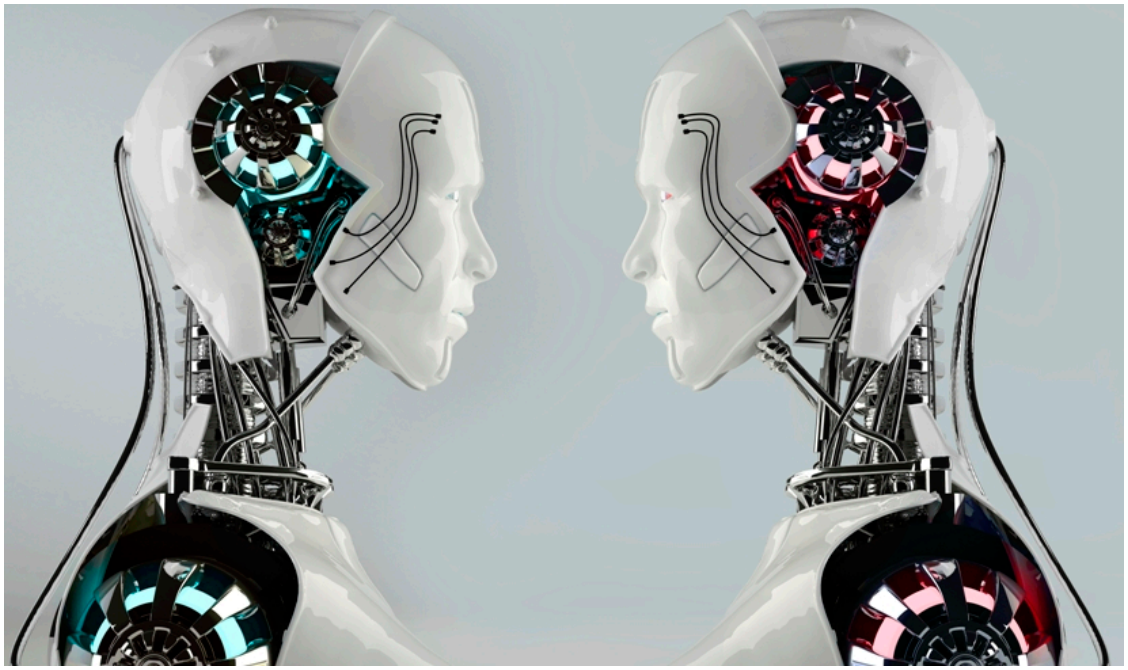
Rijksdienst voor Ondernemend Nederland



Robotics in the Netherlands

SHADANA
INNOVATION MANAGEMENT & CONSULTANCY

PREFACE

Robotics is an enabling industry that offers new opportunities in both the industry and the service sector. This report outlines the global trends and the current Dutch areas of expertise.

By connecting the two we get a better insight which topics are most promising for the Netherlands to create jobs and business opportunities for the Netherlands. This report will provide the basis to define the Dutch value proposition on robotics, which will be actively promoted through the foreign network of the Dutch government to generate awareness and leads.

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Summary

Robots have been a familiar sight in manufacturing and logistics services for a long time already. Now, rapid advancements in their dexterity and artificial intelligence will move them closer and closer towards our daily life, at home and directly interacting with customers.
Robots have the potential to enhance the way our technology interacts with us, increase productivity and create more freedom for humans to engage in creative thought, learning and leisure. Over the coming decade, robots will enter your office, your street and your home. As with all new technology there are significant benefits to be gained by successful early adopters.

In this report, we **define robots as "embodied artificial intelligence", or more simply phrases machine that can *sense, think* and *physically act* – all in complex environments**.

The big trends in robotics are the new technologies like handling big data by analyzing a huge amount of data, artificial intelligence, variable impedance actuators and the extreme connectivity through the Internet of Things. These big trends have impact on the development of the robot and the rapid advancement, like the sense, think and act part of the new generation robots. New type of robots like collaborative robots, swarm robots, autonomous unmanned vehicles, drones and advanced traditional robots will emerge from the market to the consumer. (**Technology —> Application —> Market —> Consumer)**

Two technological milestones have been set: collaborative robots based upon standard robots equipped with tested and proven controllers have demonstrated their readiness for routine use in the industrial environment and the introduction of high-payload robots capable of handling items.

The scientific challenges require cross-disciplinary research on technological and social aspects. The Dutch research community is well positioned to lead this field of research, with institutes on the forefront of mechatronics, control, machine learning, artificial intelligence, interactive robot-human systems, neuroscience, neurobotics and bio-inspired robotics.

This report identified the value chain of knowledge holders, system integrators and original equipment manufacturers (OEM) in the Dutch robotics landscape and shows that the new generation of robots offers significant new business opportunities.

The value is added to the chain by:
- Transferring the technology developed at the knowledge holders from research to the industry
- Knowledge holders starting a start-up
- Manufacturing robots and systems from components
- System integration and adaptation in different sectors
- Open innovation platforms and fieldlab facilities
- Product delivery to the market

This report aims to give a brief overview of what the Netherlands can expect in terms of trends, recent developments, and growth potentials for the Netherlands.

What is the approach?

The approach to the study of this report is a combination of desk research and expert consultation.
During the desk research, both important literature and the internet were analyzed.
The expert consultation was organized through interviews, site visits, a survey, discussions and consulting the Dutch robotics networks.

The consortium of partners are:

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Part I: trends, developments and growth

Technical trends and developments

Many technical factors and developments have contributed to the current innovations and growth in the field of robotics. A general trend that contributes to almost all of the innovations is the use of techniques from the field of artificial intelligence (AI), big data science and Internet of Things. The new skills that robots can get by using these techniques, robots have evolved from simple pick & place robots in factories to more complex systems, operating in different fields.

With the rise of embodied AI, the field of AI is changed: AI shifted from being about thinking to being about moving objects, robots. During the industrial revolution people started to work in the service sector, because machines replaced them in the factories. Robots seem to develop in the same way, while factory robots are still further developing there are also more and more robots that fulfill tasks in the service sector including social robots, who have different requirements that they should meet. In this field you see more humanoid robots, mimicking human behavior. In order to achieve this a lot of AI techniques are needed. In parallel, robots carrying out less social tasks become more sophisticated by using AI techniques.

This trend is not only seen in robots but also in robotics in general. One important development that enabled many innovations in the field of robotics is the use of the internet, robots can also use the internet nowadays which created many new possibilities that were not possible before the internet was so commonly used. One of the examples of this is the Internet of Things, in which conventionally offline appliances (like fridges or cars) are now connected with each other, allowing communication between them.

In this report, we **define robots as "embodied artificial intelligence", or more simply phrases machine that can *sense, think* and *physically act* – all in complex environments**.

Robots are systems that integrate multiple techniques of those 3 topics, in which there are different technological trends, coming from the field of AI:

- ***Sense:*** robots are able to see or observe things (vision) in a visual way with different techniques such as (3D)-cameras, infrared or laser. Technological trends that belong to this topic are:
    - Computer vision includes many different techniques that are important when working with vision in robotics, some highlighted techniques:
        - Object recognition; allowing robots to recognize objects and direct their actions towards these objects.
        - Image processing; allowing robots to gather information from an image, not only classifying the image but also information that is in the image (for example who is on the picture, what is the context, emotions etcetera).
        - Robots do not only perceive things in 2D, but there are also 3D-sensing techniques used, for example in self-driving cars and drones.
        - In medical robotics there is a trend to couple the robotics to medical image technologies such as MRI and CT. In this case the robot vision is based on these techniques and the robot must be capable of interpreting these images. Integrating (different) vision techniques in the treatment of a patient is an important trend in the medical sector.

    - Natural language processing is used in current robotics. It allows users to communicate with robots via natural language, but it also allows the robot to use natural language sources, for example online content, to expand their knowledge.
    - Voice recognition is used to recognize (different) voices, so it can respond to its owner (for example).

- ***Think:*** in order to process the sensed (observed) information thinking is needed, current robots do not only think, they also learn from experiences in order to improve their behavior. Technological trends that belong to this topic are:
    - Machine learning, which is often used in combination with deep learning algorithms and neural networks. These techniques process the information that is seen and learn from previous experiences. Deep-reinforcement learning arose from deep learning algorithms.
    - Cloud robotics is a very important trend that boosts the thinking and learning of robots. By using the cloud the computation power of a robot is no longer constrained. Also sharing knowledge between robots is easier.
    - Data mining techniques are used to process the information that a robot has, whether this comes from the cloud or from the observations made.
    - Probabilistic reasoning and predictive models are used to predict and calculate changes of upcoming events. This is also important for the mobility of robots (see 'act').

- ***Act:*** based on the sensing and thinking the robot will perform a certain action, current robots are not exclusively acting in a physical way, they are also capable of acting with speech or a combination of speech and physical actions. A technological trend that belongs to this topic is:
    - Mobile robots: robots are becoming more mobile (moving around – wireless-), this is also seen in drones. Some of the above mentioned techniques contributed to the improvements made in the mobility of robots and drones. For example learning techniques: used to learn robots to walk instead of preprogramming it, which makes robots more capable of adapting to the environment, a very important skill needed when walking. Besides mobile robots there are also autonomous vehicles which are at rise. These vehicles combine all the components of the holistic approach to AI here: sensing, perception, learning communication and action.

The following trends have been caused by the technological trends mentioned above:

- Robots are becoming more autonomous. This is due to techniques such as machine learning, enabling the robot to learn and decide without human intervention. But also due to the improved mobility of robots, allowing them to be more autonomous in their movements.
- Techniques such as computer vision, machine learning, deep learning, probabilistic reasoning and decision making have contributed to new opportunities in autonomous behavior (i.e. replacing humans) but also for human-robot interaction. Current robots can interact with humans in a more human-like manner, such as via speech or gestures, or even be trained by having a human worker demonstrate a movement once, which the robot can then copy. Such learning by demonstration . This development is further supported by the developments in actuators.
- Both the trend mentioned above and the increased connectivity have contributed to the development of robots-as-tools towards robots-as-teammates. This has lead to the origination of a new sort of robotic applications, the so called cobots, collaborative robots. Collaboration requires physical interaction with a handling robot (the first cobots), but their functionality can be greatly enhanced by clear

communication at a higher level, or even social interaction. The first cobots were a very promising development in the robotics field, and have led to the Baxter Robot to aid in . Collaborative robotics triggers different other developments, concerning ethical and legal changes that have become necessary. Robots will take another role in many processes and both we humans as well as the law needs to adapt to this new role.

- Early robots where only capable of executing one task. Current robots are capable of carrying out more complex tasks, consisting of many different subtasks, as well as being used for different purposes.
- Medical devices that were conventionally seen as 'stupid' devices are now personalized with the use of techniques mentioned before. Due to this these devices have developed into 'smart' robotic devices.

Growth potentials

The robotics market is expected to grow exponentially in the coming decades. Robots have the potential to enhance the way our technology interacts with us, increase productivity and create more freedom for humans to engage in creative thoughts, learning and leisure.

Rapid developments in cheap and powerful sensors, as well as the exponential growth of computational power (‘Moore’s Law), lead us to believe that the ‘sense’ and ‘think’ technologies have the most growth potential.

This growth will be driven partly by the first generation of robots which, since the seventies, focused on ‘manipulation’ in highly standardized environments and have been used to replace human workers in factories and warehouses due to their superior speed, precision and reliability. The second generation of robots added ‘perception’ and ‘navigation’ to their functionality. Currently, the third generation of robots will have next to ‘manipulation’, ‘perception’ and ‘navigation’ as functionality, also ‘cognition’ and ‘collaboration’.

Therefore , the development of robotic technologies can be distinguished in five distinct application areas: Manipulation, Perception, Navigation, Cognition and Collaboration.

The fastest growth of robots in the Netherlands is expected to occur in the medical/health (MedTech), industrial and agrofood domains. Looking at the application of robots in the Netherlands the robot density according to the IFR report (2015) per 10.000 employees is 107 (in 2014), which is above the global average of 66, this makes the Netherlands the 15th country, looking at the robot density. Among the countries that score higher on robot density are neighbor countries Germany and Belgium.

In 2014, the supply of industrial robots increased from 895 units to 1.234 new installed robots. This is 38% more than in 2013. CAGR 2010-2014: + 25%.

In this section some growth potentials are highlighted: sectors, systems and technologies.

Sectors
In all sectors there is growth potential. The robots will now enter new sectors in which they have not entered yet due to decreased costs and improved safety. Also the decreased costs of robotics will lead to less work outsourcing by companies, which will create new jobs in the Netherlands. Another reason why the robot will find its way to new sectors is that there is more acceptance and trust in robots due to improved accuracy.

Robotics has great growth potential in sectors with low skilled labor taking over relatively easy tasks. On the other hand robots will be used for complex tasks, for example in the care sector where they can be used by surgeons. Because of the technical developments robots are also capable of performing tasks in the service sector, which will be further boosted by more technical developments. Also in the field of consumer robotics there is growth potential (e.g. connected devices, vacuum cleaning robots). Other sectors in which robotics has growth potential are: education, industry, agro & food. One of the reasons why robotics has growth potential in these fields is cost savings. Another important reason is that robots can offer more precision, accuracy and 24/7 availability, which reduces not only costs, but also risks and loses in industrial or medical processes.

Systems
Systems with growth potential are systems for robotic inspection, assuring more precision and/or taking away risks for humans. Also self-driving cars, safety systems and drones have growth potential, both for consumers and industry. More and more systems will have self-learning abilities and multiple robots will be integrated into one system, enabled by the improved interaction skills of the robots.

Overall systems that have a good ease of use, requiring little to no knowledge, have good potentials due to the larger population of possible users.

Technologies
On the technical side there is an everlasting request for more computation power. Also there is a big request for data of a good quality (e.g. labeled contextual data) that can be used by robotic systems, for example for training purposes. As robots are gaining mobility there is a growing demand for location determination technologies.

Research areas

Three research areas that are outside the aforementioned trends are nanobots, swarm robotics and evolutionary robotics. Nanobots are tiny robots that can operate for example in the human body. Swarm robotics focuses on small robots that work together to perform complex tasks. Evolutionary robotics is based on building autonomous controllers using evolutionary algorithms. Those algorithms are based on Darwinian principles, which is important for the different way of which they learn, compared with learning based on the aforementioned methods.

In addition to these common trends miniaturization of hardware parts such as sensors and actuators and self-powering are also developments that are important for the field of robotics.

As already mentioned there are multiple factors and developments that have contributed to the current innovations. Developments in the field of mechatronics contributed to the development in the field of robotics, which is often seen as a subfield of mechatronics. Precision and actuation have benefitted from this and developed as well, boosting robotics. Enabling new applications such as a robot for eye surgery. Commercial investments from big companies that started to invest in robotics lead to more available resources. Also the globalization of robotics due to new international players contributed to new opportunities, boosted by challenges such as the DARPA challenge. Because the hardware costs are reducing new applications of robotics became possible. Also the development of cheap mass products for the gaming/entertainment industry have contributed to this. Robots are also getting integrated in domains such as virtual reality. Besides lower hardware costs also the costs for the configuration have decreases due to the improvement of the software used, this also improved the skills of the robots. Nowadays robots are no longer very expensive things, they are also affordable for

personal purposes, which also gave a boost to the field of (personal) robotics and the increasing popularity of drones in the civilian sector.

It is important to note that there are many dependencies between the trends. Innovative solutions are created with a multidisciplinary approach combining different techniques that support and strengthen each other.

Societal trends and developments

There are not only technological trends and developments in the field of robotics. There are also societal trends that change the field of robotics. The technological trends and developments have also societal implications. These will be shortly discussed here without going into ethical details.

Due to the changed application possibilities of robotics we now have more robots in our own environment. This asks for adoptions in the way we interact with our environment and how we think about robots in our environment, as it is no longer deniable that they are in it. This is further supported by the changed interaction with robots. As discussed in the section about technical trends and developments, cobots are at rise.

There are also changes in the demand for labor due to the developments in robotics. Since the ease of use has improved over the years the need for specialists has declined. Robots can also work in dangerous environments, taking away risks, but possibly also labor demand, in certain sectors. Robots are already taking over heavy and repetitive work in industry and agriculture and will continue to do this, even on a larger scale in the future.

Type of robots

Autonomous Cars

Two applications that bring most of the trends and developments together are highly-automated cars and drones.
Cars are increasingly getting more ‘intelligent’ employing sensors and advanced techniques to improve vehicle dynamics, assist the driver, or even intervene or partly automate subtasks (such as speed control, car-following, parking). There is a strong media-fueled vision towards fully autonomous driving, meaning that car should be capable of driving itself always and everywhere, without any need for the driver to intervene, essentially making the driver a passenger and allowing traffic to be optimized. If this vision becomes reality, it would have huge benefits in throughput, fuel economy, safety and freeing up time to spend relaxing or working.
However, most experts agree that this vision – despite its attraction – is not very realistic in the near future, since it imposes extreme demands on the system in terms of technical reliability. Therefore, for the foreseeable future cars will most likely be only be partly automated, and human drivers need to supervise the partly-automated vehicle. This makes it not merely a technical challenge, but also a huge human factors challenge: how to foster mutual communication and interaction between the driver and the intelligent vehicle?
Regardless of what will happen in the near future, intelligent vehicles form a strong example of current robotic challenges: the robot’s ability to sense, think and act; and the need to understand how robots should interact with humans in unpredictable environments. This raises not only technical questions (how to best sense, how to allow the robot to interpret the environment, and how to act responsibly and reliably) and human factors questions (how to design interfaces and communication that fosters trust and intuitive collaboration), but ethical and legal questions such as: “who is responsible

in case of an accident?", "can we secure the car so that it cannot be hacked?". Finally social acceptance is needed to create a market for highly-automated cars.

Drones

Drones are becoming cheaper and more common nowadays. They also have many different possible applications and fit the 'sense, think and act' definition of robotics perfectly. Generally speaking drones can be used to move to places people cannot easily access or oversee. It is their task to 'sense' the environment they are operating in for two purposes, first of all their own navigation (for autonomous drones) and to gather data about the environment in order to perform their task. For 'think' the same can be said, both thinking about how to act for the navigation when operating autonomously as well as thinking about what is being observed. In the case that the drone is used to inspect something this will lead to an action in the form of an alert about the results found during the inspection or a warning when something is wrong. It is also possible that the drone delivers something to a certain place, in this case "delivering" is the action of the robot. In the case of autonomous drones acting is also the flying itself. Drones are becoming increasingly popular due to many reasons, among which the fact that they are getting less expensive and can move to places human cannot move to, for example disaster areas (post-earthquake, post-flooding, post-avalanche). But also in less dangerous environments drones can aid in inspecting building sites or festival areas.

Both examples show how 'sense, think and act' can come together in powerful robotic applications that contribute to solving societal challenges in transport and security.

Collaborative robots (Cobots)

A collaborative robot (cobot) is a robot intended not to replace humans in separated closed-off environments, but to physically interact with humans in a shared workspace. These robots are specifically designed to work together with humans, instructing or receiving instructions (i.e. being programmed) by interaction with workers. In contrast, regular robot are programmed to work more or less autonomously. Through more flexible machines production can become profitable at a smaller scale than before. This makes it attractive to insource and reshore activities.

Cobot can allows guide humans, allowing them to perform certain operations successfully if they fit within the scope of the task and to guide the human towards a path it sees as optimal, or stay away from dangerous no-go areas (e.g. in robot-assisted surgery). Especially in unstructured environments, the individual strengths of humans and robots need to be combined effectively. The bottleneck is not merely technical, but also results from an out-dated framework of industrial robotics, where robots are pre-programmed and interaction is avoided.
In a short term there will be an increase of so-called collaborative robots. Robots like Baxter, which is used for several projects. Baxter is a robot whose arms a human operator can grab and move around, to program it for that specific movement. These robots are inexpensive and can be used for a wide range of simple activities, such as screwing bolts or wrapping parcels.

Swarm Robots

A robot swarm is a self-organizing multi-robot system characterized by high redundancy. Robots' sensing and communication capabilities are local and robots do not have access to global information. The collective behavior of the robot swarm emerges from the interactions of each individual robot with its peers and with the environment.

Inspired by insect swarms in nature, robot swarms consist of many simple robots that collectively perform tasks. Sometimes, even a complex robot cannot perform the task a swarm can do.
Learning from nature, we can let robots cooperate to perform tasks that lie beyond their individual capabilities. Just like an ant colony can perform feats of impressive sophistication, employing a ‘swarm’ of relatively simple and cheap robots may prove a better approach than designing a single, much more complex machine. Robustness, scalability and simplicity of design gives swarming robots a great advantage. One malfunctioning robot will not necessarily prevent the others from doing the job. The individual robots should be small and simple enough to be able to exploit the advantages, yet intelligent enough to perform their task and be aware of their position and role within the swarm.

Research with swarming robots is still in the laboratory stage. Crowds of more than a thousand robots have been created, but they were used mainly to test new concepts and ideas. Some of these seem exciting as long as they are tested in the lab, an environment that, for the robots, can be simple and familiar. But working in the real world outside the lab is much harder. Nonetheless, this research is crucial to the direction automation is taking. It may profoundly change the way engineers design machines.

Part II: Robotics landscape in the Netherlands:
knowledge, expertise and application domains

The Dutch robotics community consists of different holders of knowledge (universities, companies, knowledge institutes) that each operate in one or more of the following application domains, which are strongly represented in the Netherlands:

- Artificial Intelligence (AI)
- Agro & Food
- Consumer
- Health
- Industry
- Safety

Knowledge Holders: Dutch universities

The Netherlands counts 4 Universities of Technology active in the field of robotics. Each university with its own specialties together form a complementary whole, called 4TU, capable of competing with world renowned universities like MIT, Carnegie Mellon or ETHZ.

An increasingly important link to robotics is research in the field of Artificial Intelligence. The overview (below) will include the additional Dutch universities active in this field.

Each university will be discussed in the next section.

Technical Universities

TU Delft (TUD)
(http://www.robotics.tudelft.nl/)
The technical Delft university, with a long history of multidisciplinary research geared towards transfer to (inter)national industries and education. The robotics activities are organized in the **Delft Robotics Institute** in which six different technical faculties participate, both with "hard" robot disciplines and more "soft" robot disciplines. The Delft Robotics Institute is one of the biggest robotics institutes worldwide, with a very broad range of knowledge domains, applications domains (it operates in all six mentioned domains, and more), with strong links to international industrial partners. Scientifically, the institute is at the international forefront of five research fields: bio-inspired mechanical design, robotic vision, control algorithms, human-robot cooperation and value-based design.
The multidisciplinary approach and links towards industry and society are further strengthened by **RoboValley** (for more information, see final section in Part II). The focus of the TUD is on robots that *can work together with humans*, in industrial applications, transport, care&cure.

The expertise of this university is spread over the three parts of robotics; 'sense' (e.g. robotic vision), 'think' (e.g. control algorithms) and 'act' (e.g. human-robot cooperation).

Eindhoven University of Technology (TU/e)
(https://www.tue.nl/onderzoek/instituten-groepen-scholen/robotics/)

TU/e has an interdisciplinary approach to robotics, employing High Tech Systems knowledge and a system engineering approach on one hand, that on the other hand is combined with state-of-the-art use of artificial intelligence technologies to create smart

applications. Eindhoven University focusses on the fields of medical- (care & cure), agriculture-, food- and autonomous vehicle (agv, cars, trucks) technologies. Eindhoven as a center of developments of global companies like Philips, DSM, ASML, DAF and NXP, with the highest production of patents per/square mile in the world cooperate extensively with Eindhoven University of Technology. This results in the highest achievable paper index of company-industry (Leiden CTWS industry collaboration 2015)

With student team Tech United, Eindhoven University of Technology also competes in the International RoboCup competition. It competes in the @home leagues focused on home care robots and the kings class of robot soccer (mid size league). Tech United is one of the top contenders and carries multiple European and World championship titles.

The robotics spin-off company **Medical Robotics Technologies** serves as an incubator for medical robots startups and has produced two spin-off companies so far; Preceyes and MicroSure. Preceyes focusses on robot-assisted eye surgery, MicroSure focusses on robot assisted surgery for breast reconstruction.

Besides the mentioned fields of interest the TU/e also looks at the ethics that are involved in robotics and robots in education.

All the robotic activities of the TU/e are concentrated in the High Tech Systems Center, which will be discussed in the final section of this part.

This university has their expertise in all the three parts of robotics, they need all the parts in order to compete in the RoboCup with their robots for example.

Universiteit Twente (UT)
(https://www.ram.ewi.utwente.nl/)

The University of Twente applies an integral approach to robotics in which not only the technological developments are important, but also the social, ethical, philosophical and business aspects. The primary application areas are robotics in the health sector and robotics in inspection. For example image guided interventions, in which MRI compatible vision technologies are used. But also technologies for haptics and telemanipulation, exoskeletons and/or revalidation means. The social aspect of health care is also taken into account with projects in the field of social (care) robots. Examples of robotics in inspection are the use of a robot for gas pipe inspection, and drones for windmill inspection through touch. The UT has initiated LEO Robotics as the accelerator for the partnership between academia and industry, which will be discussed further in the last section.

Technologies that are needed for this and belong to the focus of the UT are: variable impedance actuation, mechatronics, control and inspection techniques and drones.

The expertise of this university is mostly in the 'sense' and 'act' side of robotics.

Wageningen University (WUR)
(www.agrofoodrobotics.nl)

Agriculture and robotics. Intuitively they hardly seem to match. But appearances can be deceitful. For agriculture worldwide faces tremendous challenges, think of food production, climate change, animal welfare. To meet these challenges, the possibilities of robotics can hardly be ignored.

That's why scientists from Wageningen UR have been working with agrorobotic solutions for decades. Within the field of robotics, they have their own approach; where others

develop robots first, and then search for an application, at Wageningen UR however the process starts with the need for innovation. This may lead to a solution that requires the use robotics. The development of new technology starts from there. Driven by a solid team of technicians and scientists, often together with external partners.

Agro Food Robotics is a joint initiative by several research groups of Wageningen UR. It has been set up to provide the technology and knowledge needed by producers and suppliers in the area of agro food robotics. Agro Food Robotics has a large network with universities, knowledge organizations and engineering companies within and outside The Netherlands and therefore plays a pivoting role in the coordination of supply and demand of knowledge and technology.

Universities with robotic research oriented towards computer science

Radboud Universiteit Nijmegen (RU)
Radboud Universiteit Nijmegen (RU) (http://www.ru.nl/icis/)

The Donders Institute or Brain, Cognition and Behaviour at the RU is a world-class research centre devoted to understanding the mechanistic underpinning of human cognition and behavior in health ad disease. This sort of knowledge is useful for the research to humanlike interaction/behavior with/of robots.

Rijksuniversiteit Groningen (RUG)
(http://www.cs.rug.nl/)

The RG has a very good computer vision department. Their knowledge about computer vision can be of big use for robotic applications of other parties.

The expertise of this university contributes to the 'sense' side of robotics with their computer vision techniques.

Universiteit van Amsterdam (UvA)
(https://www.uva.nl/en/disciplines/computer-science)

The UvA is not a technical university such as Delft, Eindhoven, Twente or Wageningen. Their focus is not so much on the technological side of robotics. The focus of the UvA is on the computer science aspect, with a high quality machine learning department.

The expertise of this university is on the 'think' side of robotics, enabling the robots to learn through machine learning techniques.

Universiteit van Utrecht (UU)
http://www.cs.uu.nl/)

The UU is also not a technical university and its quality is in the computer science that can be used for robotics. Especially their quality is the modeling behind industrial and medical applications.

The expertise of this university is on the 'think' side of robotics, creating the models used for the robotic thinking.

Vrije Universiteit (VU)
(http://www.cs.vu.nl/en/index.aspx)

At the VU there are 3 different robotics topics to which research is being done: social robots for elderly people, evolutionary robotics and the development of computational intelligence.

The documentary "Ik ben Alice" is about social robot Alice, a research project by the VU. The research is about the interaction between elderly people and a social robot like Alice. Also start-up Tinybots, a spin-off of the VU, is developing a social robot for elderly people, being a personal assistant for people with dementia.

Professor G. Eiben researches evolutionary robotics, a field that can be divided into 2 categories: evolving the controller ("brain") or evolving both the morphologies ("body"/hardware) and the controller. In the latter a breakthrough is made, in May 2016 Eiben showed the first robots that can create physical robotic offspring, by exchanging DNA codes in an evolutionary manner, both in terms of software (AI) and in terms of hardware (using a 3D-printer).

The themes that are included in the research that contributes to computational intelligence are: smart learning (machine/deep learning), knowledge sharing, personalization by analytics and internet of things

The expertise of this university is on the one hand on the social interactions of robots with elderly people but on the other hand it is in the knowledge about evolutionary robotics, which is about all the different aspects of robotics. The knowledge about computational intelligence is part of the 'think' side of robotics.

Dutch companies
Dutch companies have an important role as holder of knowledge. They are the parties implementing robotics outside the research environment and have capacities to further develop their technologies. The most important holders of knowledge are the start-ups. Students that have just graduated or finished their promotion often start working at a start-up. These start-ups have state of the art knowledge and have a good relationship with universities. This makes them very important holders of knowledge in the Dutch robotics landscape.

The Netherlands has many different companies that are active in the field of robotics, these companies can be sorted on their application area but all companies have their expertise. In the following sections for each application area the expertise of the Dutch companies will be summarized. At the end of this section there will be a list of Dutch front runners, companies operating in different application areas offering unique or innovative technologies.

AI
AI techniques play a big and important role in the current field of robotics, as became clear in part I. Companies in this sector offer solutions that can be used for robotic systems, but generally they do not deliver robotic solutions themselves. AI companies are the specialists in fields like machine learning or big data techniques (e.g. data mining and data analysis) or a combination of both. Their expertise can, and often is, used by third parties developing a robot.

Agro & Food
This sector is quite big because it includes both the food industry and the agriculture sector. The Netherlands is a global market leader in the export in the agrofood sector. Most of the companies in the food sector focus on automating a process in the sector

such as packaging, sorting and processing including peeling and cutting. The companies each have their own field of focus such as meat, eggs and vegetables. Important innovative robotic techniques used in the food sector that the Netherlands has to offer besides this are automated grading of fresh food and vegetables, milking and automated slaughtering.

In the sector of horticulture different Dutch companies are active, for example in the field of covered horticulture, environmental control for horticulture and automated production lines.

The current developments in the robotics for agro & food sector will probably change the sector in the future. As the demand for food will, globally, increase in the future, new, more effective, ways of working are needed to keep up with the food demand. This will cause changes in the way that agrofood companies are arranged due to the new possibilities robotics will bring.

For the aforementioned systems different technologies that have been mentioned in part I are needed. The expertise of the companies in this application area is in:

- Sense: using sensors in order to grade different objects (food, plants, flowers etcetera)
- Think: multiple AI technologies to process the data acquired by the sensors.
- Act: mechatronics enables the actions that the systems can carry out.

Concluding, the robotic applications in the Agro & Food sector are mainly focused at the processing of food. There are different companies active in this sector in the Netherlands, each having their own focus on a process, a process part or a certain field of focus. In the horticulture there are also some leading companies but the main focus in the agro & food sector is on food processing. The expertise of this application area is in the sensors, AI and mechatronics that is at the foundation of the aforementioned systems.

Consumer

This sector is not very present in the Netherlands. Although internationally there are (big) companies that develop and sell consumer robotics the Netherland does not take an outstanding role in this. Philips does sell vacuum cleaning robots, but there are also many other international companies selling these. This is one of the few examples of consumer robotics made by a Dutch company.

Health

Health concerns both the care for (needy) people as well as curing people. This division is also seen in the robotics field in the Netherlands where there are both socially oriented robots focusing on the care aspect of health as well as more technical oriented robots helping with the cure aspect via surgery or revalidation support. Due to the aging of the population in the Netherlands the costs for healthcare are increasing. This often leads to debates about the budget cuts. With the help of robotics different companies try to improve this situation.

Most of the companies in the Netherlands that focus on the care aspect of health care have robotic solutions that help elderly to stay independent for a longer period of time, so that they need less intensive health which saves costs. Other companies focus on social robotics that can be used for different purposes: accompanying (lonely) elderly or people with dementia, but also to teach (children) (for example with/about diabetes). Assisting technologies can help disabled people to be more mobile or independent, for example a robotic arm integrated on a wheel chair allowing a disabled to use multiple arm functions. Other technologies focus on keeping elderly active and support their daily rhythm, improving their health and independence, reducing their care need. In this field

there are still a lot of developments going on, further improving and extending the possibilities of those social robotic applications.

Another field of care that uses robotics is revalidation. Robotic aids can be used to assist during revalidation or permanently for people with a disability. Mostly these techniques still assist the human therapist, but the developments are towards systems that do not need a human trainer.

As mentioned before there are also robots that are developed for cure purposes. Robotics can assist, or even replace, humans in different cure tasks. Robots can be used in order to add precision, to reduce the risks of human mistakes or to reduce the risk for the human (for example reducing exposure to X-rays).

Most of the companies and projects in this field focus on robotic assistance to improve the precision of (minimal invasive) surgeries. With the high level of precision that is possible by robotic assistance new surgeries become possible. Some companies working in this field focus on the general precision technique, other companies focus on a specific health tasks, for example eye surgery.

For the systems different technologies as mentioned in part I are needed. The expertise of the companies in this application area is in:

- Sense: Sensors are important to measure and gather data in the environment of the different systems, for social robots this is needed to assure a human-like interaction, revalidation systems need to measure different things in order to give feedback and surgeon robots need to have very precise information from the sensors.
- Think: AI techniques are needed to process the data gathered by the sensors. Learning techniques are important to further improve the systems based on feedback, for example social robots need to learn in a human-like way. Also recognition of patterns in the data is important.
- Act: mechatronics is important in order to enable the movements of the robots. What these movements are really differs per robot. Precision technologies are very important for the surgeon robots.

Concluding we see that the health sector is a divers and big sector. Mainly on the care side we see advanced technologies being used to mimic human social behavior, fulfilling a task normally carried out by humans. On the cure side on the other hand we see that the accuracy of the technology enhances the performances of surgeons. The expertise of this application area is in the sensors, AI and mechatronics that is at the foundation of the aforementioned systems, precision techniques are very important for surgery robots.

Industry

Robots have been used in the industrial sector for long time, first they were mainly used for pick & place tasks but their tasks are evolving. The sector industry is a collective term for all the robotics used in manufacturing, material handling, logistics and maritime. Most of the companies that focus on this sector produce automations for manufacturing processes. Sometimes this is concentrated on a specific sector, other companies deliver more general solutions. Besides the automation of manufacturing processes there are companies that focus on logistic AGV systems, packaging and industrial robot arms. Important for companies to be outstanding in this sector is offering the client flexibility, for example by offering the robots per hour (as temporary employees) or, more often, by ensuring easy reprogram ability.

In order to create autonomous systems for manufacturing processes different techniques mentioned in part I are needed. The expertise of the companies in this application area is in:

- Sense: systems need to have sensors to gather information about the products they are processing in real-time.
- Think: AI techniques such as machine learning are needed in order to process the data gathered by the sensors and make decisions based on this.
- Act: mechatronics is important to enable the systems to perform the needed actions.

Concluding, the companies in this sector focus on the automation of different processes. Flexibility plays an important role in this sector. The expertise of this application area is in the sensors, AI and mechatronics that is at the foundation of the aforementioned systems.

Safety
Robotic solutions can be used in the safety sector in different ways. They can assist or take over certain maintenance and inspection tasks, improving the safety of different processes. The reason that robotics is used for this is comparable to robotics for curing purposes: they offer higher precision or encounter less risks for certain tasks. Companies that operate in this field have different targets. There are companies that deploy drones with an inspection purpose for different sectors. There even is a company using a robotic bird to scare real birds, for example to improve the safety of airplanes. These sorts of technologies contribute indirectly to more safety, but on the other hand there are companies that offer solutions that are more directly focused on improving the safety for specific tasks or sectors.

For the aforementioned systems different technologies that have been mentioned in part I are needed. The expertise of companies in this application area is in:

- Sense: sensors can be used to gather real time data both about the state of the system itself (for example the location of the drone) as well as about the environment.
- Think: AI technology is used to process the gathered data.
- Act: mechatronics is needed to enable the movement and reactions of the systems. The systems will also act in a non-physical way, for example by giving warnings.

Concluding, robotic solutions for the safety sector are very different. On the one hand there are robotic solutions improving the safety in a certain field by inspection and on the other hand robotic systems that directly contribute to more safety. The expertise of this application area is in the sensors, AI and mechatronics that is at the foundation of the aforementioned systems.

Other knowledge institutes

Next to the Dutch universities and companies there are other knowledge institutes that hold knowledge for or about the Dutch robotics landscape. This can either be because they do research to robotics itself or research technologies. There are also institutes bringing different parties together. This section will summaries which institutes hold which kind of knowledge.

TNO *(https://www.tno.nl/)*

TNO (Nederlandse Organisatie voor toegepast-natuurwetenschappelijk Onderzoek TNO) is one of the major contract research organizations in Europe. With a staff of approximately 3000 and an annual turnover of 450 million Euros, TNO is carrying out **applied research** in order to achieve impact on the following seven themes: Healthy Living, Industrial Innovation, Transport and Mobility, Energy, Urbanization, Information Society, and Defence, Safety and Security.
TNO functions as an intermediary between basic research organizations and industry. By translating scientific knowledge into practical applications, TNO contributes to the innovation capacity of (small, medium, large sized) businesses and government. TNO is involved in many international projects (about 30% of the market turnover), including EU-funded collaborations.

TNO Robotics
TNO has been active in Robotic and Autonomous application research for several decades. The fields of use and applications of the robotic solutions and technologies is very wide, such as subsea remote controlled and autonomous robotics, space robotics, industry and health care robotics. The role of TNO in many cases is to create a multi-disciplinary team to solve **technical and societal challenges** for Robotic applications. The following knowledge and technology areas within TNO have strong impact and application in robotics:

- **Sensing and localization** (optics, radar technology, acoustics and sonar, intelligent imaging)
- **Perception** (intelligent imaging, Holst, perceptual and cognitive systems)
- **Cognition** (perceptual and cognitive systems)
- **Human Robot Interaction** (perceptual and cognitive systems)
- **Integration** (Societal: sustainable productivity and employability, System: opto-mechatronics)
- **Smart materials** (equipment for additive manufacturing)

RoboNED
(http://www.roboned.nl/)

RoboNED is trying to better understand how robotics in the Netherlands could be shaped in order to yield an ecosystem able to address these goals. RoboNED was born as one of the ICT Innovation platforms in 2010 and intended to deliver a Strategic Agenda with an analysis and concrete suggestions on how to achieve the goals to connect industry, government, science and education.
This Dutch platform for robotics brings the different parties in the robotics sector together.

TU Delft Robotics Institute
(http://www.robotics.tudelft.nl/)

In TU Delft Robotics Institute over 170 researchers work together in the field of robotics. Almost all faculties are involved. The vision is to introduce novel robotics technology that will enable robots to work together with humans in human environments, contributing to all kinds of services and labor beyond ‘confined’ industrial environments.
The mission is to perform interdisciplinary research in a coordinated fashion to address all the aspects of modern robotics, including the non-technical aspects. Areas of expertise are bio-inspired robot design, human-robot interaction, functional decomposition, cybernetics, spatial presence, autonomous control and machine learning.

By uniting the various disciplines in a user-centered research approach within one TU Delft Robotics Institute, the robotics challenge can be approached on a systems level. The result is reliable and productive robot systems with the appropriate behavior, context and human interaction. This will bring the Delft University to a globally leading position in the much promising robotics arena.
Three strong themes have been chosen around which collaborative interfacultary research will be organized. The themes are based on on-going activities with momentum, are linked to regional strengths and fit within the National & 3TU context. These themes are: 1. interactive robots (robots for diagnostics and supported living), 2. swarm robots (collaborating satellites and UAVs for ship tracing, pollution and traffic monitoring), and 3. robots that work (distributed interactive work support, o.a. for robot support in warehousing, greenhouses and food production).

RoboValley
(http://robovalley.com/)

In RoboValley, more than 170 robotics researchers from a multitude of fields collaborate with other experts, entrepreneurs and decision makers in both public and private sectors. As a result, a unique network is thriving, with TU Delft Robotics Institute at its heart. Therefore, RoboValley takes a leading role in the development of the next generation robotics.

The RoboValley programme team helps companies or start-ups that want to settle in Delft. We do so by connecting companies with automation wishes to the right experts. We help attract investors: via the RoboValley Investment Fund we offer venture capital and accelerated paths to the market for the most promising robotics technologies.
Finally, we help companies and researchers in RoboValley to receive exposure and visibility. Companies that are settled in RoboValley love the fact that they can encounter the employees of other robotics companies in the hallway and discuss problems. Because RoboValley is all about communication: knowing each other's activities and being facilitated in cooperation.

LEO Robotics
(http://leorobotics.nl/)

LEO is a partnership between academia and industry in the Eastern Netherlands. LEO acts as an innovation and business accelerator for the robotics ecosystem by strengthening the network, promoting visibility, engaging the societal discussion with politics and the general audience, and exploring international collaborations.

HighTechXL (supported by Eindhoven Startup Alliance)
(http://www.hightechxl-plaza.com/)

Dutch private and public sector organizations have formed the Eindhoven Startup Alliance support HighTechXL in its mission to create at least 20 high-growth hardware companies by the end of the decade. HighTechXL is a startup accelerator with different acceleration programs covering all the phases of the development of a prototype of the market entry and support afterwards. They are located in Eindhoven, together with the High Tech Campus Eindhoven which is globally known for its high-tech innovation.

High Tech Systems Centre (HTSC)
(https://www.tue.nl/en/research/research-institutes/top-research-groups/high-tech-systems-center/)

This centre brings together four high-level industry technology themes: hardware and system design, model based design, advanced precision control and disturbance & environment uncertainties. Bringing together different research fields and researchers of different levels. HTSC also has different strategic partnerships with the industry.

At the TU/e and UT a "free zone for robots" is being worked on. In this zone robots will be able to work without any barriers, in order to facilitate research to the integration of robots in different environments.

Open Innovation Platform

i-Botics (TNO and UT)
An important challenge in robotics is to fully exploit and scale the combination of the cognitive- and motor intelligence of humans with the power, speed and accuracy of robotic systems. This forms the focus of the Joint Innovation Centre i-Botics, which is a collaborative initiative of TNO and University of Twente. I-Botics is an open innovation centre in which researchers of TNO, UT and (industrial) partners will perform research and development with a dedicated research agenda.

TNO focuses primarily on the **telesensing** and **situational awareness** around the robotics to develop value adding **telerobotics**. Examples are the telepresence unit developed for the Royal Netherlands Army EOD robot and the Remote Vision Tanker System for the Royal Netherlands Airforce. TNO has been or is involved in several projects where **exoskeletons** are researched and developed to support (disabled or partially disabled) humans in various tasks (such as lifting heavy loads.

The current state of the art is restricted to partial solutions for instance telepresence with sound and vision but without haptics, control algorithms optimised for a single modality, and dedicated hardware that is non-modular and non-scalable.

The lines of research foreseen in this R&D initiative are of great relevance for inspection and maintenance. There are two main advantages when implementing robotics for this domain. The first is the large amount of money that could be saved if installations do not have to be shut down, in order for inspection and maintenance to take place. The second is the safety of personnel; inspection and maintenance is often a dangerous, if not impossible, task for people. The main requirements for the application of robotics in this domain are efficiency, reliability and safety. It is expected that telerobotics will become more and more present in this domain in the coming five to fifteen years.

Robotics Experience Center

Robotics Experience Center by ESPS in Almelo. An open lab in which one can get acquainted with the latest developments in collaborative bots and Industry 4.0. Companies and research institutes can come for inspiration, experience, ideas for projects and business cases for industrial cobots.

RoboEarth door de TU/e (FP7)

Building an Internet for robots: a worldwide, open-source platform that allows any robot with a network connection to generate, share, and reuse data.
http://roboearth.org/
Technische Universiteit Eindhoven, Philips NV, University of Stuttgart, ETH Zürich, University of Zaragoza, Technische Universität München, Universität Bremen

STW
Technology Foundation STW realises the transfer of knowledge between the technical sciences and users. It does this by funding excellent technical scientific research and by bringing researchers and users together in each project.

About 55 million euros of STW's budget comes from the Netherlands Organisation for Scientific Research (NWO) and the Ministry of Education, Culture and Science (OCW), 22 million euros from the Ministry for Economic Affairs (EZ), 10 million euros from third parties and 14 million from cash co-financing by companies participating in research projects. In addition to this the partners make in-kind contributions to the research.

Facilities and field labs

Unmanned Valley Valkenburg
Test Centre for unmanned innovation. It is uniquely capable of allowing tests beyond the visual line of sight over the North Sea. It is within 30 minutes from drone manufacturers, as well as leading research institutes like TU Delft, University of Leiden, and the European Space Research and Technology Centre. Finally, Valkenburg is accessible to international parties through its close proximity to Schipol Airport.

The Green Village
The Green Village's goal is to accelerate the development and implementation of radical innovations. by bringing together everyone who needs to be involved – scientists and engineers, businesses, the public, and government – at an inspiring place where innovations can be developed, tested and demonstrated by these partners. In some cases innovations will benefit from government "switching off" some regulations. In real-life setting, a true living lab at Delft University of Technology that is open to anyone.

Smart Industry program
The Dutch ambition is to join the frontrunners and gain a strong position within that group. The Dutch industry has every chance to succeed in this challenge and further action to support this will be aligned with top sector policy. The Dutch business community – large and small – holds all the keys to engage with this promising development and to join forces with the frontrunners. The Netherlands has a strong tradition of collaboration in networks and clusters. Add to this world class ICT infrastructure and 93% internet penetration in households and it becomes evident that the Netherlands are poised to play a leading role in Smart Industry.
http://www.smartindustry.nl/

http://smartindustry.kennispark.nl/fieldlabs/smart-welding-factory/

Sprint Robotics

SPRINT Robotics Collaborative. The SPRINT Robotics Collaborative aims to achieve field use of robotics for inspection and maintenance of capital intensive infrastructure assets on a very large scale within the next ten years. Using robotics in the domain of technical inspection and maintenance of capital intensive infrastructure is of vital importance because of the urgency to minimize the impact on safety and the environment. http://www.sprintrobotics.org/

Summary of the Dutch Robotics landscape

There are many different holders of knowledge in the field of robotics in the Netherlands. Universities that are important for robotics due to their research. Companies are getting their knowledge from universities and some are working together with the universities and help creating start-ups.
Some universities specifically focuses on robotics, e.g. TU/e and UT, other universities their excellence is in a specific computer science, ethics or artificial intelligence topic that can be used in robotics. Start-ups that originate from the universities often have the most state-of-the-art knowledge and because of their often close relationship with the universities their knowledge keeps up-to-date.

There are also numerous robotics companies in the Netherlands, each with their own focus on a certain sector, or specialized sectors. Between the companies a similar division as between the universities is visible, some companies deliver robotic solutions, other deliver technologies that can be used in robotic applications.

The Netherlands has excellent expertise in some specialized fields, such as precision techniques, these technologies needs to be integrated within different technologies. Robot network such as RoboValley (powered by TU Delft Robotics Institute), RoboNED, LEO Robotics and High Tech Systems Center try to improve the Dutch situation by bringing different parties together and providing a robotics platform for the different parties in the Dutch robotics landscape.

<u>Agro & Food</u>
Most important robotic system in this area is a processing system, for example processing tomatoes, deciding which tomatoes can be sold and pack them for transport. For such systems the robot abilities can be described as follows:

- Configurability: most systems in this field are programmed for a certain task. Often when a whole process is being automated the system consists of different robots, these can individually be replaced or altered/updated in most cases.
- Adaptability: the systems need to be flexible in recognizing different objects. Processing robots need to recognize a certain object, that can occur in many different forms and shapes. The robot needs to be able to handle the high variety of appearances and environmental factors such as lightning. However the task the systems need to perform are static.
- Interaction ability: the systems don't have an advanced interaction ability such as speech.
- Motion ability: most of the systems perform a repetitive task
- Perception ability: see adaptability
- Decisional autonomy: the systems have a great autonomy, making decisions about which objects are "good" and which are "bad"
- Cognitive ability: the systems have a limited cognitive ability. As discussed above they are mostly specialized on a certain task and only need flexibility for the recognition of objects. Also the way the system interacts with humans is not very cognitive demanding.

A SWOT analysis of the sector:

Strengths: the Netherlands has traditionally a leading role in the agriculture internationally. Robots are becoming more economically feasible and have the potential to solve the issue with the shortage in labor demand that is expected to increase in the upcoming years.	**Weaknesses:** the available technology is still not suitable for every process in the agriculture sector. Different companies develop comparable systems, but for different purposes, there is often a lack of collaboration that could strengthen and speed up innovations, also due to the larger financial possibilities.
Opportunities: Improve collaboration between different holders of knowledge and companies. The large demand and need for food.	**Threats:** Too little collaboration and financial possibilities.

Health

- Configurability: assisting robotic devices are often the most configurable robots (in this sector), it is easy to alter these devices to make them more suitable for the situation of the user.
- Adaptability: social robots need to adapt themselves in order to learn about behavior in a humanlike way.
- Interaction ability: some of the robots used in the health sector, e.g. surgery assistants and revalidation/assisting robots, interact with the user via movements. Social robots on the other hand interact with the user in a more humanlike way, e.g. via speech.
- Motion ability: the motion ability of each robot is very different. There are assisting devices, such as robotic arms and exoskeletons that have a big motion ability. Also many of the social robots have the ability to move, however their strength is more in the 'thinking'.
- Manipulation ability: not all of the health robots have the ability to handle objects, for social robots this is not their main concern, however they sometimes do have some grasping abilities. For surgery robots and revalidation/assisting robots it is often much more important to be able to handle objects in a trustable manner.
- Perception ability: the perception of the robots in the health sector is very different on the task they are performing. However, due to the way the interaction takes place, perception is very important.
- Decisional autonomy: robots such as a surgery robot are assisting devices, they assist a person, in this case a surgeon, who has the autonomy. Other robots have more autonomy, for example social robots in the way they react to the user, because they involve less risks.
- Cognitive ability: most of the robots used in the health sector have high level cognitive skills, see also perception and interaction.

A SWOT analysis of this sector:

Strengths: many research is going on in this area, also in international collaborations and collaborations with companies. Rapid growth of the market.	**Weaknesses:** there are many different subjects and many different researches, however some focus is lacking. The health sector is not technology-minded.
Opportunities: due to the aging population and the increasing cost for healthcare there is a big market potential. Improvement of the quality of cure. Improving the collaboration between different parties.	**Threats:** acceptance by the patient and caregiver as well as political, legal and social acceptance. The costs and financial risks in combination with the cost-cutting by the government and the budgets of health care institutes. Fragmented development and investments, more collaboration is needed. The safety and liability of systems needs to be very high.

Industry

- Configurability: for robots used in the industry sector their flexibility in programmability is very important. Robots that are reprogrammable are more cost-efficient.
- Adaptability: the tasks that the robots have to perform are often static, however they need to be able to recognize objects/the environment in different settings, e.g. changing lightning.
- Interaction ability: the robots don't interact in an advanced way such as speech.
- Motion ability: the motion ability differs per robot. Some robots have many degrees of freedom, allowing them to do many different motions. Others are built to perform a certain move repetitively.
- Manipulation ability: most of the robots are designed to handle certain objects. How they handle them differs a lot per robot.
- Perception ability: the robots need to be able to recognize their subject.
- Decisional autonomy: robots in this sector are very autonomous. In order to automate a manufacturing process for example you have to give a robot a lot of autonomy, otherwise human autonomy is still needed which prohibits the full automation of the process.
- Cognitive ability: besides the cognition needed to percept the subject and perform the task not much cognitive ability is needed. The way the human-robot interaction takes place does not require additional cognitive abilities.

A SWOT analysis of this sector:

Strengths: innovations in this sector change the working conditions in a positive way and reduces the labor demand in this sector. Many different research projects focus on this sector. There is a large investment budget available. The Netherlands has state-of-the-art know-how in the area of navigation and motion planning as well as strong mechanic know-how.	**Weaknesses:** new development is needed to increase the market. There is a strong need for skilled technicians. Compared to other countries the Netherlands has no major defense industry to drive the R&D. Companies often focus more on the R&D stage than on the real business. Because the application domain is very scattered the financial leverage of application-specific solutions is reduced.
Opportunities: there is a lot of promising technology and a large potential market. Knowledge and experience is available in the Netherlands. Low-skilled labor for monotonous and repetitive work will be replaced and the performance improved. High-wage countries will have a productivity gain.	**Threats**: there is not a large manufacturing industry in the Netherlands. There is heavy competition. Negative reactions about how robots steal jobs. Lack of safety standards for new applications. Lack of money to scale up know-how to an actual business.

Safety

- Configurability: the robots are often only meant for a certain task. However sometimes this can be used for different purposes. Drones for inspection have the tasks to 'recognize objects' however the application of this can differ from agricultural to maritime and other application fields.
- Adaptability: when it comes to recognizing objects training is very important.
- Interaction ability: the interaction between the user and the robot differs a lot per application.
- Motion ability: this is also very different for each application. Robots used in this sector often don't need motion to execute their task. For example drones for inspection need to be able to fly, but once they have inspected their area it is often another machines/robot/human that takes action based on the observations.
- Manipulation ability: often these robots do not need to handle objects (see motion ability)
- Perception ability: the perception ability is of a high level. In order to inspect an area or object a robot needs to have advanced perception abilities.
- Decisional autonomy: often the robots have autonomy, but it depends on the task they are performing.
- Cognitive ability: in order to perform the high level perception the robots need to have high level cognition. Also the smart movement of the robots requires cognitive skills. However no additional cognition is needed for the interaction of the robot.

Dutch front runners in Industry

Airborne

Description:	Composites automation solutions for affordable scalable manufacturing.
Main application area:	Aerospace, Maritime,
Keywords:	Industry, Integrator

Atmos UAV

Description:	Delivers turnkey unmanned aircraft systems that solve information gathering problems in a wide range of applications. The core of the system is a fully automated unmanned aerial platform that is equipped with the appropriate payload sensors. The systems furthermore comprise customizable hardware and software that facilitate control, data processing, data analysis and data management.
Main application area:	Maritime, offshore
Keywords:	Safety and security, inspection

Avular (http://avular.com/) OEM / Start-up

Description:	Develops and produces drones that can be used for inspections. Mainly focused on the safety of the drones. This company develops drone systems enabling more difficult and more complex. For example enabling flying in zones that might contain dangerous gasses. This offers solutions to markets that are not yet served by drone companies.
Main application area:	Safety
Keywords:	drones, inspection, safety

Aweta (http://www.aweta.nl/)

Description:	Supplier of turn-key solutions for the grading of fresh food and vegetables, using internal and external optical sorting sensors and tracking & tracing of products. Resulting in a more sustainable production because less products are thrown away. Aweta is an international organization with hightech sorting technologies and great growth potential.
Main application area:	Agro & Food
Keywords:	agro & food, international, sorting, sustainability

Clear flight solutions (http://clearflightsolutions.com/) OEM / Start-up

Description:	Using a robotic bird to keep airplanes safe from birds. The technique used for this, Robird, is very unique due to the fact that the Robird is unpredictable which is needed to prevent familiarization among the real birds. Clear flight solutions collaborates with Twente University to further develop their product. For this collaboration they have won the TechTransfer award in 2016.
Main application area:	Safety
Keywords:	collaboration, robird, safety, TU

Delft Robotics BV (http://www.delftrobotics.com/)

Description:	Delivers robotic solutions, adapted to the wishes of the costumers, to automate an existing production process. Integrating advanced robot intelligence (AI techniques such as vision and deep learning) with high quality industrial robotic systems, without using conventional mechanics that are often cumbersome and expensive. Internationally there are barely other companies offering these kind of solutions.
Main application area:	Industry
Keywords:	ai, industry, integration

DEMCON (https://www.demcon.nl/) OEM

Description:	Delivering high-end technologies focusing on hightech systems, industry and medical devices. DEMCON has an multidisciplinary approach to mechatronics in order offer the complete production process. They help clients with specific questions by offering specialized solutions. DEMCON has grown into a company with multiple locations and great growth potential.
Main application area:	Health
Keywords:	health, hightech, industry, mechatronics, multidisciplinary

Focal Meditech (http://focalmeditech.nl) OEM / SME

Description:	Focuses on assisting technologies and robots for healthcare purposes, both imported technologies and own developments. Their strength is in the integration of robotic arms (JACO) on wheel chairs and tuning the input systems on the condition of the client. This financially healthy company can be seen as a role model for (robot) innovation in the care sector as it is capable of developing and selling advanced care technology. Comparing to other companies they are performing outstandingly well. One of their strengths is their well developed vision on how technology can be used to help people in their daily lives. Their robotic arm is being sold globally and delivers the most advanced modular headrest system. Internationally they can not only offer interesting products but they are also an interesting partner to collaborate with for further innovations.
Main application area:	Health
Keywords:	assisting technologies, health, robotic arm

Focal Vision & Optics (http://www.focal.nl/)

Description:	Develops precision inspections, position and optical measurement systems. Focal has a multidisciplinary approach to fulfill client specific needs in the design and engineering process. Systems are delivered as modules that can be integrated in robots. Focal has international clients and is unique in the diversity of their knowledge and their experience. The company is very creative and tries to offer out-of-the-box solutions. There are no other companies offering these unique combination of expertise.
Main application area:	Health
Keywords:	health, international, multidisciplinary, optics, vision

FROG AGV systems (http://frog.nl/) OEM / SME

Description:	Develops, produces and maintains intelligent, flexible and reliable AGV systems. Although the company is recently taken over by another company it is still a Dutch leading company. The company is commonly known in the AGV sector, their systems are used in big factories. However, FROG AGV is not very innovative itself. A remarkable project has been done in collaboration with VDL Steelweld. They have worked on a autonomous transport system for containers in the terminal of the port of Rotterdam.
Main application area:	Industry
Keywords:	AGV, industry, international

Gable (http://www.health-valley.nl/partners/gable-systems-bv/)

Description:	Develops a gait & balance training robot for the rehabilitation of stroke patients. In contrast with other gait & balance training robots, their robot is a substitute of the normal trainers.
Main application area:	Health
Keywords:	balance, gait, health, rehabilitation, stroke, training

Heemskerk Innovative Technology (http://heemskerk-innovative.nl/)

Description:	Develops remote handling simulations for industry and care, including the semi-autonomous care robot *Rose* that assist daily life activities of elderly people in domestic environments. Where needed Rose can be remotely operated by healthcare supervisors to assist in tasks that require human insight and coordination. There is a strong research collaboration with the TU Eindhoven and TU Delft in terms.
Main application area:	Health
Keywords:	care robot, health, Rose

Lacquey (http://lacquey.nl/) OEM / SME

Description:	One of the few companies, globally, that offers robot handling for natural products. The robotic solutions they offer are complete modules, including processing of fresh products as well as the packaging of it.
Main application area:	Agro & Food
Keywords:	agro & food, handling, natural products

Lely (http://www.lely.com/nl) OEM/Large Company

Description:	The first company to produce a milking robot. This company is unique in 3 different ways: it helps the costumer to optimize his profit and durability, for the cow it reduces stress and improves the health by allowing the cow to choose when to visit the milking robot and finally the robot is robust and adaptive to ensure worldwide applicability.
Main application area:	Agro & Food
Keywords:	agro & food, durability, flexibility milking robot

Medical Robotic Technologies (http://www.medicalrobotictechnologies.nl/) incubator for medical robotics technology

Description:	Develops robotic technology for medical applications, using research by the TU Eindhoven. The focus is on cure, mostly working on technology to assist surgery.
Main application area:	Health
Keywords:	cure, health, precision, surgery

Microsure (http://microsure.nl/) OEM / Start-up

Description:	Focuses on robotic assistance to offer a level of precision for microsurgical performances that is not reachable for humans. This is the first robot that is capable of this, which gives this company a unique position worldwide. There are various different application areas that this robot can be used in, enabling surgeries that were not possible before.
Main application area:	Health
Keywords:	cure, health, precision, surgery

Moog (http://www.moognetherlands.nl/) OEM

Description:	Develops precision motion control solutions and products that can be used for a wide array of applications. Unique is the combination of knowledge present in the company, both about the design of motion control parts and about the integration and development of complete systems.
Main application area:	Industry
Keywords:	industry, motion control, precision

Motekforce Link (http://www.motekforcelink.com/)

Description:	Experience with high-quality rehabilitation technologies and virtual reality techniques for real-time feedback.
Main application area:	Health
Keywords:	health, rehabilitation, virtual reality

MPS Group (http://www.mps-group.nl/)

Description:	Company selling machines for the processing of meat. They have their own complete program for the automated slaughtering of pigs, using different robots. The company operates internationally and is globally known for its innovativeness.
Main application area:	Agro & Food
Keywords:	agro & food, full-line solutions, meat processing

Penta Robotics (http://pentarobotics.com/)

Description:	Specialized company, working on the development of high performance robotic solutions.
Main application area:	Industry
Keywords:	industry, high performance

Preceyes BV (http://www.preceyes.nl/) OEM / Start-up

Description:	Medical robotics company focused on ocular surgery with the vision to help fighting blindness. Innovative robotic solutions are developed to assist eye surgeons in performing the most demanding surgical tasks. The company enables the development of new, high-precision treatments and facilitates existing vitreoretinal surgery. It is the first company that sold an eye surgical robot for clinical usage, which makes it a leading company for the Netherlands.
Main application area:	Health
Keywords:	eye surgery, health, precision

Robot Care Systems (http://www.robotcaresystems.com/) OEM / Start-up

Description:	This start-up uses robot systems to support elderly people so they can stay active. One of their products, LEA (Lean Elderly Assistant) offers walking support, as well as offering support for the daily rhythm of the elderly user. There is still ongoing research to extent the possibilities of LEA.
Main application area:	Health
Keywords:	care, daily rhythm, elderly, health, LEA

Robot Security Systems

Description:	Efficient Safety & Security solutions based on Robotics. The robotics technology ensures both time and money savings. The quick and automated alarm response of the Robots makes them extremely effective. Developer of the Security and Surveillance Robot, SAM (Secure Autonomous Mobile).
Main application area:	Industry, Guarding companies
Keywords:	Security, industry

Rolan Robotics (http://www.rolan-robotics.nl/)

Description:	Specialized in robotic systems for industrial applications. Offering robots both for welding and cutting as well as for handling food and non-food products. They offer more than 600 robotic systems, which makes them one of the biggest companies in the Benelux in this area.
Main application area:	Industry
Keywords:	cutting, handling, industry, welding

Scyfer (http://scyfer.nl/)

Description:	Specialized in machine learning and capable of solving complex data-analysis problems. Also using deep-learning techniques for computer vision applications that can be used in many different sectors. Scyfer has costumers worldwide and offers their clients the latest innovations in the field of machine learning. Scyfer is also working on a machine learning technology that can recognize rotated pictures, this will reduce the amount of pictures needed to train a machine learning system.
Main application area:	AI
Keywords:	ai, big data, deep-learning, machine learning

Smart Robotics (http://smart-robotics.nl/)

Description:	Employment agency for robots that can be used in the industrial sector. Their robots can quickly be adjusted to the specific needs of the client, in order to automate complex tasks. This company is unique because of both the flexibility of the technology as well as their business model.
Main application area:	Industry
Keywords:	employment agency, flexibility, industry

Tech United (http://www.techunited.nl/)

Description:	RoboCup Team from the Eindhoven University of Technology. Top team within international RoboCup competition in the fields of robot soccer and homecare robots.
Main application area:	Education
Keywords:	home, RoboCup, soccer

Valk Welding (http://www.valkwelding.nl/)

Description:	Specialized in the automation of the welding process, including welding, cutting and handling robots. However they also sell 'standard' robotic concepts.
Main application area:	Industry
Keywords:	cutting, handling, industry, welding

Part III: International position of the Dutch robotics community

This part will elaborate on the position of the Dutch robotics field, compared to the international robotics field, and explain what makes the Netherlands interesting for other countries.

The Netherlands is one of the leading global innovators in service robots and robots. It is one of the few countries in the world with an organized robotic sector. RoboNED is the Dutch branch organization that brings different stakeholders from all over the country together. They focus on influencing national policies through roadmaps and strategic agendas.

The Netherlands has a broad array of high-quality universities, both academic and applied sciences. The unique Helix structure, public authorities, entrepreneurs and the education sector are well working together within this Triple Helix. We have living labs, high-tech companies that invest in companies and strong emerging sectors. The power comes from the strength in system thinking and integration and using our unique knowledge.

The scientific challenges require cross-disciplinary research on technological and social aspects. The Dutch research community is well positioned to lead this field of research, with institutes on the forefront of unique knowledge like mechatronics, sensors, optics, precision, 3D-vision systems, machine learning, speed and a combination of the latter.

The opportunities for the robotics industry can be found in different market sectors in the short and medium term. The market for traditional classic industrial robots is still growing. Collaborative robots will enable small and medium enterprises in particular to automate processes in a flexible and affordable manner.
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.

Other opportunities for robotics applications are presented in the medtech and automotive sector. Exoskeletons and medical robotics like image guided interventions and microsurgery are innovative application in the medtech sector. The automated guided vehicles will also be an emerging market, because of the unique knowledge in the Netherlands.

Universities

There are four technical universities that focus as an innovation hubs for developments around robotics. The big trends in robotics are the new technologies like handling big data by analyzing a huge amount of data, artificial intelligence, variable impedance actuators and the extreme connectivity through the Internet of Things. These big trends have impact on the development of the robot and the rapid advancement, like the sense, think and act part of the new generation robots. New type of robots like collaborative robots, swarm robots, autonomous unmanned vehicles, drones and advanced traditional robots will emerge from the market to the consumer.

(**Technology —> Application —> Market —> Consumer)**

The Netherlands is also good in adapting a robot of a third party so that it can be used for a different purpose. The different knowledge holders in the Dutch robotics landscape are getting more and more involved with each other in international and national

consortia to bundle their knowledge and strengthen each other and their position in the landscape outside the Netherlands.

Once such collaborations are established, different components come together and create a strong foundation for innovations. The Netherlands might not have a booming robotics business at this moment but the knowledge present in the Netherlands covers the whole spectrum of required knowledge and skills.
Dutch Universities are front runners on collaborating with industries, this is reflected in top rankings where scientific papers are co-written with industry authors.
(Source: http://www.leidenranking.com/ranking/2015)

No. 1	TU/e
No. 4	Delft University
No. 50	Wageningen University
No. 66	Twente University

Companies

More and more companies are strategically positioning themselves into robotics. These companies are not just focusing on industrial robotics anymore, but a significant portion of them is focusing on a wide variety of sectors, such as health care, rehabilitation, inspection, agriculture and prevention.

Knowledge Institutes/Facilities/Fieldlabs

However the Netherlands distinguishes itself mostly from other countries by a pragmatic mindset and strong drive towards multi-disciplinary collaboration. This mindset includes practical but innovative and out-of-the-box thinking, while for example the global leader of robotics Japan often thinks either very conventionally (in terms of functional robotics) or very ‘playful’ for entertainment.

The Netherlands boasts an open innovation culture which is structured with different facilities, fieldlabs and open innovation Platforms, interesting for international parties.

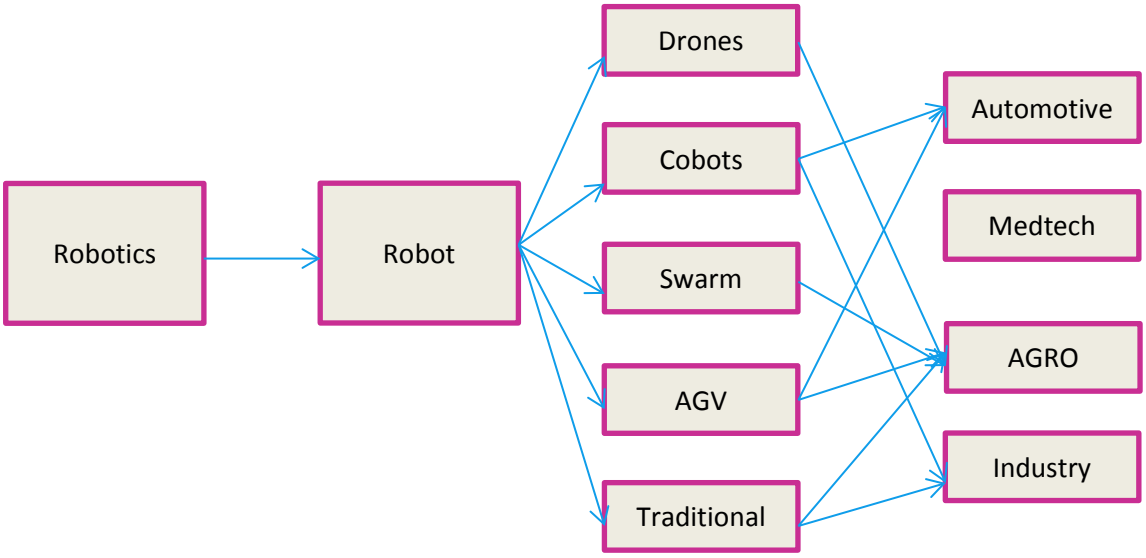
STW
Technology Foundation STW realises the transfer of knowledge between the technical sciences and users. It does this by funding excellent technical scientific research and by bringing researchers and users together in each project. This foundation is able to stimulate collaboration between robot producers, researchers and end users, as a result to bring the innovations beyond the ‘proof of concept’ stage.

About 55 million euros of STW's budget comes from the Netherlands Organisation for Scientific Research (NWO) and the Ministry of Education, Culture and Science (OCW), 22 million euros from the Ministry for Economic Affairs (EZ), 10 million euros from third parties and 14 million from cash co-financing by companies participating in research projects. In addition to this the partners make in-kind contributions to the research.

Most importantly, collaboration is an important factor in the Dutch robotics landscape, and collaborating internationally is one of the strengths that can be offered to other countries.

The Netherlands got the whole value chain of knowledge, system integrators and Original equipment manufacturer (OEM) parties, start-up companies, fieldlabs and open innovation platforms. The OEM and start-up part of the value chain is interesting for foreign countries to invest in.

Companies like Yaskawa and IBM wants to help the knowledge and system integration a step further, but foreign companies should conquer the market outside the Netherlands by being an System Integrator or OEM.



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Questionnaire

The questions

1. What are the international trends and developments in the area of robotics?
2. Where is the growth of robotics?
3. What are the expertise groups? What are the application groups?
4. How does the robotics landscape looks like in the Netherlands?
5. Where does robotics in the Netherlands differentiates itself internationally?
6. What are our areas of expertises? What is the unique selling point?
7. Where is the knowledge? Mention the technology and application areas.
8. Mention the companies, start-ups and institutes
9. What can we offer foreign companies? Think about outsourcing, R&D, questions to high tech suppliers, entrance special facilities.

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