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# Robots in the food industry

## Our robot 'slaves' are now taking on increasingly sophisticated tasks

**Monotonous tasks such as picking and checking are often beyond the bounds of human concentration. The more time we spend doing such activities, the less objective and reliable we become. Working in refrigerated rooms or by ovens pushes us to our physical limits – it can impair our physical strength and stamina, as well as our health in general. Tasks that involve repeating the same steps over and over again in quick succession are unnatural for humans. The longer people are asked to do them, the more stressed they become and the more breaks they need to take. Having hands, mouths and noses close to food means a risk of contamination – the hygiene offered by a machine minimises the transfer of germs and pathogens. Robots are used on the production side in lots of different industries, but in the food industry are usually deployed only for packing and palletising. However, thanks to the huge leaps forward that have been made in gripper technology, hygienic design and intelligent image processing, there is now huge potential for the use of robots in the processing and production of food.**

The term robot was coined in the early 20th century by the Czech artist Josef Čapek. It is derived from the Slavic word *robota*, which roughly translates as work, drudgery or forced labour. The concept immediately captured the public imagination, as demonstrated by countless science fiction novels and the films based on these books. However, we are still a long way from the visions proposed by this genre, despite the huge steps forward that are currently being made in robot development.

## Automation

According to Dolezalek, automation describes the mechanisation of a process so that it does not require the intervention of a human worker, either continuously or at predetermined intervals. Every time a company considers automating a task, it has to first ask itself whether it really does make sense to do that, and then – if it makes sense – how best to approach this. The criteria listed in figure 1 can help them to answer the first question. But even if an automation task makes sense in theory, it doesn't necessarily mean that it is feasible in practice. Firstly, the process must be definable by algorithm, i.e. it must be clear what has to be done. Secondly, it must be possible to capture the data generated for the required parameters using technological means. This requires not only suitable sensor technology but also algorithms for analysing its readings. Thirdly, the processes have to repeat themselves so that there is a pay-off to automation in the form of increased efficiency.

A process can be automated using either an automatic machine or a robot (fig. 2), which are differentiated as follows: the DIN 19233 norm states that an automatic machine is an independently operating artificial system whose behaviour is determined either step by step according to prescribed decision rules or on a continuous basis according to pre-determined relationships, and whose output values are based on its input and operational variables.

## Robots

The Association of German Engineers (VDI) offers a definition of a robot in its 2860 standard. According to this, industrial robots are automated moving devices that can be deployed universally and that have multiple axes, the motion paths, sequences and angles of which can be freely programmed (i.e. without mechanical intervention) and controlled by sensors. Robots can be fitted with grippers, tools or other manufacturing equipment, enabling them to manipulate objects and carry out production tasks. Their flexibility, stemming from their freely programmable movements, means they can be used for all kinds of different tasks. It is precisely this flexibility that makes the robot particularly well suited to the

*Fig. 1: Criteria used to determine when it makes sense to automate a process*

| **low** ← | **practicality of automation** | → **high** |
|---|---|---|
| low ← | throughput | → high |
| low ← | market stability | → high |
| high ← | development costs | → low |
| low unemployment ← | labour market | → high unemployment |
| low ← | experience with automated systems | → high |
| low ← | hygiene requirements | → high |
| standard ← | environmental conditions | → extreme |
| low ← | traceability requirements | → high |
| low ← | requirements in terms of reproducibility of the end product | → high |

Source: Naumann, 2010

*Fig. 2: Automation engineering versus robotics – the pros and cons of the two technologies*

| | Automation engineering | Robots |
|---|---|---|
| Type of movement | Simple (≤ 3D) | Complex (> 3D) |
| Sensor data | Has no impact on movement | Potential input variable for motion control |
| Scope of work per station | One process | Multiple (different) processes |
| Variant flexibility | Manual, mechanical conversions | Loading of other program/parameters |
| Reusability | Specialised in one task | Standard components, robot + peripherals |

Source: Naumann, 2010

needs of small and medium-sized enterprises in the food industry that carry out many different tasks and make frequent changes to batches and products.

The scientific discipline that deals with the development and control of robots is robotics. Of particular importance in this field are mechanical modelling, control mechanisms, electronic control mechanisms, information technology and sensors. Given the complexity of these applications, it should come as no surprise that there is a growing demand for roboticists.

## Application areas of industrial robots

Traditionally, the automotive and automotive supplier industry as well as industry in general have led the way when it comes to using robots on a large scale to perform tasks of varying complexity. But for a long time now, robots have also been playing a key role in the food and beverage industry. ‘Robots in the food and beverage industry’, a trend report published by the German Agricultural Society (DLG) in 2014, indicated that robots are still being used mainly for heavy work such as palletisation and for other tasks related to packaging and repackaging (fig. 3). The companies surveyed that did deploy robots in production used them for cheese smearing, for work in cheese maturing rooms, for depositing and traying functions and for loading of bread into ovens.

The International Federation of Robotics (IFR) reports that 178,132 industrial robots were sold worldwide in 2013, of which 6,200 (approx. 3.5 per cent) were destined for the food and beverage industry. 18,300 of the 43,300 robots sold in Europe went to German companies, which represent the biggest market for industrial robots in Europe. With 282 robots in use for every 10,000 workers, Germany has the third highest density of robots in the world, behind South Korea (437) and Japan (323).

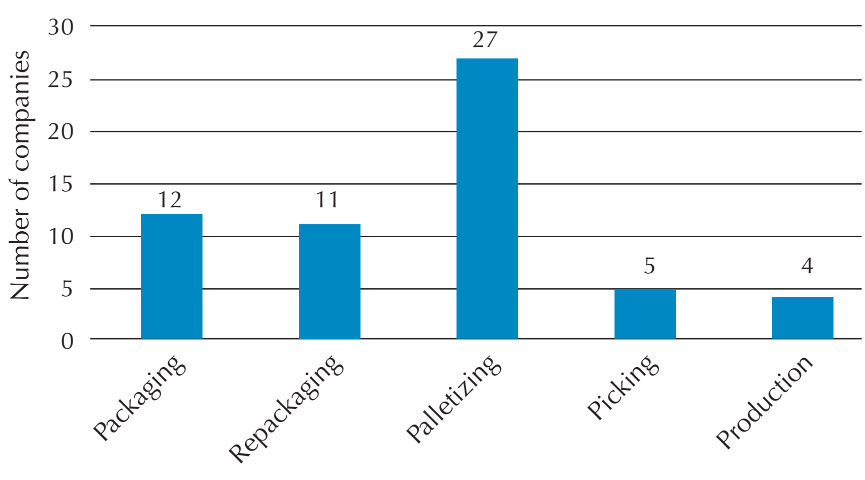
Although the food and beverage industry lags well behind other industries when it comes to the number of robots it uses, it is increasingly being seen by the robot manufacturers as a key growth market. This is because installations to date have been small in scale and because robots in this sector have the potential to increase productivity, reduce the occurrence of accident at works and improve hygiene.

## Types of robots

Robots can be categorised using various criteria: as stationary or mobile robots, or in industrial robots, service robots or harvesting robots. A robot is usually classified in accordance with its kinematics, i.e. its mechanical arrangement.

The main types of robots used in the food and beverage industry are (see fig. 4 on the following page):

*Fig. 3: Tasks for which robots are used in the food and beverage industry*




Source: Buckenhüskes and Oppenhäuser, 2014

*Fig. 4: Types of robots used in the food and beverage industry*

**Portal robots:**
Portal robots are mounted robotic systems that span a cubic handling area by means of three linear axes. The actual robotic kinematics (the moving axes) are located above the mounting.

**Articulated robots:**
Articulated robots are industrial robots with multiple interacting jointed arms that can be fitted with grippers or tools. Because these arms can move through three dimensions, articulated robots offer a high degree of flexibility. Depending on how many axes they have, they can offer up to six degrees of freedom, which enables almost any combination of movement. A limitation of articulated robots is that they generally have a restricted range and load capacity.

**SCARAs:**
Selective Compliance Assembly Robot Arms, or SCARAs, are a particular form of articulated robots. They have a single articulated arm that can only move horizontally. They work in a similar way to human arms and are often called ‘horizontal articulated arm robots’. SCARAs work in series, with each arm connected to only one other.

**Delta robots:**
Spider-like delta robots – a special form of parallel robot – typically have three to four articulated axes with stationary actuators. Because their actuators are located in the base, these kinds of robots have only a small inertia. This allows for very high speeds and acceleration.

It is a certainty that the latest development in robotics, namely industrial lightweight robots, will be also relevant for the food industry. These robots are small, light, convenient, sensitive and above all flexible – properties that make them an interesting option for tasks that have previously not been automated. Thanks to their low weight and integrated torque sensors that cover all directions, these robots are able to work in unstructured environments, meaning there is no longer anything preventing man and robot from working together.

## Challenges and opportunities in the food industry

It should come as no surprise that robots are still mainly used in the food and beverage industry for ‘heavy work’, i.e. for packing, repacking and palletising. Normally the products involved are packaged foods. Handling these is relatively straightforward and can usually be done with a standard model chosen from the broad spectrum of robot designs.

However, before robots were able to perform tasks in the actual production of food, and therefore to come into direct contact with food, huge hurdles had to be overcome that also demanded a re-think among the robot manufacturers. After all, food products are made from natural ingredients that cannot be standardised, have specific rheological properties and are often highly sensitive to mechanical interference.

Moreover, the required degree of product safety and length of shelf life calls for stringent hygiene practices that meet the relevant cleaning and disinfection requirements, and this applies equally to robots. The environmental conditions in food production are often complex: both food and machinery can be the source of corrosive properties (water, acid, salt), while the ambient temperature can range from extremely hot to well below freezing.

However, it was exactly these conditions that made the use of robots in the food and beverage industry sensible and desirable. The driving forces behind this argument were the humanisation of the working world and the further improvement of food safety by stepping up efforts to implement hygienic practices in production. Then there was the ongoing challenge of maximising efficiency and minimising costs. Who would want to spend eight hours a day performing the same action over and over again at a temperature of 8 °C? Who would want to spend the best part of their day working in a freezer? And how are we supposed to permanently exclude the potential for microbial contamination from contact with human skin? How it is possible to guarantee a standardised production process not just over eight hours, but over 24 hours?

The food industry is mainly made up of small and medium-sized companies with extensive product ranges. This, coupled with the associated need for flexibility at various levels, means it is crying out for the technological solutions that robots can offer.

An inarguable point with regard to the use of robots in production is that if they are to work directly on and with food, it must be possible to clean them properly and with the usual means and methods, and, where required, to also disinfect them. A variety of solutions have been adopted to ensure the hygienic design of food-grade robots: while ‘wash-down robots’ have an IP65 hygiene cover that’s easily washed down and changed, manufacturers of other variants opt for protective coatings such as epoxide, or they make their robots entirely out of stainless steel, which does not react with cleaning agents, acids or alkalis. The lubricants used with these robots are also food-grade (certified NSF H1). Despite all this progress, there are undoubtedly many more advances and improvements that are possible in the development of food-grade robots.

## Robots are getting smarter

The development and application of robots, including in food production, has taken a quantum leap forward thanks to advances in informatics. Radically improved computing power and matching software solutions have made robots smarter and more productive. But that’s not all. In combination with high-tech optical systems designed to capture and analyse images, they are now able to ‘see’ and react to different situations on the basis of clearly defined parameters.

Advances in the field of image capture and processing were instrumental in this. According to Angelika Erhardt, digital image processing encompasses a number of processes, all of which are designed to obtain useful data from a picture or sequence of pictures. In an industrial context, real-time images of actual processes are captured through contactless means, visually represented and automatically analysed. At the end of an industrial image processing cycle, automatic decisions are made on the basis of the results or measurement readings. These can then be used as parameters for controlling entire manufacturing processes or sub-processes and for monitoring individual pieces of production equipment and machinery.

In simple terms, the process of capturing and processing an image involves having the object in

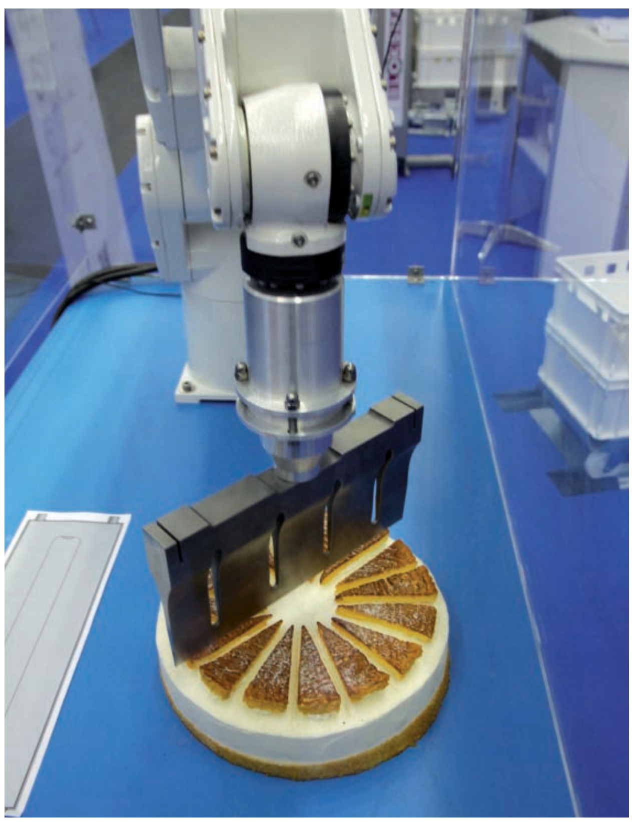


*Fig. 5: Thanks to ultrasonic cutting sonotrodes, robots can even be used to gently portion frozen cream cakes with pinpoint precision.*

question photographed using a suitable camera in suitable light conditions and then transferring these images to a computer. After the images are prepared, there then follows an analysis step that is designed to generate control commands, such as the triggering of an ejector mechanism. Potential criteria for the selection of a suitable image processing system include environmental conditions, production speed, guidance precision, isolation of products and product diversity.

The complex analyses available today were only made possible by the introduction of logic-based image analysis by ‘perceptrons’, multi-layered neural networks similar to the ones that evolved naturally in our nervous systems.

## Gripper technology

Another highly relevant aspect in the automation of processes using robots is gripper technology, and there are two main points to mention here. Firstly, solutions are required that can cope with both the physical and mechanical properties of the food being produced, because the grippers must be able to handle the product without leaving any visible marks on it. Secondly, the gripper systems also have to meet the high hygiene standards of the food industry in every regard. Hesse defines grippers as sub-systems of handling equipment that temporarily come into contact with a gripped object. They secure position and orientation in relation to the handling device when picking up and depositing objects. The term ‘gripper’ is also used when the action is not strictly a ‘grip’ but instead a kind of holding action, as with vacuum suckers. Most grippers work on a mechanical, pneumatic, pneumostatic/pneumodynamic, electric or adhesive principle, almost all of which are appropriate for use in the handling of food. Although significant progress has been made in the field of grippers in recent years, there is still much work to be done before the diverse requirements of the various branches of the food industry can be properly met.

One of the more recent developments in the field of grippers was pioneered by the German Institute of Food Technologies (DIL) in Quakenbrück. The idea was to create a gripper system that could be used universally, was simple to clean in its entirety, and was versatile enough to cope with the diverse demands of the food industry. To give the system the requisite flexibility for handling of food with highly variable dimensions, the developers opted for the vacuum gripper principle. Negative pressure between the gripper and the surface of the food creates the holding force for the product. Unlike with previous vacuum grippers, hygiene was a major consideration in the design of the system. For example, the negative pressure is created within the gripper itself, meaning there are no pipes or tubes whose insides can be contaminated. Furthermore, all parts of the gripper are made from either food-grade stainless steel or food-grade plastics. The gripper itself comprises a universally applicable HDHF vacuum generator that is combined with a product-specific gripping cover.

Bringing together all relevant developments in robotics and associated disciplines and implementing these in new robot models is just one side of the coin, however. In industrial environments, the robots also have to synchronised with each other and with the other components of a manufacturing process or production line, which is where the IT and system specialists come in.


*Fig. 6: HDHF grippers use vacuum suckers to handle food hygienically*

## The first robot in food production – not just a technology matter

Using a robot for contact-based food production tasks for the first time involves much more than just making the right technological decisions. The entire operation has to be brought on board in an often protracted and time-consuming process. Each individual has to be persuaded of the merits of the project, for which a variety of arguments can be used. At the end of the process, everyone in the company has to believe that they are among the vanguard of the industry and at the cutting edge of technology. And ‘the whole company’ does actually mean ‘the whole company’, starting with the CTO and management board and moving down through the product committee, quality management

*Fig. 7: HDB gripper for stable-form foods with rough surfaces*

team, shopfloor managers, maintenance technicians, works council and all members of the workforce. With everyone on board, the technical side of things will then take care of itself.

**The 'human colleague'**

What traits does the robot's 'human colleague' have to have in order for the robot to be deployed as effectively as possible. There are not yet any clear notions or even a clearly delineated job profile for this, and there cannot yet really be any because of how young the field still is. Although the role of mechatronics engineer has now become established as a profession in its own right, the men and women who work in this field lack knowledge about food processing and in particular the hygiene aspects related to this. An alternative would be to train specialists in food technology in the relevant areas of mechatronics/electronics. The decision as to which path seems the most prudent should be made as soon as possible so that the training organisations can prepare themselves accordingly and ensure a supply of skilled workers.

At present, training is mainly being provided by the robot manufacturers themselves or by chambers of industry and commerce. Just recently, universities have also begun to offer industry-oriented courses in applied robotics. The WIR robotics training initiative (http://www.robotik-weiterbildung.de/) set up by the Bremen Center of Mechatronics, for example, offers short training courses in the fundamentals and specifics of food industry robotics as well as a modular, two-year degree at the University of Bremen.

*Fig. 8: Articulated robot being used to package meat*

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