WHITE PAPER

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Vision Technology in Robotics - with a Sense of Sight for More Flexibility

Machines and robots equipped with the power of vision can achieve more and be used more flexibly. What are the possible applications of cameras and image processing systems in combination with robots? What do you have to pay attention to?

Content

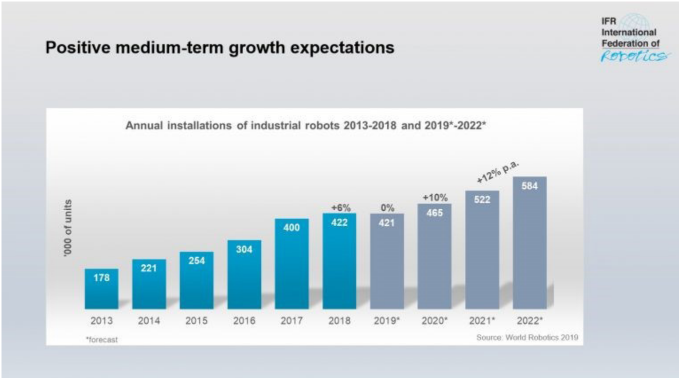

Figure 1: According to the latest World Robotics Report of the International Federation of Robotics (IFR), 422,000 robots were delivered globally in 2018, representing a record sales value of 16.5 billion US dollars.
Picture source: International Federation of Robotics (IFR)

1. Robots in Industry

Around the clock without fatigue, with the same precision and speed, they perform even the most monotonous tasks with absolute reliability - robots. Due to their performance, they have proven to be extremely useful and economical solutions in numerous industrial sectors over the past decades and are therefore being used more and more frequently around the world. According to the World Robotics Report of the International Federation of Robotics (IFR), 422,000 robots were delivered globally in 2018 and a remarkably high average growth rate of 12 percent per year is expected between 2020 and 2022.

Singapore is the world leader in the use of these flexible handling devices: in 2018, 831 robots were working there per 10,000 employees. In this statistic, Germany ranks an impressive third place with a robot density of 338 robots per 10,000 employees worldwide. This technology thus plays a significant role in the high level of automation, which is essential for the economical production of all types of goods, especially in high-wage countries.

2. Large Variety of Robots

Robots exist in various designs, sizes, force ranges and accuracy classes. This variety has resulted over time from the most diverse fields of application for which these handling devices were developed. Examples of typical industrial applications include:

- Handling robots that can be used to move parts of the most varied types and which are often used to remove heavy loads and replicate very fast or precise motion sequences from people
- Palletizing and depalletizing robots that automatically place pallets and packages on--or remove them from--load carriers,
- Welding robots for spot or path welding, which are very widespread, especially in automobile production for welding vehicle bodies

- Adhesive robots that--for example--insert car windshields into the body opening provided for this purpose,
- Painting robots, which are also frequently used in the automotive industry,
- Assembly robots which assemble individual components to form a defined product or subsystem, and
- Many other robots that are specially designed to perform specific tasks, such as cleaning, deburring, testing, measuring, marking or labelling, as well as surface treatment and many other purposes.

In addition, a special type of robot has been developing in industry for some years now: so-called collaborative or collaborating robots (often referred to as cobots) are specially designed to work directly with humans and to support them in complex or not fully automated tasks. Due to the close cooperation with human colleagues, special protection regulations exist for this type of robot to avoid endangering the humans involved.

Figure 2: Cobots are specially designed for direct cooperation with humans.

3. Classification According to Kinematics

Based on their kinematics, industrial robots can be divided into different classes.

- Gantry robots are constructed in gantry design; they usually have large dimensions and are particularly suitable for transport tasks.
- Articulated arm robots (often referred to as jointed-arm robots) have a serial axis arrangement and are particularly suitable for complex motion sequences. A further distinction is based on the number of axes available, which is usually a maximum of six.
- Robots with parallel axes, including hexapod and delta robots. These mostly very light and fast robots are often used for packaging, sorting and assembly tasks.

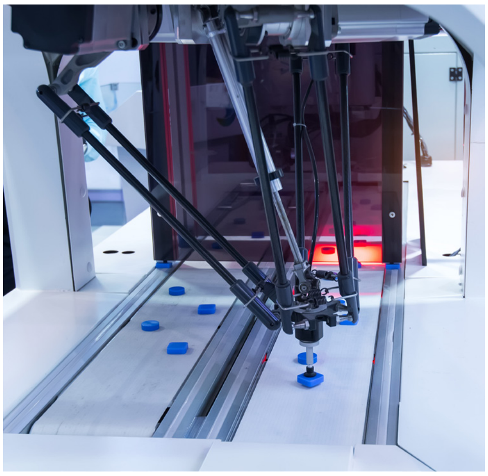

Figure 3: Delta robot

Depending on the area of application, there are also other robot classes such as dual-arm robots, which are usually designed for low payloads of up to 20 kg, or SCARA robots (Selective Compliance Assembly Robot Arm), which often work with very high precision and-for example-move workpieces from defined positions to an assembly location and join the parts together there.

Figure 4: Articulated arm robots often have up to six serial axes and enable complex motion sequences.

4. Gripper as Interface to the Objects

Before a robot can move an object, it must first grip it. The variety of possible shapes, sizes and weights of the objects that robots handle in the various areas of application naturally necessitates an equally wide selection of possible gripping systems and their basic physical principles.

Mechanical grippers exist in an almost infinite number of different versions, including simple parallel or angular grippers with two fingers, and models with a large number of gripping elements.

Magnetic grippers use magnetic attraction force to securely hold ferromagnetic objects. Grippers of this type are often based on a permanent magnet that is activated by compressed air or vacuum. They are relatively compact and are characterized by a high holding force.

With vacuum grippers, negative pressure and suitable suction cups provide the necessary holding force. Prerequisites for the use of these gripper types are smooth object surfaces and materials that are as air-impermeable as possible, in order to pick up the gripped objects securely and not lose them during the movement through the handling device.

Figure 5: The use of vacuum grippers to pick up objects is widespread among robots.

5. Complex Programming

To move to the desired positions exactly and at the required speed, and to carry out machining or gripping operations, these robot controllers must be programmed by the user. They can be accessed via various programming languages that make it easier for users to create the desired motion profiles.

In robot programming, a basic distinction is made between offline and online methods. For offline programming, there are numerous approaches, from text-based methods to 3D simulations, all of which have the goal of virtually mapping the robot, its controller and the desired motion sequences as accurately as possible, taking the environment into account, while eliminating the risk of collision with adjacent systems. The robot to be programmed is not yet integrated in its final position in a system.

In contrast to offline methods, online methods require plants or production processes to be interrupted if robots need to be programmed or adjustments have to be made. The most common way of programming robots directly in a plant is still teaching the desired movements and positions using an operator terminal. However, this procedure takes a relatively long time, as the individual positions have to be approached with slow movements, and confirmed for storage. During such set-up procedures, the production process of the associated system parts must be stopped.

To minimize these unproductive periods of time, the trend in robot programming has therefore been moving towards virtual methods and suitable simulation tools for years. In addition, the tools for programming robots are becoming simpler and simpler, and can increasingly be operated by employees who do not necessarily have many years of experience in this field. New software products such as drag&bot, from the Stuttgart-based drag and bot GmbH, rely among other things on graphical programming interfaces, and thus make commissioning considerably easier. In addition, the current trend towards artificial intelligence has also arrived in robotics, where it already allows robots to make their own decisions within certain limits and act largely independently to solve unforeseen situations independently.

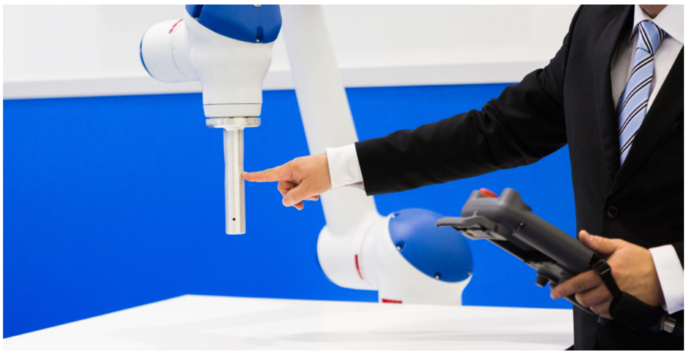

Figure 6: Teaching a robot with the aid of an operating terminal takes a relatively long time, which is why offline methods are increasingly being used.

6. Achieving Even More with the Power of Vision

Modern industrial robots usually have a certain amount of sensor technology--for example, to detect the presence of gripped parts. However, the data that can be recorded by conventional sensors only provide limited information. Clear advantages are offered here by systems that have an image processing system and can collect and evaluate considerably more details in this way. Robots in combination with a vision system have a considerably better basis for decision-making based on evaluated camera images, so that they can react flexibly to unforeseen situations. Robots can also cause high costs and downtimes, e.g. if they damage workpieces or other automation devices through incorrect movements. Here, too, camera systems help to increase the reliability of plants with integrated robots.

In addition to avoiding such undesirable situations, „seeing robots“ offer many other advantages: they enable more flexible processes, since the evaluated image data can be used to precisely control the robot movements. Even simple gripping tasks of components from a defined position can fail without the use of image processing--for example, if a component does not arrive at the expected position exactly where a robot is supposed to pick it up. In many cases, this does not present a problem for a robot system extended by a vision system: a camera takes an image of the incorrectly positioned component, the subsequent image evaluation calculates its position deviation and passes the corrected 2D or 3D gripping coordinates to the robot controller. Within process-dependent limits, this ensures that components are picked up safely.

7. Pick & Place and the Grip into the Box

In many manufacturing companies there are tasks that are constantly being repeated. These include the pick-up, positioning and, after carrying out a machining process, the subsequent depositing of workpieces. The term pick & place has become established for picking up and later depositing parts. With the aid of special handling equipment or suitable robots, these activities can be carried out safely, without fatigue, with maximum precision and economy.

If the components to be gripped cannot always be picked up at exactly the same position, the combination of pick & place robot and vision system offers an extremely powerful duo: The vision system detects the positional deviation of the part to be picked up and passes this information on to the robot controller. On this basis, it is then easy for the pick & place robot to approach the corrected gripping position and pick up the part safely and feed it to the next processing step.

The supreme discipline of picking up components is the so-called gripping into the crate: Sophisticated vision systems are required to be able to grip parts lying in a disorderly mass in a container, via a robot. They detect the next grippable component and determine its exact 3D position and pass this information on to the robot. Without the use of image processing, this task would be unsolvable in many cases according to the current state of technology.

Figure 7: Pick & Place robots pick up parts and place them safely, without fatigue and with maximum precision at another location.

8. The Correct Setup of the Vision System is Crucial

Which machine vision system is best suited for combination with a robot in a particular application depends on a number of factors. A basic criterion here is the positioning of the camera in the system: It can, for example, be permanently installed above a robot cell („off-arm“) or attached directly to the robot arm („on-arm“). In the second scenario, the robot‘s „sense of sight“ is available very close to the action or the gripper, but the movements require the lowest possible camera weight, a high degree of robustness in terms of acceleration and vibration, and well thought-out, robot-compatible cable routing.

Before a „seeing“ robot can be implemented, the basic question must also be answered as to whether a conventional industrial camera or a so-called intelligent camera (or smart camera) is more suitable for the task. With smart cameras, the evaluation of the recorded images takes place directly in the camera housing, whereas industrial cameras pass on their images to a PC system for evaluation, which usually allows higher accuracy and speed for image processing than intelligent cameras. Both architectures have their advantages and disadvantages, so that criteria such as the required precision, the speed of the processes and movements, the type of industrial environment and the resulting necessary protection class of the vision system, the load capacity of the robot, and the preferred interfaces for communication or other boundary conditions decide which vision system is the optimal solution for the respective application.

However, the camera is not the only decisive factor for the successful use of vision systems in robotics. An important element for every machine vision system is the lighting. Only with lighting that is optimally adapted to the task at hand are cameras able to capture images in the required quality to enable reliable evaluation afterwards. The optics used also play an important role in image acquisition. In robotic vision applications with on-arm architectures it must be ensured, among other things, that vibrations and accelerations do not lead to changes in the settings, such as the aperture. Autofocus lenses can be a useful solution for frequently-changing working distances. Particularly in on-arm applications, even the cabling of the vision system has an important influence on the stability of the entire system: due to the constant movements of the robot, special torsion- and bending-resistant cables and, if necessary, drag chains should be used to ensure that communication functions correctly in the long term.

Figure 8: The constant movements of a robot require special torsion- and bending-resistant cables and, if necessary, drag chains.

9. Robot Vision Made Easy

In addition to the selection of the optimal vision hardware for a „seeing“ robot cell, the software also plays an essential role in making such systems economically successful. As a rule, robots, the possibly-required grippers, the cameras used and sometimes even lighting systems work with their own proprietary controllers. The integration of all subsystems involved, their programming and control as well as ensuring smooth communication at all levels therefore requires well thought-out concepts. The total costs for the implementation of such systems often result, to a large extent, from the length of the development time. The question of whether the complex tasks can be solved with minimum effort using suitable software and appropriate programming tools is therefore crucial.

Some manufacturers of image processing components recognized years ago the opportunities that arise from combining robotics and image processing. To make the interaction of these two automation areas easier for users, software approaches to connect both worlds are now available. Basler is breaking new ground in this area and has already developed various camera drivers for the open source project ROS (Robot Operating System). It includes software libraries and tools that support the creation of various robot applications and provide development tools, algorithms, and drivers for a variety of robot platforms. ROS can process a large number of executable files in parallel and exchange them between the existing systems synchronously or asynchronously. In practice, this data is usually generated from sensor queries and, after processing, is used to initiate specific robot actions. With its ROS-compatible camera drivers, Basler makes it easy for users to use GigE and USB 3.0 cameras in robotic applications

10. Opportunities for Industry

The implementation of „seeing“ robots is not a trivial task. However, the attractive opportunities offered by the high reliability, precision and consistency of robots, and the combination with an additional sense of sight, justify the efforts in many cases. Robot vision has therefore become an indispensable element of production for many companies of all sizes, enabling innovative, flexible and economical solutions in numerous industrial fields of application.

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Sören Böge is responsible for the new Basler ace 2 camera platform and the entire lifecycle of the existing mainstream portfolio.

After graduating with a degree in industrial engineering, he worked for many years in the automotive industry as a Product Director and Project Manager for a measurement system. Since 2015 Sören Böge has been employed in product management at Basler.

About Basler

Basler is an internationally leading manufacturer of high-quality cameras and accessories for applications in factory automation, medicine, traffic and a variety of other markets.

The company's product portfolio encompasses line scan and area scan cameras in compact housing dimensions, camera modules in board-level variants for embedded vision solutions, and 3D cameras. The catalog is rounded off by the user-friendly pylon SDK and a broad spectrum of accessories, including a number developed specially for Basler and optimally designed for the Basler cameras. Basler has 30 years of experience in the area of computer vision. The Basler Group is home to approximately 800 employees at its headquarters in Ahrensburg, Germany, and its additional sites in Europe, Asia and North America.

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