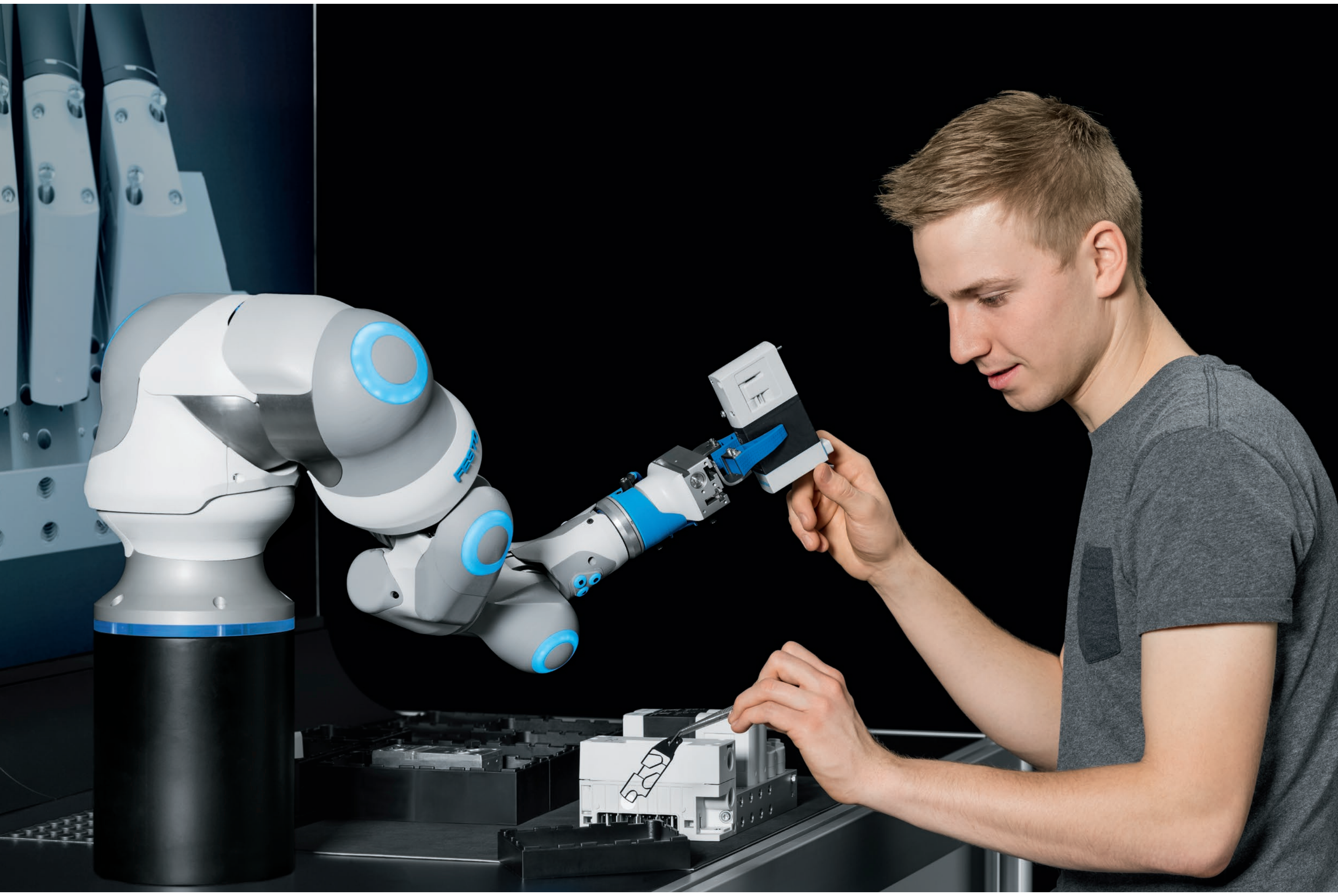
BionicCobot

Sensitive helper for human-robot collaboration



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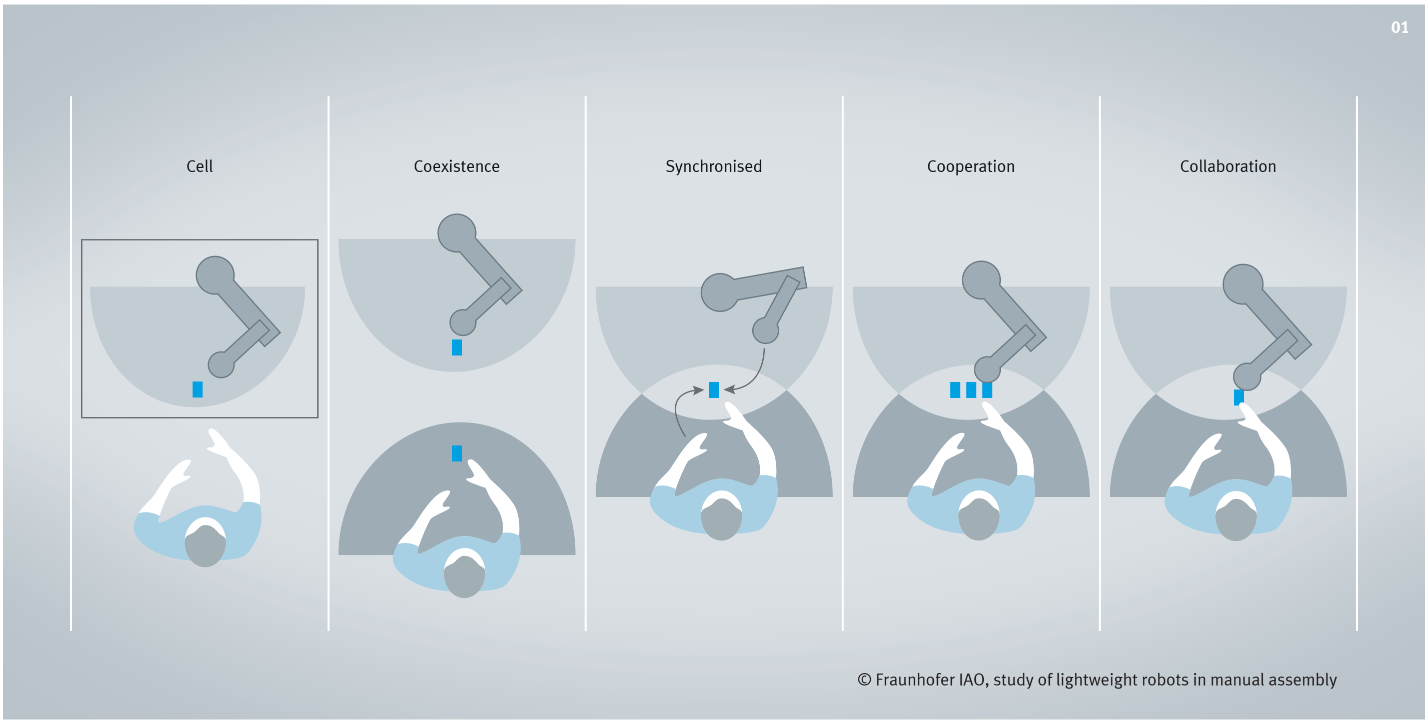


Whether it is shorter lead times, faster product life cycles or high flexibility with regard to quantities and variety, the requirements of the production of the future are manifold and are changing faster than ever before. This industrial change requires a new way for humans, machines and data to interact.

Besides the digital networking of entire facilities, above all robot-based automation solutions, which work hand in hand with people, play a critical role in this development. In the production of tomorrow, direct interaction between man and machine will be part of the daily routine.

Collaborative working spaces of the future

The strict separation between the manual work of the factory worker and the automated actions of the robot is being increasingly set aside. Their work ranges are overlapping and merging into a collaborative working space. In this way, human and machine will be able to work together on the same workpiece or component simultaneously in future – without having to be shielded from each other for safety reasons.

Being at the forefront of industrial automation, it is Festo's core business to help shape the production and working worlds of the future. A key element for coming up with ideas is the Bionic Learning Network. In an alliance with external partners, Festo looks for natural phenomena and operating principles that can be transferred to technology.

Paradigm shift in robotics

At the focus of the current research work are lightweight bionic robots, which due to their natural movement patterns and the pneumatics employed are almost predestined for collaborative working spaces and in future will be able to represent a cost-effective alternative to classic robot concepts.

The strengths of pneumatic drives have always lain in their simple handling and robustness, the low costs of acquisition and their high power density – in other words comparatively large forces in a small space and with a low weight. Holding processes get by without further compressed air consumption and are therefore extremely energy efficient.

01: **Collaborative working space:** Simultaneous, common processing of a workpiece by human and robot

02: **Conceivable future scenario:** The BionicCobot as a supporting assistance system in assembly

For direct contact between human and machine, pneumatics offer another critical advantage, however: their system's inherent flexibility. If an actuator is filled with compressed air, the motion generated can be exactly set in terms of speed, force and rigidity. In the event of a collision, the system eases off, thus posing no risk to the worker.

To be able to adjust the whole system to any settings in its dynamics, the valve technology used must be able to control the air flows and pressures with extreme precision and at the same time ensure the complex interconnections of many channels.

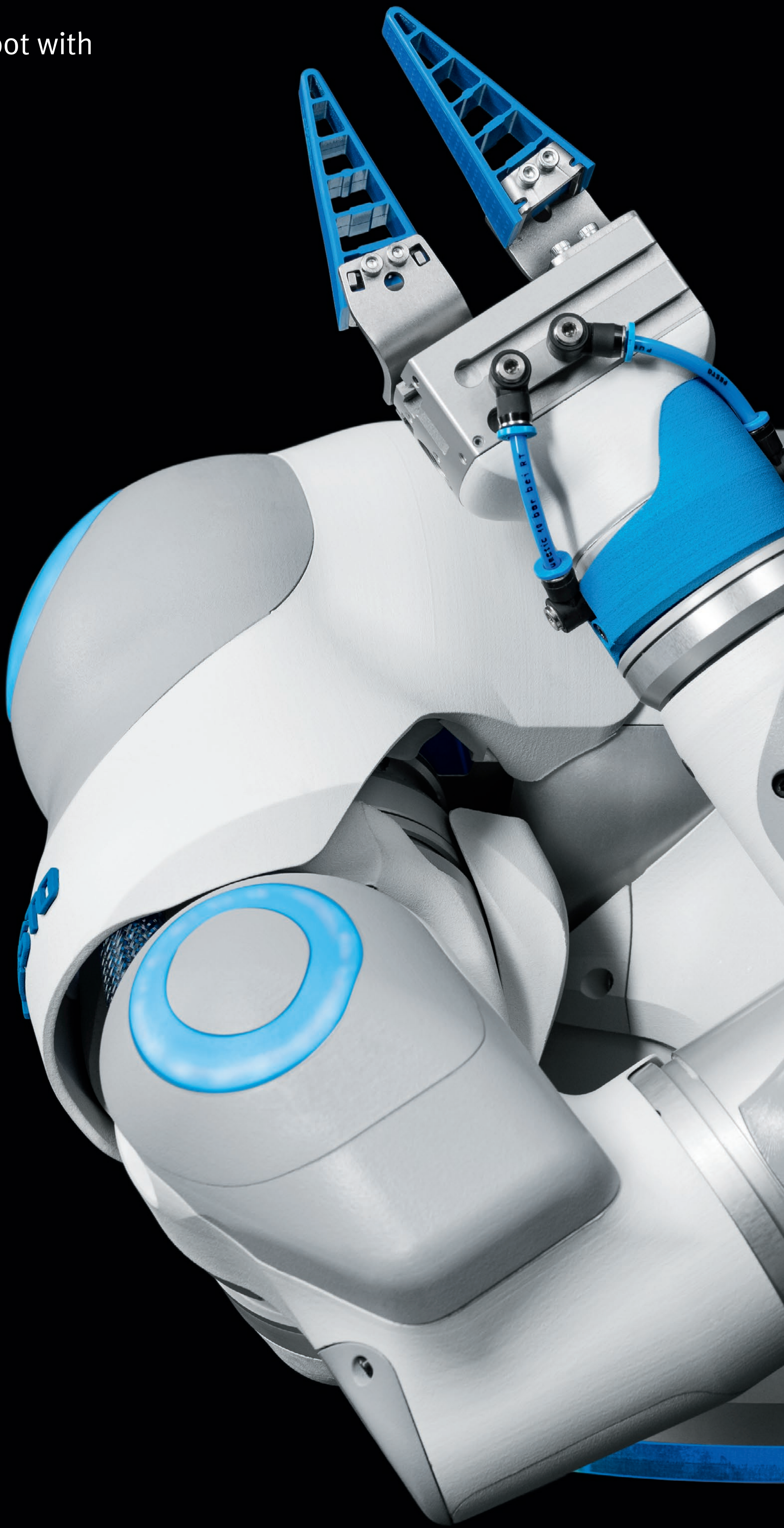
Digitisation of pneumatics
What could only be implemented with a great deal of effort until now is made easily possible by a world first from Festo: the Festo Motion Terminal is the first pneumatic automation platform, which, using its software control system, combines the functionalities of over 50 components using apps. Digitisation is opening up completely new areas of application for pneumatics, which until now have been the reserve of electrical automation.

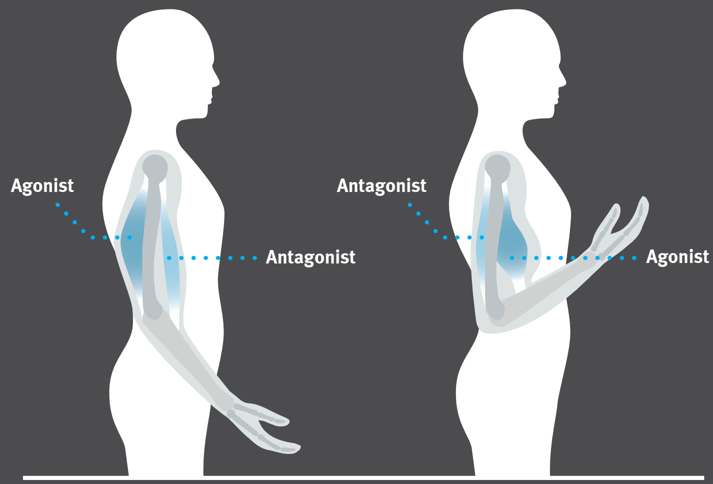
Festo Motion Terminal for controlling complex kinematics
The Festo Motion Terminal combines high-precision mechanics, sensor technology as well as control and measuring technology in the tightest space. With the internal control algorithms of the Motion Apps and the installed piezo valves, flow rates and pressures can be exactly dosed and also varied to any setting in several channels simultaneously. That enables both powerful and fast, as well as soft and sensitive motion sequences.

Flexible robot arm with seven degrees of freedom
With the BionicCobot, Festo has now developed a pneumatic lightweight robot with seven degrees of freedom for the first time, which due to this flexibility can work together with humans directly and safely.

In terms of its kinematics, the robot is based on the human arm. Like its biological role model, it solves many of its tasks with the help of sensitive movements. Due to its unique drive concept, which works according to the agonist-antagonist principle, the motion dynamics and rigidity can be variably adjusted.

BionicCobot
Pneumatic lightweight robot with human motion dynamics





The natural model

Whether it is gripping powerfully or lifting carefully, pressing firmly or touching gently – for us humans to be able to execute a movement, the interaction of counteracting muscles is always necessary. This principle of agonist (player) and antagonist (opponent) also influences our daily routine where we perhaps do not even suspect it: we solve many tasks not with precision and accuracy, but do so with flexible and supple movements. If, for example, we put our house key into the door lock, the key finds its destination even without us looking closely at it. If the door is opened from the inside, we automatically give way and follow the movement with appropriate care.

The technical implementation

By applying the agonist-antagonist principle, the BionicCobot takes advantage of the natural mechanism of biceps and triceps. The interaction of flexor and extensor takes place not only in the robot's upper arm, however, but in all seven joints. There are three axes in its shoulder area, one each in the elbow and lower arm plus two axes in the wrist. In each axis there is a rotary vane with two air chambers. These form a pair of drives, which can be infinitely adjusted like a mechanical spring by filling them with compressed air.

The industrial benefit

The BionicCobot's movements can thereby be controlled powerfully and dynamically, but also sensitively and flexibly depending on the situation. Even in the event of a collision, the system poses no danger and does not have to be shielded from the worker like a conventional factory robot. Based on this safe interaction, the natural motion sequences and its intuitive operability, the BionicCobot has great potential in a wide range of industries: especially when it comes to monotonous or risky activities, it could be used as an assisting robot and relieve humans.

Mode of operation and potential uses

For a safe and more ergonomic future working world

01

The BionicCobot is operated intuitively by means of a graphic user interface developed in house. The user can use a tablet to quite easily teach the actions to be performed and set their parameters. In this respect, the defined work steps can be arranged in a timeline in any order using drag and drop. In doing so, the complete motion sequence is virtually depicted and simulated at the same time.

Software architecture with three levels

The interface between the tablet and the Festo Motion Terminal is the ROS (Robot Operating System) open source platform, on which the kinematics' path planning is calculated. In addition, the ROS interprets the incoming code from the tablet and forwards the resulting axis coordinates to the Motion Terminal.

Based on the coordinates received, the Motion Terminal can use its internal algorithms to regulate the respective pressure in the air chambers and hence determine the position of the individual axes. The incoming sensor data from the seven joints is also channelled into the actions in real time.

Construction and drive concept based on a natural role model

The construction of the BionicCobot is the same as the human arm from the shoulder to upper arm, elbow, ulna and radius down to the wrist and the gripping hand.

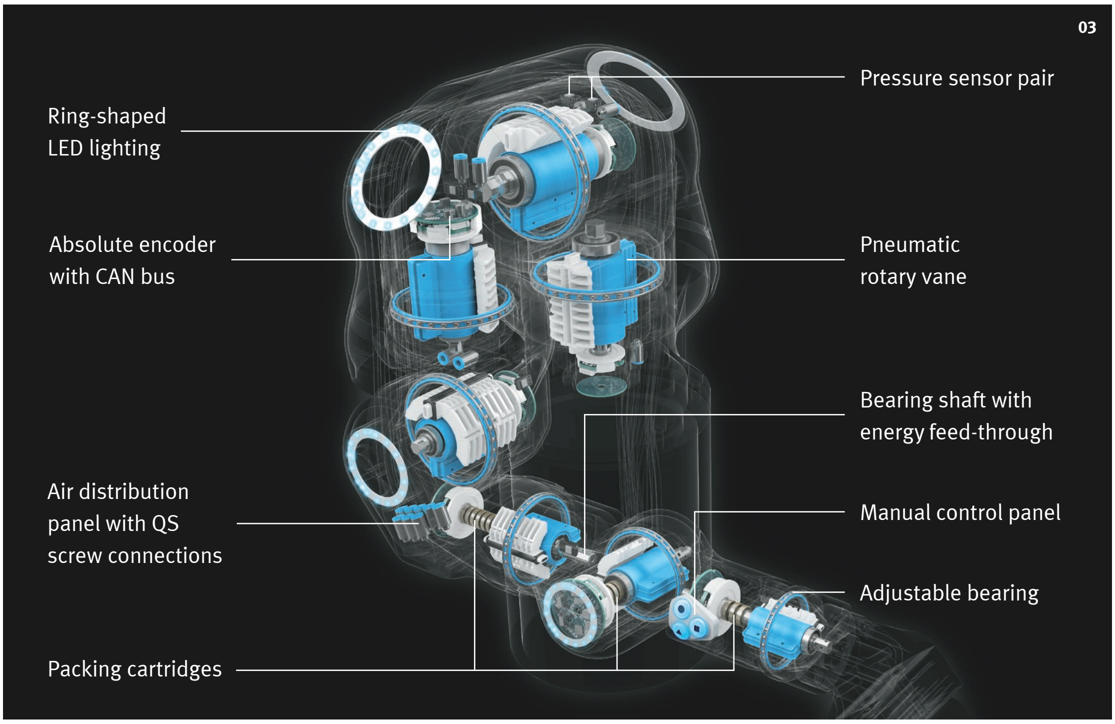
Like the blood vessels and nerve fibres in the human body, the compressed air lines run safely inside the construction and thus cannot become bent. They supply the pneumatic rotary vane drives, which are located in the seven joints of the robot arm. Installed in each joint are also two pressure sensors and an absolute encoder with CAN bus for determining the positional data.

If compressed air is supplied to the air chambers in the drives, the rotary vanes move in a certain direction, which is transferred to the integrated bearing shafts. From the elbow downwards, all the lines down to the gripper are laid directly through the shafts. Special packing cartridges enable this rotary through-feed of up to six channels, of which two air lines ultimately supply the gripper. Depending on the task, different gripping systems can be connected to the BionicCobot.

01: **Intuitive operability:** The robot arm can easily be taught using the tablet interface

02: **Safe handling:** The manual control panel and one of the LED rings for communication with the user

03: **Sophisticated interaction:** The new drive concept of the seven-axis robot arm



The technical implementation of the agonist-antagonist principle allows the force potential and hence also the rigidity level of the robot arm to be exactly determined. In so-called balancer mode, the BionicCobot is controlled in such a way that it balances gravitational force and payload and can calmly hold a desired position immediately. The holding process is done almost without energy and is ideal for assembly activities.

Safe collaboration and high user acceptance
Apart from the tablet interface, the user also has a manual control panel on the gripping joint at their disposal. The robot can communicate with the user via signals from the blue LED lighting on the joints – for instance to indicate a waiting mode or to send warnings.

If, despite this, there is a collision, the robot arm automatically gives way and poses no danger for humans. By using pneumatic semi-rotary drives, the system cannot overheat. In addition, the natural movements of the bionic robot arm create a sense of familiarity for the user, which increases acceptance for working together.

Many possible applications to relieve humans
In future, the BionicCobot could relieve humans in many places where monotonous and mindless or even dangerous and unhealthy motion sequences are involved. It improves the ergonomics at the workplace and increases productivity. Particularly in production, manual work, service or maintenance, the pneumatic lightweight robot could be used to partly automate work steps simply and economically.

Conceivable future scenarios
In future the system can be flexibly extended and enhanced if required: for instance by adding speech control, image processing, infrared tracking or artificial intelligence. The specially developed software technology, such as the user interface, can also be transferred to other robot kinematics.

As the BionicCobot can also work in dirty or unhealthy environments, it is also predestined for use in telemanipulation: with the aid of VR goggles, a person could be made able to control the robot arm as intuitively as his own arm.

Technical data

Degrees of freedom: 7
Net weight: .... approx. 6 kg
Payload: .... approx. 1.5 kg
Positioning accuracy: .... 1 mm

Software architecture:
- User interface: C# WPF application
- Calculation and path planning: Robot Operating System (ROS)
- Steering and control: Festo Motion Terminal

Pneumatic drive concept:
- 3 pivoting axes, 4 modified rotary axes based on the DRVS semi-rotary vane drive
- 16 compressed air lines
- 7 sintered aluminium bearing shafts
- 7 adjustable Franke wire race bearings
- 15 packing cartridges

Displacement encoder system:
- 14 pressure sensors
- 7 absolute encoders with CAN bus
- 4 CAN bus cables

Project participants

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