

BionicMotionRobot

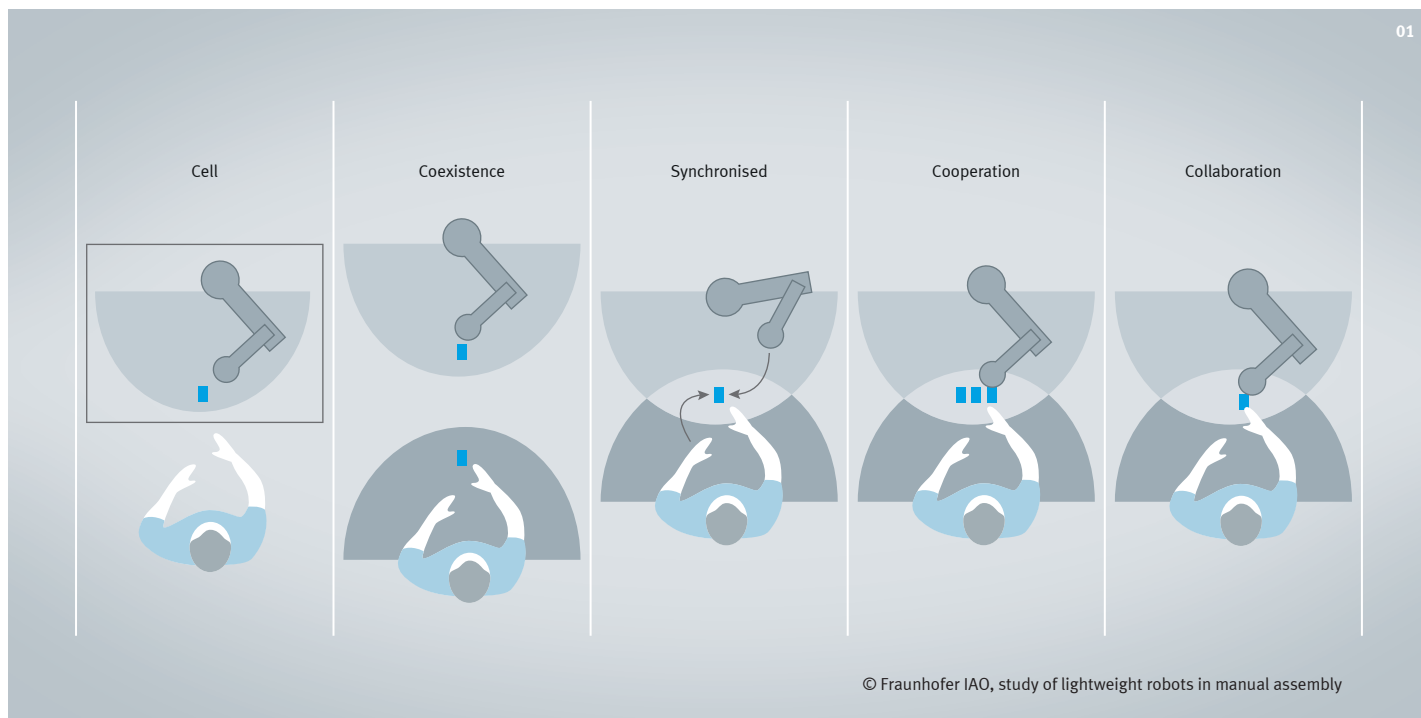
Pneumatic lightweight robot with
natural movement patterns

FESTO



BionicMotionRobot

New approaches for human-robot collaboration



Sensitive and gentle or powerful and dynamic – in terms of its movements and functionality, the BionicMotionRobot is inspired by an elephant's trunk and an octopus's tentacles. The pneumatic lightweight robot features 12 degrees of freedom and, with its flexible bellows structure, can effortlessly implement the fluent motion sequences of its natural role models.

Impressive power to weight ratio

The bionic robot arm has a load capacity of around three kilograms and weighs approximately the same itself. Depending on which gripper is fitted, it can handle a number of different objects and be used for a wide range of tasks.

The concept of the flexible kinematics is based on the Bionic Handling Assistant from 2010, which, due to the safe collaboration between man and machine, was given the German Future Award. Since then, Festo has been looking intensively into systems that could relieve people of monotonous activities and at the same time pose no risk – an aspect that is becoming increasingly important in everyday factory life.

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.

01: Collaborative working space: Simultaneous, common processing of a work-piece by human and robot

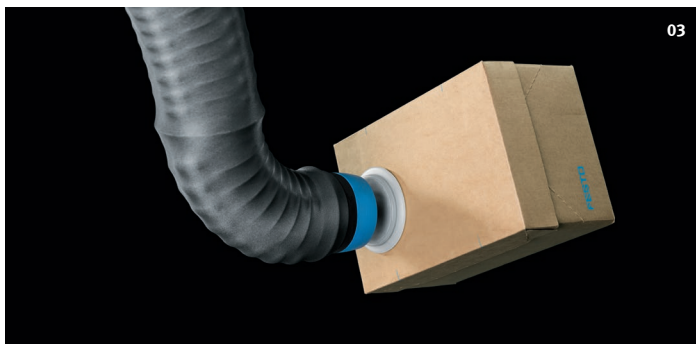
02: Safe handling: The combination of the BionicMotionRobot with the highly elastic TentacleGripper

03: Conceivable scenario: In action with a vacuum suction cup for flat and smooth objects

04: Tremendous power potential: The outstanding ratio of inherent weight and payload



02



03



04

As a worldwide supplier of automation technology, 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.

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.

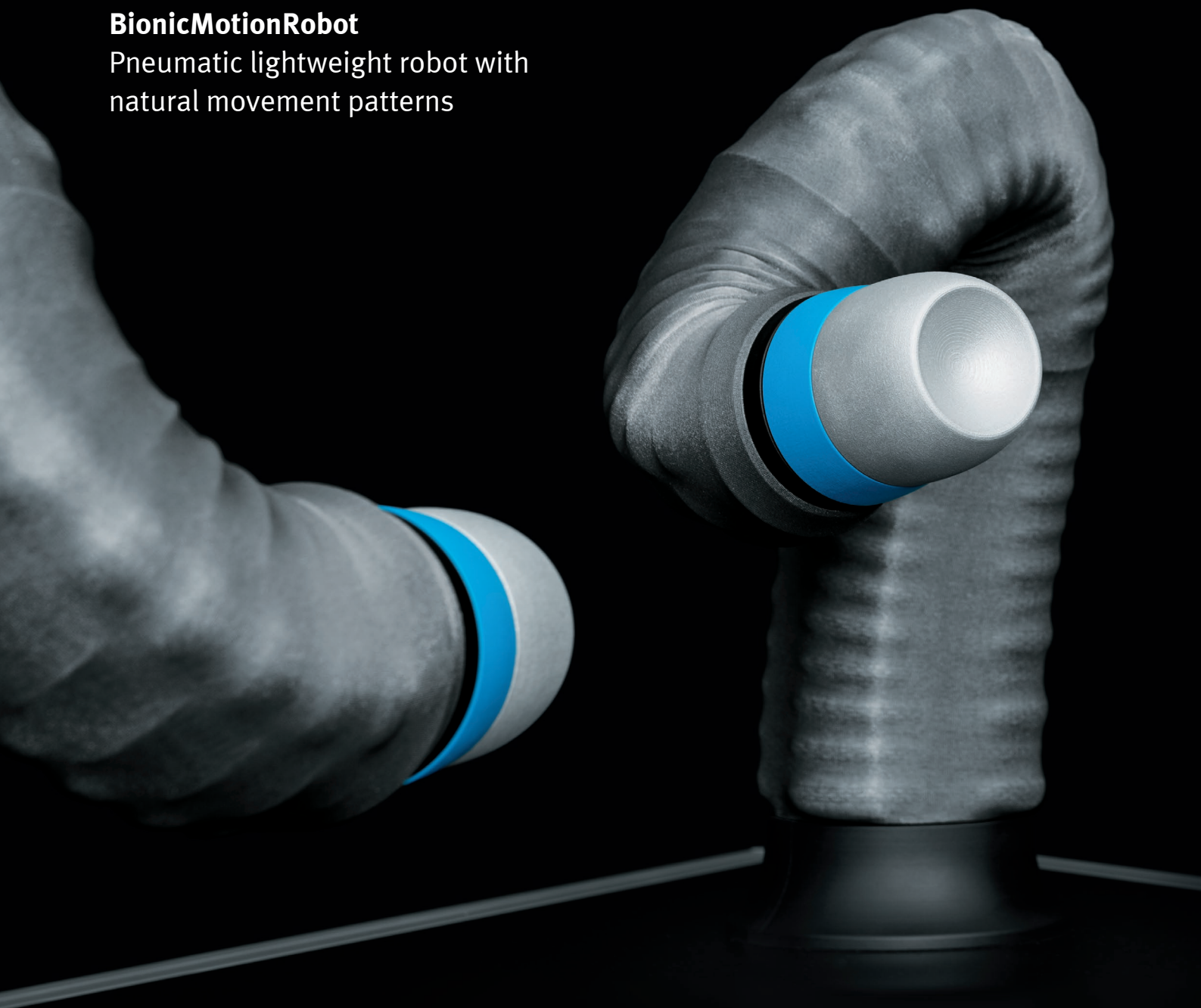
To be able to adjust the whole system to any settings in its dynamics, the valve technology used must be able to control the air flows and pressures with extreme precision and at the same time ensure the complex interconnections of many channels.

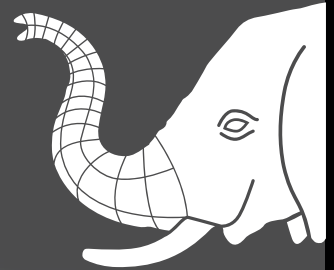
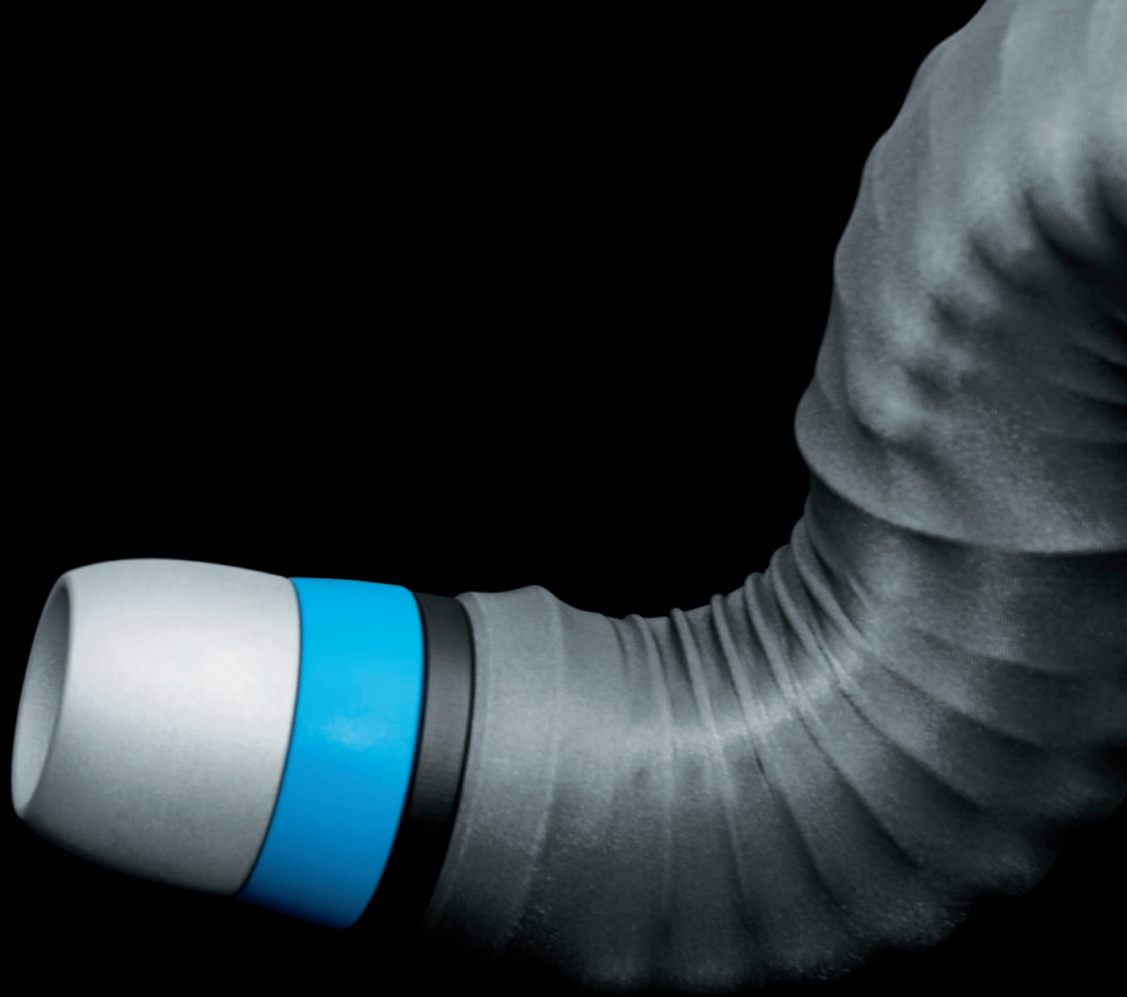
Digitisation of pneumatics

What could until now only be implemented with a great deal of effort 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 has been the reserve of electrical automation.

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Natural role models

An elephant's trunk and octopus tentacles have a special feature in common: due to their slender kinematics, they can master a variety of flexible movement patterns. Soft and supple or powerful and energetic – depending on the required action, they can bend freely and stiffen as much as needed.

The technical implementation

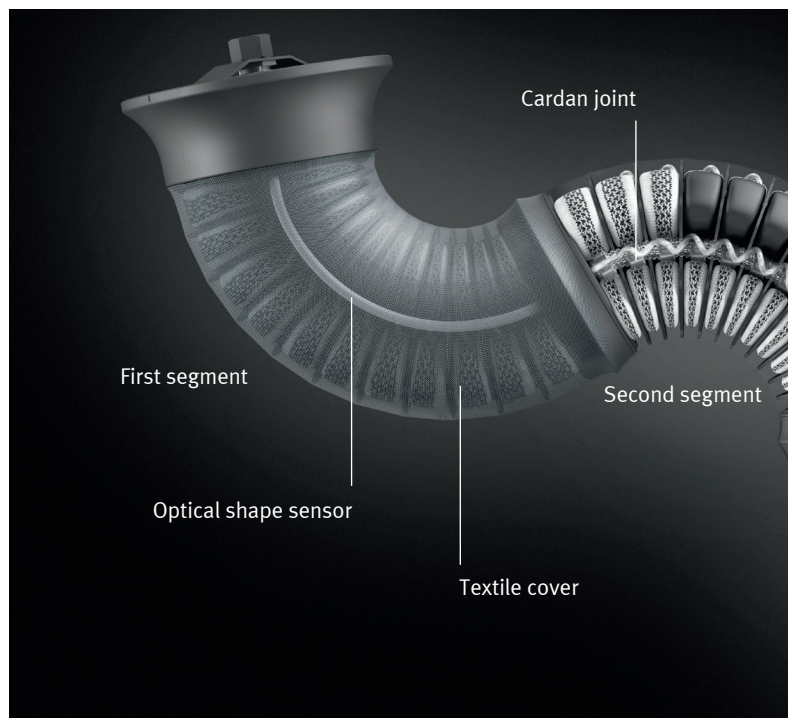
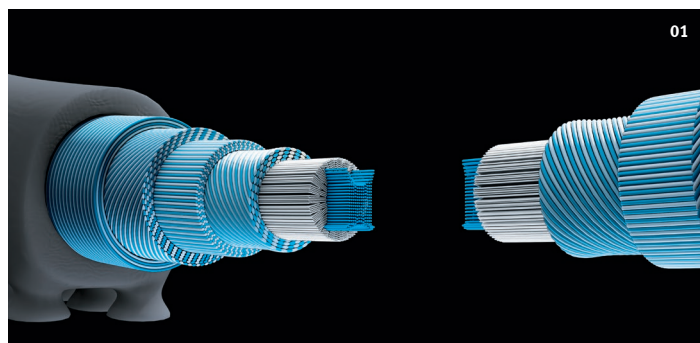
This behaviour can be imitated very well using pneumatic drive units and corresponding valve and control technology. The bellows on the BionicMotionRobot are also covered with a special 3D textile knitted fabric, which reveals another amazing analogy with nature in terms of its function. Just like the muscle fibres in an octopus's tentacle, its filaments are oriented so that they allow the bellows structures to expand in the required direction of movement and at the same time limit this in the other directions. It is only thanks to this new fibre technology that the power potential of the whole kinematics can be exploited.

The industrial benefit

The adjustable rigidity achieved by this enables direct contact between man and machine. In the event of a collision, the system no longer poses a danger and does not have to be shielded from the worker like a conventional factory robot. In this way, the system is able to relieve people from monotonous, strenuous or even dangerous motion sequences and improve ergonomics at the workplace of the future.

Mode of operation and potential uses

For a safe and more ergonomic future working world



The freely moving arm on the BionicMotionRobot is covered with an outer textile skin and consists of three flexible basic segments which can be put together in a modular fashion.

3D textile knitted fabric represents new fibre technology

In each of the three segments, four bellows are fitted which are held together by disk-shaped ribs with a gap of about two centimetres. A cardan joint runs between them, housing the pneumatic actuators and making sure the ribs do not twist. The 12 bellows are made of sturdy elastomer. Each one of them is surrounded by a special 3D textile cover which is knitted from both elastic and high-strength yarns.

For this unique 3D textile knitted fabric, the developers took a closer look at the muscular structure of the octopus: the muscle fibres in the tentacles are aligned differently in several layers. This interaction of radially, diagonally and longitudinally oriented fibres allows the creature to move its tentacles in a targeted manner. Based on this model, the yarns in the 3D textile knitted fabric run around the bellows structures in a special pattern.

If a set of bellows is supplied with compressed air, it can extend lengthways and thereby deflect the joint structure. In the radial direction, the expansion of the elastomer is limited by the fixed threads in the fabric. This means that the textile can be used to exactly determine at which points the structure expands, thereby generating power, and where it is prevented from expanding. This allows very large forces to be generated and turned into movement.

Guidance and control with the Festo Motion Terminal

The complex guidance and control of the 12-bellow kinematics is assumed by a Festo Motion Terminal. It 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.

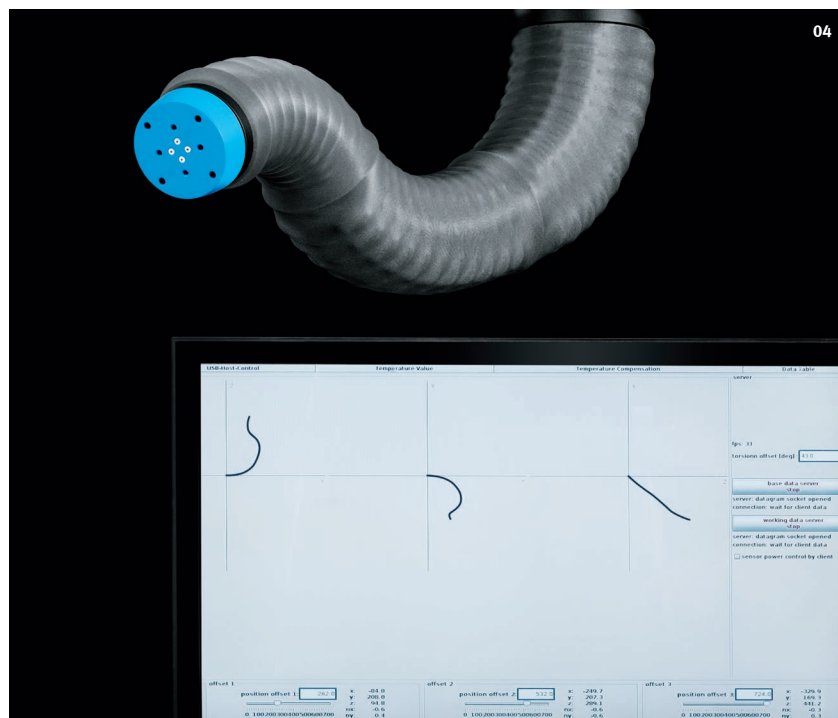
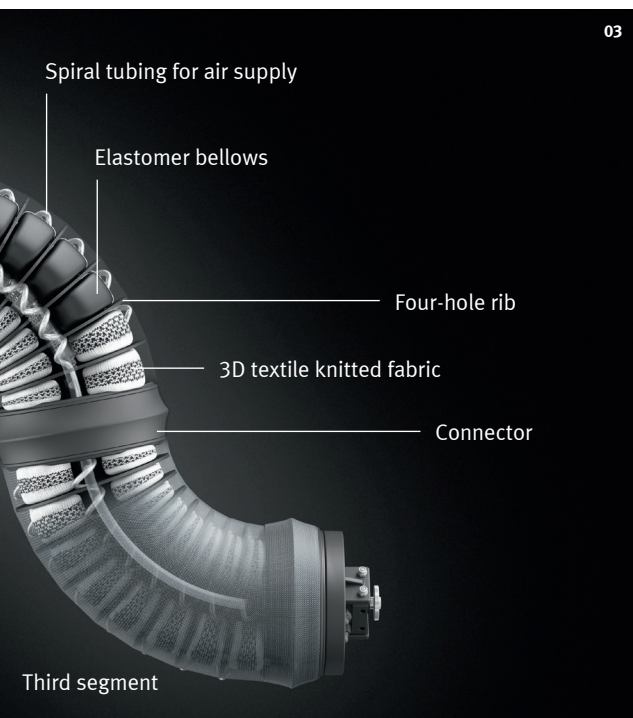
That enables the BionicMotionRobot to perform motion sequences that are both powerful and fast as well as soft and precise – whilst the rigidity of the kinematics is freely adjustable.

01: **A natural role model:** The counter-acting muscles in an octopus's tentacle

02: **A new fibre technology:** The special 3D textile knitted fabric surrounding the flexible bellows structures

03: **Modular structure:** A look inside the pneumatic robot arm

04: **Virtual image:** The shape sensor enables a simulated model of the entire kinematics



Due to its modular structure and this precise control of the flexible bellows structures, the robot arm can bend in three different directions simultaneously and implement the fluent movements of its natural role models.

Optical shape sensor for exact routing

A shared shape sensor is fitted in the cardan joints on the three segments and runs like a cable along the system's whole longitudinal axis. This allows it to record the position, shape and interactions of the whole kinematics and illustrate them virtually. The simulated model of the sensor cable follows the real sensor in real time and thus enables positioning and routing accurate to around ten millimetres.

Many potential uses and application fields

The BionicMotionRobot could be used anywhere that compact, powerful and efficient systems are required. Its pneumatic construction is insensitive to dust and dirt, which also makes an application in polluted and contaminated or unhealthy surroundings conceivable.

Supporting assistance system for assembly

The BionicMotionRobot is virtually predestined to be a helping third hand in the assembly sector. The pneumatic structures can provide relief by holding objects without heating up or consuming additional energy.

A scenario in which the robot arm picks up various workpieces on its own, passes them to a person for processing and then puts them down in another place is imaginable. The worker can thus go about their work in a more ergonomic, precise, concentrated and hence more efficient manner.

High user acceptance and safe handling

The natural movements of the bionic robot arm create a sense of familiarity for the user, which increases acceptance for direct collaboration. In the event of a collision, the pneumatic kinematics automatically ease off and do not pose any danger to humans. This inherent flexibility of the system and the low tare weight allow it to be used without a protective cage, thus making an immediate and safe collaboration between human and machine possible.



Project participants

Project initiator:

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Plastics engineering:

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Helmut Müller, Mattias-Manuel Speckle, Festo AG & Co. KG

Technical data

Total length: 850 mm
Diameter: 130 mm/100 mm
Degrees of freedom: 12
Robot arm weight: 2,950 g
Moved weight: 2,950 g
Working pressure: 3 bar
Repetition accuracy: ±10 mm
Distance between the ribs: 19 mm
Centre distance of the ribs: 21 mm

Steering and control:

Festo Motion Terminal

Sensor technology:

3D-effective optical shape sensor

Actuator technology:

Bellows produced using immersion
method made of natural rubber with
high-strength 3D textile knitted fabric
Gimbally connected ribs made of
carbon-fibre-reinforced polymer

Ribs:

Picture credits

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