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- THEME: AGROROBOTICS
- COMBINING LAPPING, FLAT POLISHING AND CMP
- WIM VAN DER HOEK'S FOCUS ON MANUFACTURABILITY
- LIS STRATEGY: NEW MODERN NATIONAL VOCATIONAL SCHOOL

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The cover image (featuring the Sparter asparagus harvesting robot) is courtesy of Cerescon. Read the article on page 10 ff.

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FEATURES

SWITCHING FROM HIGH-TECH TO AGRI-TECH IS A BUMPY RIDE

In the eighties, ASML started pioneering with its technology in the semiconductor industry. At the same time, I was working with ASM-Fico, which has been called BESI since the nineties; we were pioneering with our technology at the back-end of the semiconductor production process chain with our moulding and trim & form systems. Once you have pushed innovative high-tech products successfully to the market, it is difficult to stop pioneering in this way.

In 2014, after more than 25 years, I decided to leave the semiconductor industry and start pioneering all over again, this time with agricultural technology, or agri-tech. I left ASML and, as a son of a former farmer, I started Farmertronics to develop and build an unmanned, fully electric robot tractor. My father had worked the land with a horse; I planned to build an electronic horse, the eTrac. This gave me the opportunity to return to my roots.

Not knowing that much about the market and the requirements of farmers, I started searching for the right market niche in which to develop this new product. Developing a mobile machine seemed to be quite different from developing a static machine. In particular the battery pack needed to drive the robot forced me to choose applications that did not require that much energy. I ended up at the orchard, where no heavy-duty equipment is needed.

Now, we are developing and building a first prototype of the eTrac for repetitive tasks in the orchard, such as mowing, weeding and spraying. During these repetitive tasks, data will be collected by several 3D sensors mounted on the eTrac; at that moment, AI and deep learning come into play. We will hire the knowledge of companies such as VBTI and Avular in the Brainport region to turn the eTrac into an advanced mobile platform. Knowledge about mowing and weeding comes from LS Products and DvO Engineering.
In a similar way to that in which BESI or ASML work together with many technical partners, I have selected these partners, each with their specific knowledge, to make our venture into a success.

As well as pushing technology, there was also a market to find, as well as customers willing to buy our robot tractor. Due to the high-end components used to build the eTrac, such as an expensive, advanced battery pack, it seemed to me that it would be difficult to sell the first eTrac due to its relative high sales price. Marketing is always a matter of timing; you shouldn't be too early but also not too late. And you need some luck.

With the help of an incentive from the government that opened at the end of 2021, I found three tree nursery farms willing to buy a first-edition robot tractor, so production and sales can really take off next year. One day I hope that all my efforts with Farmertronics and the eTrac will pay off. After leaving the semiconductor industry and pioneering for nearly ten years in the agricultural market, things seem to be developing in the right way.

Thieu Berkers
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EMBEDDING MORE FLEXIBILITY IN ROBOTIC SYSTEMS

Robots have been extremely successful in the past decades, for instance in the car industry, and have also entered the agri-food production chain. However, current robot technology is no match to human workers when it comes to dealing with variation and flexibility. The NWO Perspective programme FlexCraft addresses the scientific challenge of how to deal with large variations in shape, size and softness of agri-food products in combination with variations in environment and tasks in a robust way. To that end, it aims to equip robot technology with generic capabilities in active perception, world modelling, planning and control, and gripping and manipulation.

ELDERT VAN HENTEN

Robot technology has been extremely successful in the past decades, for instance in the car industry. Repetitive operations on large numbers of objects that are well defined in terms of location, orientation, shape and size were instrumental to this success. Robots have also entered the agri-food production chain, where adoption continues to grow rapidly. This trend expresses the readiness of that agri-food industry to adopt more advanced technology.

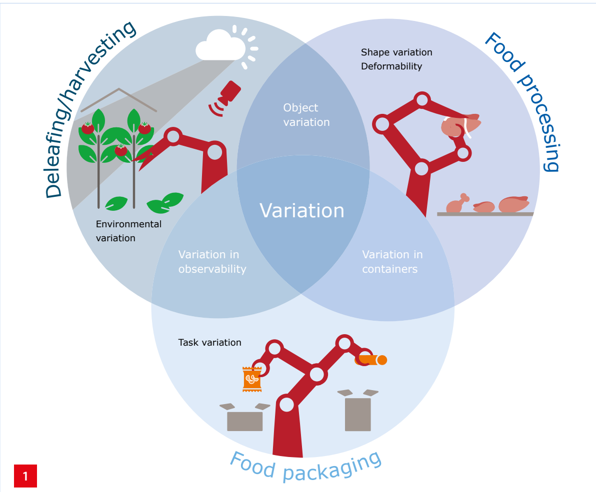
However, the robots currently used in the agri-food domain are based mainly on industrial robotic pick & place technology and still cannot meet the requirements of flexibility and the capabilities to handle complex manipulation tasks or natural environments. In terms of the above-mentioned capabilities, current robot technology is no match to human workers in the agri-food industry, where dealing with variation and flexibility proves to be the biggest challenge.

What makes humans so flexible and capable in dealing with complexity and variation? Firstly, active perception allows humans to adapt their observations to the conditions at hand and effectively identify location, orientation and material properties of objects in complex environments where objects are only partially visible. Secondly, humans learn from previous experiences and build a world model, which they use to reason about the environment and to guide their active perception as well as the planning and control of arms and hands. Thirdly, humans employ very effective eye-hand coordination, i.e. planning and control of their arms and hands with respect to the object to be manipulated. Finally, humans are equipped with hands; hands are gripping and manipulation systems that are compliant and very effective in dealing with objects that have widely differing shapes and sizes as well as differing material properties, ranging from solid to soft and deformable.

The NWO Perspective programme FlexCraft addresses the scientific challenge of how to deal with large variations in shape, size and softness of agri-food products in combination with variations in environment and tasks in a robust way. The FlexCraft programme aims to equip robot technology with generic capabilities in active perception, world modelling, planning and control, and gripping and manipulation; capabilities that are needed to deal with the aforementioned conditions in a robust way.

Benefits to society

Besides building on a novel network of research institutes and agri-food industry in the Netherlands, the FlexCraft



1 *The use-case projects and the challenges they address. 'Deleafing/harvesting' in the upper left corner refers to the Greenhouse use case.*

AUTHOR'S NOTE

Eldert van Henten is professor of Biosystems Engineering in the Farm Technology Group at Wageningen University & Research in Wageningen (NL). Input was provided by members of the FlexCraft team, including Gert Kootstra, Robbert van der Kruk, Herman Bruyninckx, Rehka Raja, Xin Wang, Akshay Burusa Kumar, David Rapado Rincon, Ad Huisjes and Rodrigo Perez Dattari. The financial and in-kind support of the FlexCraft programme by NWO and companies under Grant Nr. P17-01 is gratefully acknowledged.

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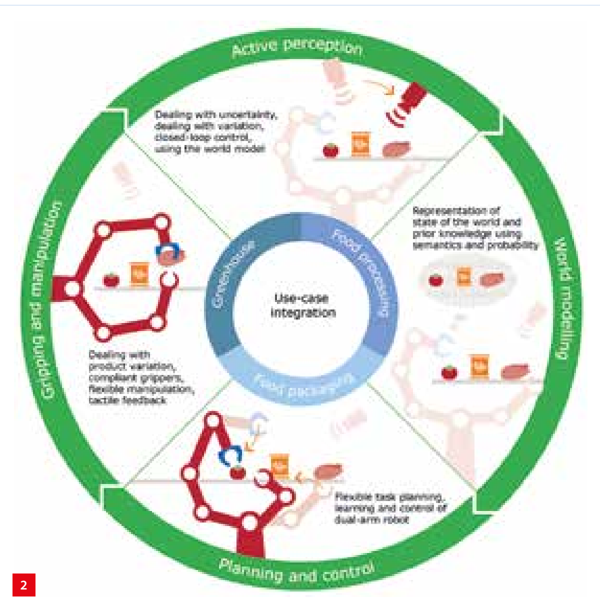
programme aims to improve flexibility in food processing and food packaging, allowing further progress in customer-specific production. Also, it will improve efficiency and effectiveness of agri-food production by implementing robotic systems that can operate tirelessly at high speeds and allow easy upscaling of the production. Using robotic systems instead of human labour in food production and food processing will improve hygiene. And last but not least, FlexCraft aims to mitigate the continuously growing labour scarcity in agri-food production.

Use cases

Central to the programme are three use cases that will demonstrate the technology developed. Addressing variation in objects and environment are the key challenges and as illustrated by Figure 1, use cases share some challenges but also differ on the challenges encountered in practice. The three use cases:

- The greenhouse use case will address the removal of leaves (deleafing) and ripe fruits (harvesting) from tomato plants, two important plant-maintenance operations. This use case addresses the challenge of how to deal with variations in the environment, such as changes in illumination and humidity, as well as variations in objects (leaves and fruits), and complexity in the environment due to a high level of clutter and partial occlusion of objects by other plant parts.
- The food-processing use case will address poultry processing. This use case addresses the challenge of how to deal with variation in shape and size of objects (chicken fillets, wings, thighs), deformability of objects, and the picking of these objects from large piles or bins.
- The food-packaging use case addresses packaging of various food products, such as packs of cookies and bags of chips.



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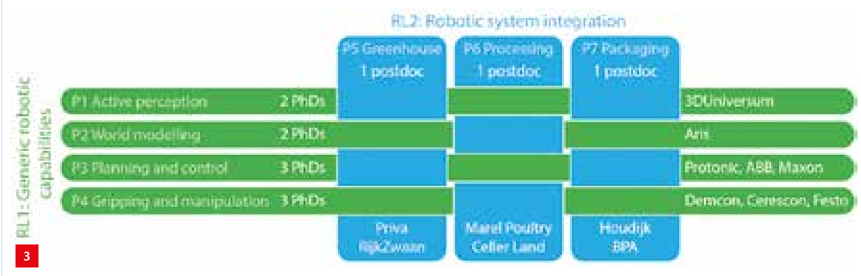
The FlexCraft paradigm for dealing with variation in objects and environment in the agri-food chain.



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The matrix structure of the FlexCraft programme, with along the horizontal axis the four generic capabilities of active perception, world modelling, planning and control, and gripping and manipulation, and along the vertical axis the three use cases on greenhouse production, food processing and food packaging, respectively. Key staff in terms of Ph.D. candidates and post-docs are indicated.

Key challenges

Robotic research is a multi-disciplinary endeavour, with perception, cognition and action aspects, and entailing both hardware and software components. A robot is a sensori-motor system, where perception and action are tightly coupled through the interaction of the robot with the environment.

Through its sensors, the robot perceives the environment. By processing this information and combining it with prior knowledge, an internal world model is formed. The robot then reasons about that state of the world in relation to the task, in order to plan its actions, both at an abstract level, as well as in the low-level control loops. Through its actuators, the robot interacts with the environment.

From the scope of the programme, this entails the manipulation of objects. This interaction has an immediate effect on new sensory observations, completing the cycle. Figure 2 illustrates the FlexCraft paradigm for dealing with variations in objects and environments when deploying robotics in the agri-food chain.

Programme overview

The FlexCraft programme builds on a strong and multidisciplinary research community led by Wageningen University and including Delft University of Technology, Eindhoven University of Technology, University of Twente, and the University of Amsterdam. This community covers all academic disciplines needed to tackle the challenges of variation and deformability when manipulating products encountered in the agri-food domain. As shown in Figure 3, the programme is supported by industry having stakes in the agri-food chain, represented by 14 companies including Marel Poultry, Priva, Houdijk, BPA, ABB, Aris, Festo, Demcon, Celler Land, Protonic, ABB, 3D Universum, Maxon and Cerescon.

The research programme operationalises a matrix structure as shown in Figure 3. Along the horizontal axis, research Line 1 focuses on the generic methodologies and concepts

CUTTING-EDGE MECHANISATION

Automation of asparagus harvesting has been a long-time challenge because of the delicate nature of the crop. Cerescon has now developed the first selective harvesting solution for white asparagus, called the Sparter, which both reduces harvesting costs and significantly improves quality. What is characteristic and distinctive in the design is its underground detection of asparagus, using a box of probes that is attached to the machine through a well-thought-out suspension, while the design of the Sparter robot features an ingenious actuation concept.

AD VERMEER AND THÉRÈSE VAN VINKEN

Mechanising selective harvesting

Asparagus cultivation has been under pressure for years, partly due to the lack of manual workers for harvesting. The current manual way of working also has its limitations in terms of the quality of the harvested products. In a harvest round, asparagus spears cannot always be detected by eye, so by the next round they are protruding far above the sand bed. This causes the asparagus heads to fold open and exhibit violet discolouration, both of which result in lower sales value.

For almost all crops where the harvest is done in one go (bulk harvesting), the harvest is mechanised. Examples of these are grain, potatoes and sugar beets. Indeed, the first patent for a combine for the grain harvest dates back to 1831. Some crops, however, have to be repeatedly harvested for each part of the yield, which is called selective harvesting. This affects crops such as apples, mushrooms, strawberries and also asparagus. Still now, all selective harvesting worldwide is done manually, which makes these types of crops very labour intensive and more and more expensive. There is a clear need for the robotisation of selective harvesting.

Advantages

Cerescon has developed a selective harvesting solution for white asparagus, called the Sparter, which both reduces harvesting costs and significantly improves quality. What is characteristic and distinctive, is its underground detection of asparagus, after which the vegetable is removed from the sand bed by a robot.

The Sparter offers asparagus growers the following advantages when compared to traditional hand cutting:

- Better quality asparagus due to a patented underground detection system. This means that the asparagus is harvested before emerging from the soil, thus avoiding violet discolouration and reducing the number of open heads.
- Higher yield through improved quality, because the asparagus harvester restores the sand bed after picking, thus reducing the percentage of (discarded) bent spears caused by inhomogeneous compression of soil.
- Reduction of the harvesting frequency with subsurface detection to once every three days, thus tripling the harvesting capacity per passage compared to a (daily passage) system with detection upon surfacing.

Mode of operation

The machine has been designed as a one-row machine with an internal drive train. It is suspended by caterpillar tracks without additional castor wheels (like an army tank), which facilitates sharp turns. An operator drives the machine in the row with a remote control; see Figure 1, which also shows the handling of the plastic foil covering the asparagus beds. Once positioned in the row, both the steering and the speed control are switched to fully automatic for harvesting. The machine stops when it detects the end of the row. While harvesting, the operator's only tasks are to monitor the process and put the asparagus in crates.

For subsurface detection of the asparagus, on both sides of the machine a slider with a knife cuts into the soil at approx. 80 mm depth (Figure 2). A detection signal is injected into the soil making the asparagus detectable for sensors. The knife needs to reach wet soil, as very dry sand does not conduct the electric signal.

The detection module incorporates a number of probes with sensors that move through the soil at an adjustable depth (Figure 3). When a probe detects an asparagus spear via the sensor, the coordinate is registered and the probe is withdrawn at high speed to prevent the asparagus being damaged. In this way, the probes do not touch the asparagus spears.

AUTHORS' NOTE

Ad Vermeer and Thérèse van Vinken are the co-founders of Cerescon, a high-tech scale-up in agritech, located in Heeze (NL). Cerescon's mission is the development and marketing of advanced mechanised selective harvesting solutions.

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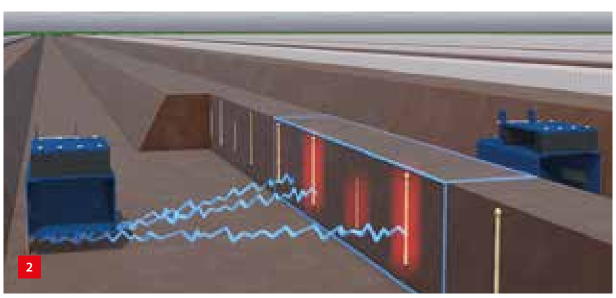
Remote control of the Sparter by an operator. The inset shows the handling of the plastic foil. At the row entrance, the operator puts the foil in the machine; then further along the row, the Sparter picks it up and places it back on the bed at its rear.

The measured coordinates are transmitted to the harvesting robot, which picks the asparagus from the top side of the bed, cutting and lifting it in one swift action (Figure 4). During this picking action, the robot moves synchronously in the opposite direction of the machine. Even during driving accelerations, the cutting knife is stationary relative to the soil while performing its picking action, so the machine does not have to slow down or even stop during harvesting. There are two robot heads to increase the capacity of the machine. While one robot head is picking, the other head is putting a harvested asparagus on an adjacent conveyor belt.

Asparagus that are placed on a conveyor belt are transported to the operator position on the rear platform of the machine (Figure 5). The asparagus are handled deliberately with some sand to avoid damaging the spears. This is a well-known trick in harvesting machines, also used for potatoes and sugar beets. Finally, the sand bed can be homogenised to ensure that the next asparagus spears will grow straight.

Steering and driving

Steering is done by adjusting the speed of both hydraulically driven tracks via proportional valves, based on measurement of the lateral position of the machine in relation to the sand bed. At the front of the machine,



Injection of the detection signal into the soil.

Detection trigger at close proximity of an asparagus spear to a probe.

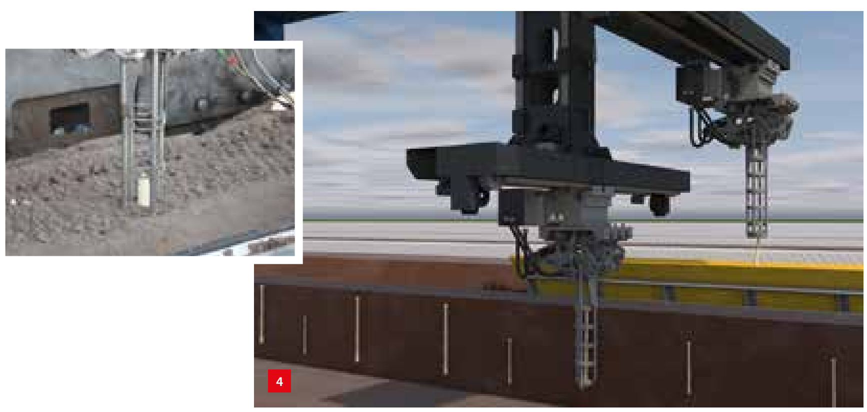
two steering wheels follow the side of the sand bed. The movement of the steering wheels is measured with analogue position sensors. The control loop of the steering has been designed to adjust the driving direction only gradually, in order to secure the position accuracy between the asparagus detection and the asparagus picking robot.

The driving speed is also adjusted automatically based upon the number of asparagus detected. The maximum speed is configured at 0.6 m/s, but this speed is not often reached because the robot cycle determines the harvesting capacity. With subsurface detection, sufficient asparagus spears are detected to keep the robots occupied at a moderate driving speed.

Detection

The detection module contains a number of probes that move through the soil at an adjustable depth (Figure 6). The depth adjustment and the sand bed tracking movement are realised by a control loop with ultrasonic sensors (the little green device at the top in Figure 6) and linear electric actuators.

In the first version of the Sparter, the box with all the probes was suspended using: three pivoting couplings that were to a large extent horizontally oriented in the X-direction, i.e. driving direction; one linear actuator oriented in



Cutting and extracting asparagus spears from the top of the sand bed. The inset shows a live close-up.