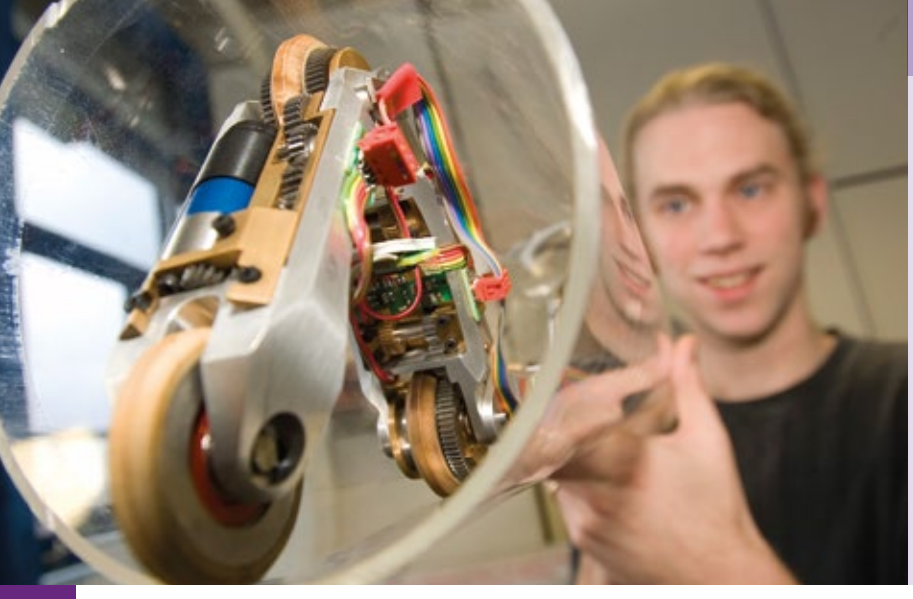
Eldert van Henten, Professor in Farm Technology at Wageningen University & Research Centre

[10] *'Nederlandse robotarm vindt partner voor internationale expansie', [Trans: "Dutch robot arm gets partner for international expansion" Het Financieele Dagblad, 2 March 2015 (http://fd.nl/ondernemen/1094734/nederlandse-robotarm-vindt-partner-voor-internationale-expansie).*

[11] *See www.agrifoodcapital.nl.*

Gripper of Lacquey (photo: Lacquey)

Gripper from RightHand Robotics (photo: RightHand Robotics)



PIRATE: robot for inspection of pipes (photo: University of Twente)

3.4 Maintenance and Service

The Maintenance and Service market sector has much in common with the 'Cure' sub-sector of the healthcare market. Both markets require very specific robotics applications. The Maintenance and Service sector is a potentially lucrative one for robot producers but development costs are high.

In this sector, robots are used principally for inspection and cleaning, especially equipment items that are difficult to access and pose health and safety risks to humans. Examples include the inspection of oil and gas pipelines or the cleaning of tanks.

British company OC Robotics has developed a line of snake-arm robots to meet this unique need. These robots have been specially developed for the inspection of locations that are difficult to access, such as enclosed spaces, large machines or installations. Without robotic applications, these locations would have to be partly disassembled at great cost. Drones also play a part in this sector, with applications such as inspections at high elevations.

Robots for pipeline inspection and paint removal

In The Netherlands, Twente University is at the forefront of the development of robots for the Maintenance and Service sector. The project RoboShip has seen the university work to develop a robot that can inspect ballast water tanks in ships. This is a dangerous activity for inspectors since the tanks are slippery with algae, full of poisonous gases and are more or less inaccessible due to beams, pipes and cables.

In The Hague, LCR Systems is working on a robot which, through the use of a laser, can remove the paint coating from aircraft. Aircraft maintenance companies typically use chemicals for this purpose, but due to the increasing use of special composites, this method is no longer adequate. A budget of EUR 10 million has been allocated for this project, which is expected to be ready for use by 2016.

Eindhoven's NTS Group is involved in a collaboration to develop robots for the process industry. Work is ongoing to produce a 'coating robot' able to treat and paint large surfaces such as tanks without interruption and with improved quality.

A conservative market with conflicting concerns

Within the field of Maintenance and Service, robotics offers considerable opportunities for improving not only productivity but also quality and safety. Brabant offers a platform in which businesses and research organisations can collaborate on innovations. With its available competencies in robotics and system integration, Brabant is able to play significant role in this field. The question is the degree to which companies in this sector are open to innovations involving robots. Investigations show that the market is very conservative in this regard.[12]

A further barrier to innovation is the fact that the owner of the assets, the service provider and the robot producer all have different business concerns. Robots only become attractive when they contribute to the efficiency of the asset owner and mutually beneficial business solutions need to be forged.

One notable company in this respect is Alstom, which

[12] *'Key technology or just a trend? Future influences of robotics in the oil and gas industry', Accenture, 2015.*
[13] *'Wehkamp schakelt logistiek op de automatische piloot', RetailTrends nr. 1, 2014.*

Thanks to the rapid developments in robotics, there is a growth in the possibilities for using robots outside industry, in locations close to people, such as in healthcare. In The Netherlands, thanks to industries such as the large petrochemical industry, there are additional opportunities for robots for inspecting pipelines. The Netherlands is one of the leading countries worldwide in mechatronics and can play a significant role. One key issue is legislation, which should not get in the way of innovation. And companies should have the boldness to develop new markets.

Stefano Stramigioli, Professor in Robotics and Mechatronics at Twente University

constructs power plants and takes particular responsibility for the optimisation of maintenance. Together with the Swiss Federal Institute of Technology, Alstom has set up a business to develop inspection robots for power stations in the (petro) chemical industry. In 2013 this company began to develop the 'Petrobot', an inspection robot for pressure vessels and storage tanks.

3.5 Intra-logistics

Logistics is a labour-intensive and often physically demanding activity. Robots for storage, order picking and internal transport can make a contribution in this sector by achieving higher productivity, higher quality (fewer mistakes) and shorter through-put times. Through-put times are particularly important for e-commerce. Thanks to robots in its new distribution centre, Wehkamp will soon be able to send out every order from a consumer within half an hour, which makes it possible to place an order in the lunch break and have it delivered home on the same day.[13]

The Dutch regions of Brabant and Limburg together comprise the logistics hotspot of Europe, which international companies use as a base for their European distribution networks. The use of robotics applications will further strengthen this dominance.

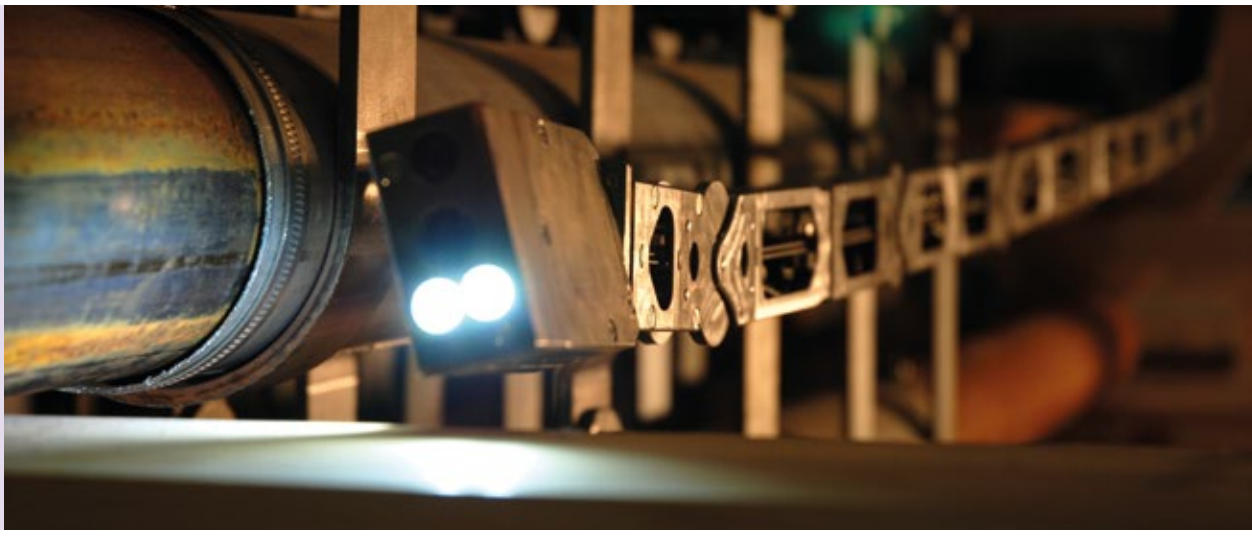
Robots moving goods into and out of stock

Robots have been used in storage systems since the 1970s. These robots take the form of 35-metre high storage and retrieval machines on rails that facilitate the inward and outward movement of pallets or good containers. These are machines are limited in terms of capacity and over the past ten years alternative storage systems using smaller, more mobile robots have been put into use.

The most significant improvement uses several "shuttles" that can operate above one another in a single aisle. This significantly boosts both input and output capacity. In the new Wehkamp distribution centre in Zwolle, 468 shuttles from the Austrian company Knapp are in circulation, bringing containers of goods to 20 workstations. In the Netherlands, Vanderlande has developed a similar type of shuttle system.

Other new applications are based on brand new concepts. One example is 'AutoStore' from the Norwegian company Hatteland. This system consists of robots that travel over an aluminium grid in which containers of goods are stored. The robot "unearths" the required container and brings it to a workstation.

Snake-arm robot for inspection of locations that are difficult to access (photo: OC Robotics)



AutoStore-robot digging up goods

The robots manufactured by Amazon-owned company Kiva are also significant. These robots fetch large-scale storage modules and bring them to workstations. Other companies have developed similar solutions, such as the 'G-Com' from German company Grenzebach. In all these solutions, people no longer need to go to the goods and to look for them. The goods are brought to the operator instead.

One continuing challenge to robotics manufacturers is the actual picking of orders. Developments in this field of bin picking and intelligent grippers, such as the solutions from Lacquey and Righthand Robotics, show great potential.

AGVs alongside humans

Automatically-guided vehicles (AGVs) have been used for internal transport for many years, but only in structured environments in accordance with fixed, pre-programmed routes. Thanks to smart sensors and vision technology, a new generation of AGVs is emerging, which can be implemented flexibly and dynamically and which can move between people. They can collect materials together and take them to a production line - as for kitting - or remove finished products to the stores.

The adaptation of AGVs for internal transport purposes is developing along two paths. The first is increasing use of unmanned autonomous lift trucks or warehouse trucks. The advantage of these machines is that the controls can be taken over by people when required. The second path is the development of AGVs for a specific purpose, such as the transportation of bins or boxes. Examples of these machines include the Lynx from Adept and the MiR100 from Mobile Industrial Robots.

Robots can not only be used for intralogistics but also for container handling. The new Maasvlakte Two container terminal in Rotterdam uses remotely-operated cranes to unload the ships. AGVs are then used for transport between the quay and the storage yard, while unmanned stacker cranes place the containers on the correct storage location.

WWA, a trend-setter among the system integrators:

"It's time we started providing some good training"

Robots for personal use

The consumer market is a major growth industry for robotics manufacturers. Demand for consumer robotics will be driven by household applications, such as robot mowing machines or robot vacuum cleaners, over the coming years. Increasing numbers of robots are also being developed for children and entertainment purposes. It is difficult to place new products in this market without having well-known name or distribution channels. Marketing, image-building and publicity all play a considerable role in launching these products.

Interesting examples are the domestic robots from iRobot and the robots "Pepper" and "Jibo", which have been developed to interact with family members and which can give replies to questions. One example from Brabant itself is ixi-Play, a game robot from Witty Worx in Eersel. You can get a good overview of robots for personal use on www.robots.nu.

Flexible, versatile and attractively priced

In addition to these solutions, robots are also being developed for more specific tasks, such as unloading containers. In Brabant, under the name TEUN, a robot is being developed for this purpose, which has attracted a lot of attention, although from a commercial point of view, it has not proved successful.

What is hindering the application of robots in the intralogistics sub-sector is the fact that many storage companies have subcontracted their logistics to specialised service providers on relatively short-term contracts. This means it is less attractive for the logistics service providers to invest in process automation. This highlights to need to develop flexible, versatile robots that are easy to configure and attractively priced.

Automated guided vehicle (photo: Mobile Industrial Robots)

WWA develops and produces adaptations of industrial robots, including ones involved in producing cheese. "As an example, we have developed a robot that can put the coating layer on cheeses. This robot picks up the cheese, dips it into a vat of coating material, and brushes off the surplus. The result is better adhesion, preventing mould formation. At the present time, we are busy with the automation of a new cheese factory in Rouveen, which will operate completely using robots", says WWA commercial director Maarten Hoogwout.

"The importance of robots is increasing now the financial crisis is over", says Hoogwout. "With eight people, we are making a turnover of EUR 1.4 million per year, but just now, we have a five-fold increase in enquiries. Within five years we want to double the number of employees, but we then have the problem of finding them."

Hoogwout is concerned about making the link with education. "It is true that there are a few college courses in mechatronics in this region, but there is still an unsatisfactory link to the requirements of businesses. It's high time that as a sector we put our heads together and collaborated with the educational institutions, to make sure there is some good training. For us as a sector, we will then have the task of making the profession more attractive, so more people will choose these courses." ■

4 Technological trends

When we review developments in robotics technology, we can distinguish four distinct application areas: Manipulation; Perception; Navigation; and Cognition (see Figure 6). Within these areas there are a total of thirteen research sectors, where efforts in research, development and innovation are concentrated.
For many years, the robotics market concentrated principally on a single area of technology - manipulation. This led to the development of classic industrial robots which, thanks to extensive developments in mechatronics, drive technology and motor control, offer excellent performance in loading capacity, speed, precision and reliability.

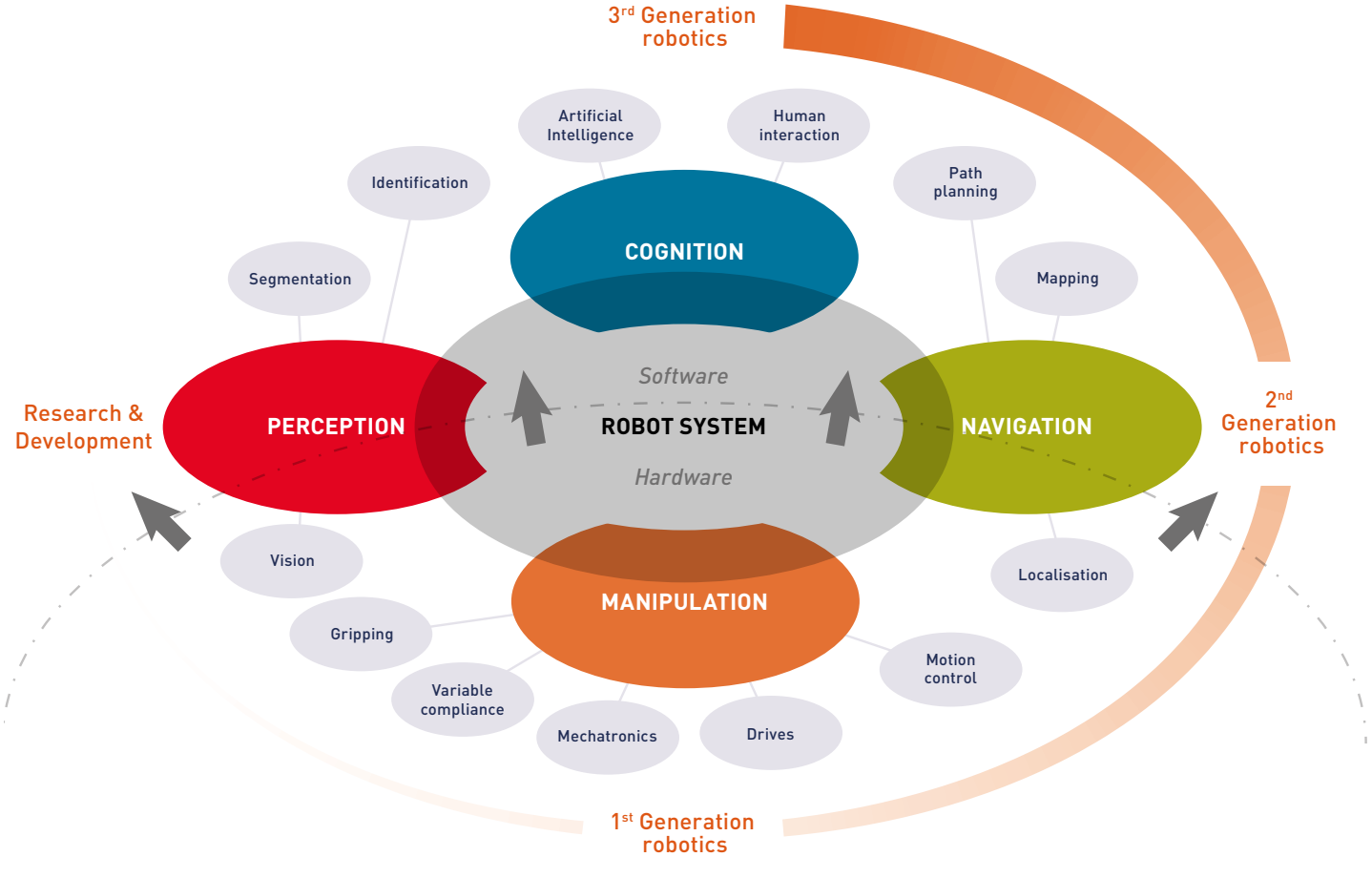


Figure 6 - In robot technology, we can distinguish between four technology areas: Manipulation; Perception; Navigation; and Cognition. Current efforts in research, development and innovation are concentrated within the 13 grey research sectors.
Source: BOM 2015

> *The new generation of robots that can work alongside or together with people forces us to reconsider the question of safety. At the beginning of 2014, this led to a new ISO standard (ISO13482), with which we are running ahead of the technical developments. Companies that already want to operate with these robots can limit safety risks by using this standard and increase their chances on the market.*

Henk Kiela, lecturer in Mechatronics and Robotics at Fontys Engineering College and member of the ISO working group "Safety for service robots TC184 SC2"

Perception and Navigation

A new generation of robots is emerging. What distinguishes this second generation of robots from the first are their competencies in the fields of perception and navigation (see Figure 6). Robots can now detect people and identify products, thanks to vision systems and sensors working in combination with intelligent algorithms. The same technology, sometimes in combination with gyroscopes and GPS systems, enables robots to determine their location, map out their environment and match their movements accordingly.

The first generation of robots was used almost exclusively for the manipulation of products or equipment. The second generation of robots offers an enormous range of potential applications. These robots can move freely and safely, even in busy environments. They are not intended to replace people, but to support and assist them or collaborate with them. They relieve us of physically demanding, repetitive and monotonous activities. They enable us to work with greater accuracy and precision. They hand us materials, tools or instruments at just the right time. They carry out tasks in locations that we cannot access or simply do not wish to venture.

Current developments

A number of technological developments have contributed to the emergence of the second generation of robots. The growing availability of affordable 3D-vision systems with cameras, lasers, sensors, gyroscopes, GPS systems and other technologies has facilitated progress in the fields of perception and navigation.

The increasing computing power of processors makes it possible for robots to analyse accumulated data in real time and adapt their behaviour accordingly. With the evolution of a new open software platform - the Robot Operating System (ROS) - it is becoming increasingly simple to integrate new components and develop applications. Thanks to the "internet of things", a robot can itself learn tasks from another robot in a completely different location.

Developments in hardware have also made a significant contribution. Robots are today becoming ever more affordable, thanks to the increasing standardisation of drive and control technology. Developments in batteries and drive technology are bringing enhancements in mobility and operating time. The new generation of robots will be distinguished by the strong development of a fourth application - cognition. Further developments in the field of artificial intelligence will enable robots to increasingly able to adapt to their environment, solve problems and interact with people.

Further challenges remain, particularly in the fields of perception, navigation and cognition. To fully utilise opportunities in these areas will require increased software and hardware capacity. Initial investment costs in robotics remain high. Perhaps the most significant challenge lies in the development of applications that fully meet the wishes and requirements of the market. Applications must be simple, reliable, productive, efficient, flexible, safe and acceptable.

Brabant possesses a large high-tech ecosystem, which has all the elements needed to confront these challenges: renowned research institutions; innovative hardware and software producers; and creative system integrators with a knowledge of the markets in which they operate.

5 Opportunities for Robotics in Brabant

This survey has made it clear that the fast-growing robotics market offers opportunities for Brabant - but where can we find them? And how can we exploit them?

5.1 Opportunities in technology

Despite growing efforts in the fields of research, development and innovation, there are still considerable technological challenges to overcome, particularly in the sectors of perception, navigation and cognition. In order to convert these challenges into concrete opportunities, development in software and hardware must also be expanded.
Furthermore, the integration and installation of robots still requires considerable time and money, which represents a major obstacle to the successful application of robotics for many companies. Nevertheless, robots that can be employed flexibly and rapidly in different markets remain an attractive prospect.

Under the name SPARC, a public-private platform has been established in Europe, through which research organisations, business and the European Commission are collaborating in order to exploit these opportunities. SPARC has established an extensive roadmap for research, development and innovation[14]. The European Commission is making EUR 700 million available to fund this initiative. The European robotics industry has made EUR 2.1 billion available. The Netherlands' efforts in this sector are being supported by the group RoboNED, which published its own road map in 2012[15].

It remains difficult to covert academic advances in robotics into solutions that can be rolled out in the market, despite the financial resources available. This is strikingly illustrated in terms of the "technology readiness levels"[15] which have been defined within the context of Horizon 2020, the research and innovation program of the European Union.

Many developments in the Dutch universities are still at the stage of "proof of concept" and are at best being tested under laboratory conditions (Level 3 or 4). From that stage, it is still a big step to achieve systems which have been proven in practice, and for which profitable applications exist (Level 9). Therefore, systems are required which are simple, reliable, productive, efficient, flexible, safe and acceptable. In this context, Echord++ looks very promising - it is a European initiative designed to stimulate collaboration between robot producers, researchers and end users, and as a result bring the innovations beyond the 'proof of concept' stage[16].

One note of caution is that The Netherlands is considerably behind Germany and Switzerland in terms of the number of robotics start-ups.

"We are the world champions for football robots and we are the second in the world ranking with our care robot. We are working hard to develop robots for many more different applications in the healthcare and agrofood sectors. Brabant is able to play a dominant role in the robotics market. Public authorities, entrepreneurs and the education sector are all working well together within the Triple Helix. We have living labs, high-tech companies that invest in innovation, and a strong agrofood sector. Our power comes from our strength in system thinking and integration and in using mechatronics for innovative robotics applications, like our high-precision robot for eye surgery and the micro-surgery robot. What we really need is venture capital. We have enough ideas but not enough money."

Maarten Steinbuch, Professor in Control Systems Technology at Eindhoven University of Technology and co-founder of Medical Robotics

[14] 'Robotics 2020; Multi-Annual Roadmap for Robotics in Europe', SPARC, february 2015
[15] 'Dutch Robotics Strategic Agenda', RoboNED, june 2012
[16] 'Horizon 2020 – Work Programme 2014-2015' (http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf)
[17] 'Echord++, European Clearing House for Open Robotics Development Plus Plus (http://www.echord.eu).

> *Today's robots are specially engineered solutions for very specific tasks, and are therefore only attractive to companies that produce large series for long periods. The future belongs to robots that are flexible, moveable and simple to configure. This needs a different service model that stimulates innovation, such as, "paying for the number of actions" instead of "purchasing the robot". It is only then that the application of robotics becomes interesting for companies with a large degree of variety in their production. A kind of field lab may assist in helping them to discover the advantages of this kind of robot.*
>
> *Heico Sandee, Technical Manager at Alten*

5.2 Market opportunities

The market survey shows that opportunities for the robotics industry can be found in different market sectors in the short and medium term. Firstly, the market for classic industrial robots is still growing worldwide at 12 per cent a year. In The Netherlands opportunities for growth exist, in view of the relatively low density of robots. Furthermore, 'cobots' will enable small and medium enterprises in particular to automate processes in a flexible and affordable manner. This gives these companies the opportunity to move their operations nearer their market outlets. In the agrofood sector, there are abundant opportunities for increasing the already high productivity of the Dutch agricultural and horticultural sectors, through the use of precision agriculture techniques.

The position of Brabant as the logistics hub of Europe can be strengthened by further increasing the efficiency of our distribution centres through the use of robotics solutions. Other opportunities for robotics applications are presented by the Healthcare and Maintenance and Service sectors.

Unfortunately, some obstacles can also be identified. A conservative attitude in combination with a fragmentation of interests by the parties concerned prevents companies and organisations in many market sectors from investing in the relatively difficult robot technologies. Examples of fragmented interests are particularly evident in the Maintenance and Service sector, where service providers see a danger to their earnings model if they use robots.
Logistics providers remain wary of investing in robotics. In the healthcare and agrofood sectors, conflicting priorities can hamper innovation. The implementation of robot technology therefore requires an integral approach, in which the benefits and burdens of the investments can be distributed through the whole chain. This places the before robotics industry the challenge of bringing together the different sectors, and developing a proposition which gives added value to all parties.

5.3 Opportunities for Brabant

Brabant is well positioned in order to benefit from

STRENGTHS	WEAKNESSES
Competencies of system integrators Specialists in mechatronics, vision and software High-tech machine construction with supply chain Top high-tech-ecosystem Connection with worldwide robotics network Collaboration with educational and research institutions A number of start-ups in the Cure sector Leading position in agrofood Leading position in logistics	Different interests within the value chain Earnings models block investment Gap between research institutions and market sectors No research for applications in industry and logistics. Little readiness to invest Little standardization No major robot producer
OPPORTUNITIES	**THREATS**
Growth market industrial robotics Field labs Flexible Manufacturing Produce locally via automation Cobots for SME automation Business cases in agrofood Telepresence in Care sector Connection of technology sectors Innovative ideas available Specific robot training	Many developments abroad Large, establish dominate the market Lack of venture capital for development of market-ready applications Availability of flexible and affordable work is an obstacle to high investment Legislation blocks innovation

Figure 7 - SWOT – analysis of the opportunities for the robot industry in Brabant
Source: BOM 2015

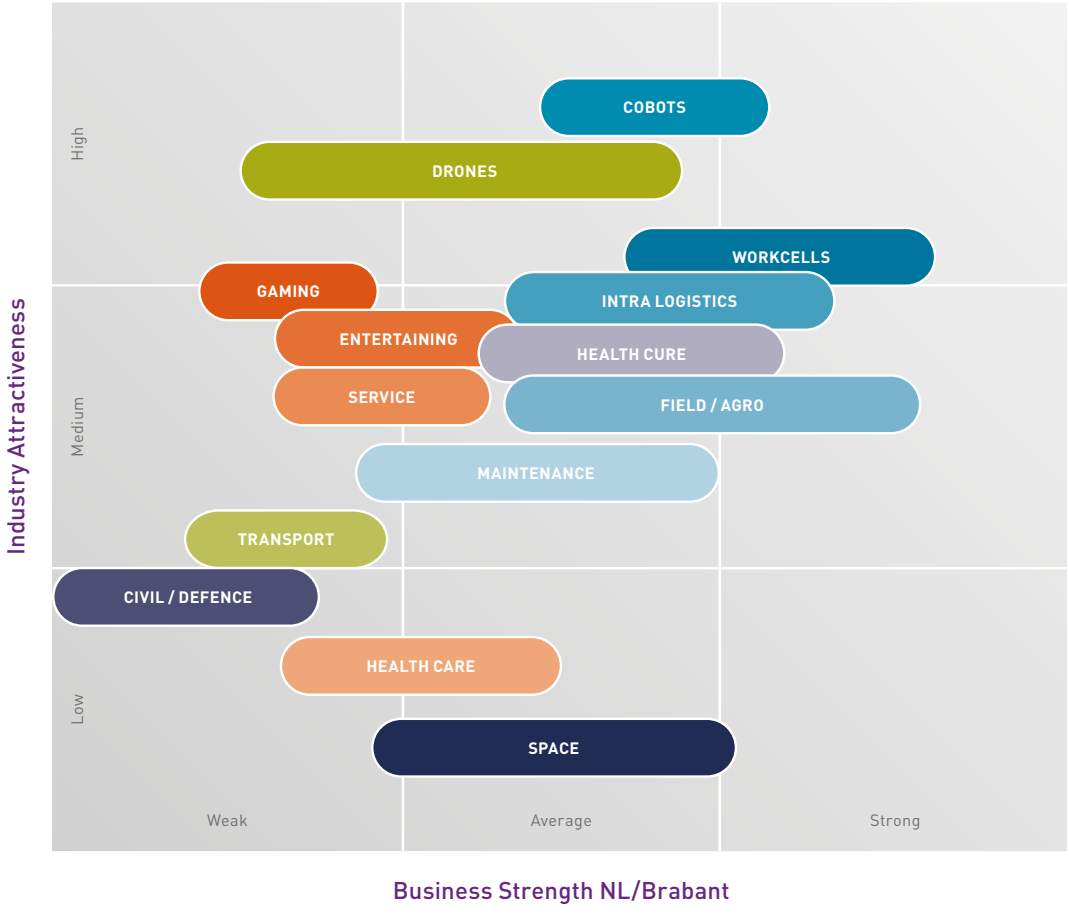


***Figure 8** - Opportunities for robotics in Brabant*
Source: BOM 2015

the opportunities offered by robotics, both from a technological and from a market point of view (see Figure 7). With regards to technology, we are strong in mechatronics, possess considerable experience with industrial automation and robotization thanks to a number of outstanding systems integrators, and boast a number of specialised companies in the fields of vision technology and software.

In terms of market sectors, Brabant is strong in agrofood and logistics, has a modern industry, invests significantly in Maintenance and Service is among the forerunners in the development of new healthcare concepts.

In view of Brabant's strength, our province has opportunities, particularly for classic robots, cobots, drones and for specific adaptations in intralogistics, agrofood and the medical sector. With its knowledge institutions, high-tech ecosystem, the field lab "flexible manufacturing"[18] and the available experience in industrial automation, Brabant has an excellent starting position to play a significant role in the field of robotics.

The real challenge is to make full use of one further strength: our ability to link and integrate technologies. If we want to take advantage of these opportunities, then research organisations, companies in the robotics industry and companies within the different market sectors need to collaborate more closely. Through cross-pollination, we can integrate the different technologies and link them to market sectors. Only then will we be able to develop concrete applications that can be rolled out on a mass-market basis.

The new generation of robots can support us, assist us and collaborate with us. BOM offers support and assistance in order to bring these robotics projects to full maturity, working together with companies and institutions. We are developing new markets, forging collaboration and investing in start-ups and growing innovative enterprises.

Brabant would like to work with you to harness the opportunities provided by the robotics market.

[18] *Part of Smart industry (www.smartindustry.nl/fieldlabs)*

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