

BionicSoftArm

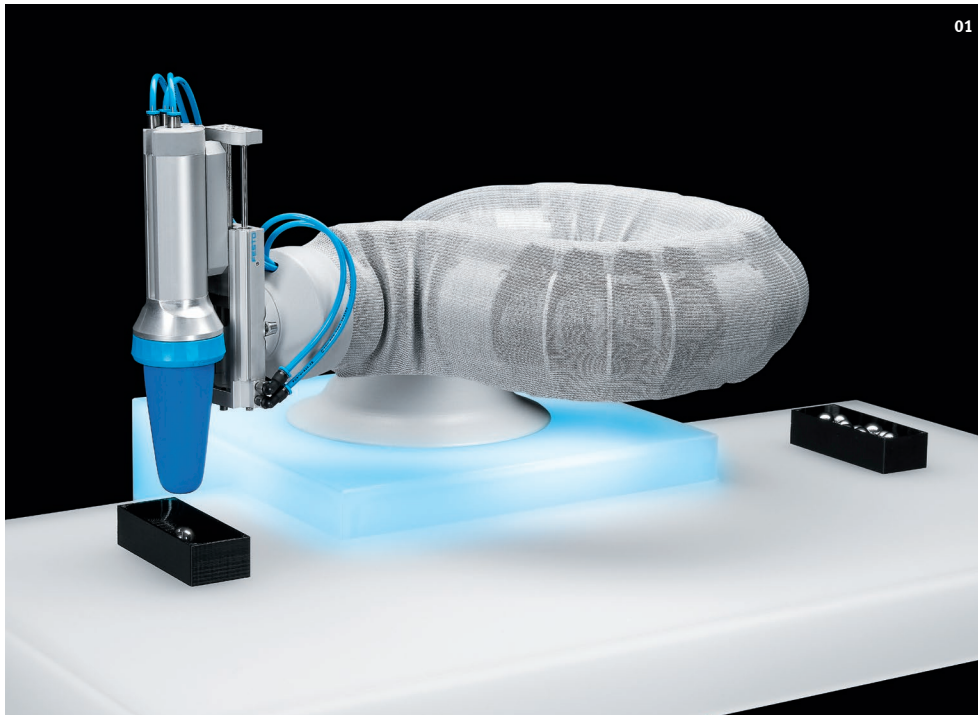
Modular pneumatic lightweight robot

FESTO



BionicSoftArm

Working in collaborative spaces



One robot arm, many variation possibilities: the BionicSoftArm is a compact further development of the BionicMotionRobot, whose range of applications has now been significantly expanded. This is made possible by the modular design of the BionicSoftArm, which can be combined from several pneumatic bellows segments and rotary drives. This enables it to master both free and flexible movements as well as defined sequences. At the same time, it is completely compliant and can work safely with people.

Optimum cover of a wide range of working spaces

Depending on the requirements, the length of the BionicSoftArm can be varied with up to seven pneumatic actuators, thus providing maximum flexibility in working range and mobility. This makes it very easy to implement applications that are difficult to realise with a standard robot.

This allows the BionicSoftArm to work around obstacles even in the tightest of spaces. Direct human-robot collaboration is just as possible as use in classic SCARA applications – for example, pick-and-place tasks.

The concept of flexible kinematics of the BionicSoftArm and BionicMotionRobot is based on the Bionic Handling Assistant. The free-moving gripper arm was given the German Future Award in 2010 for the safe collaboration between human and machine.

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.

Paradigm shift in robotics

The focus here is on pneumatic lightweight robots, which are virtually predestined for collaborative working spaces and may in the future represent cost-effective alternatives 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. This enables them to apply comparatively high forces with a low dead weight. Holding processes get by without further compressed air consumption and are therefore extremely energy efficient.

01: **Classic SCARA application:** picking- and-placing of different objects and shapes with the DHEF adaptive shape gripper

02: **Flexible assistance system:** as a helping third hand in assembly in combination with the BionicSoftHand

03: **Graphical user interface:** for fast programming of processes and intuitive operation



Safe handling due to inherent flexibility of the system

For direct contact between human and machine, pneumatic robots offer another decisive advantage: their inherent flexibility. If an actuator is filled with compressed air, the movement generated can be exactly set in terms of speed, force and rigidity. In the event of a collision, the system automatically eases off and thus poses no danger to humans.

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 simultaneously work together on the same workpiece or component in the future – without having to be shielded from each other for safety reasons.

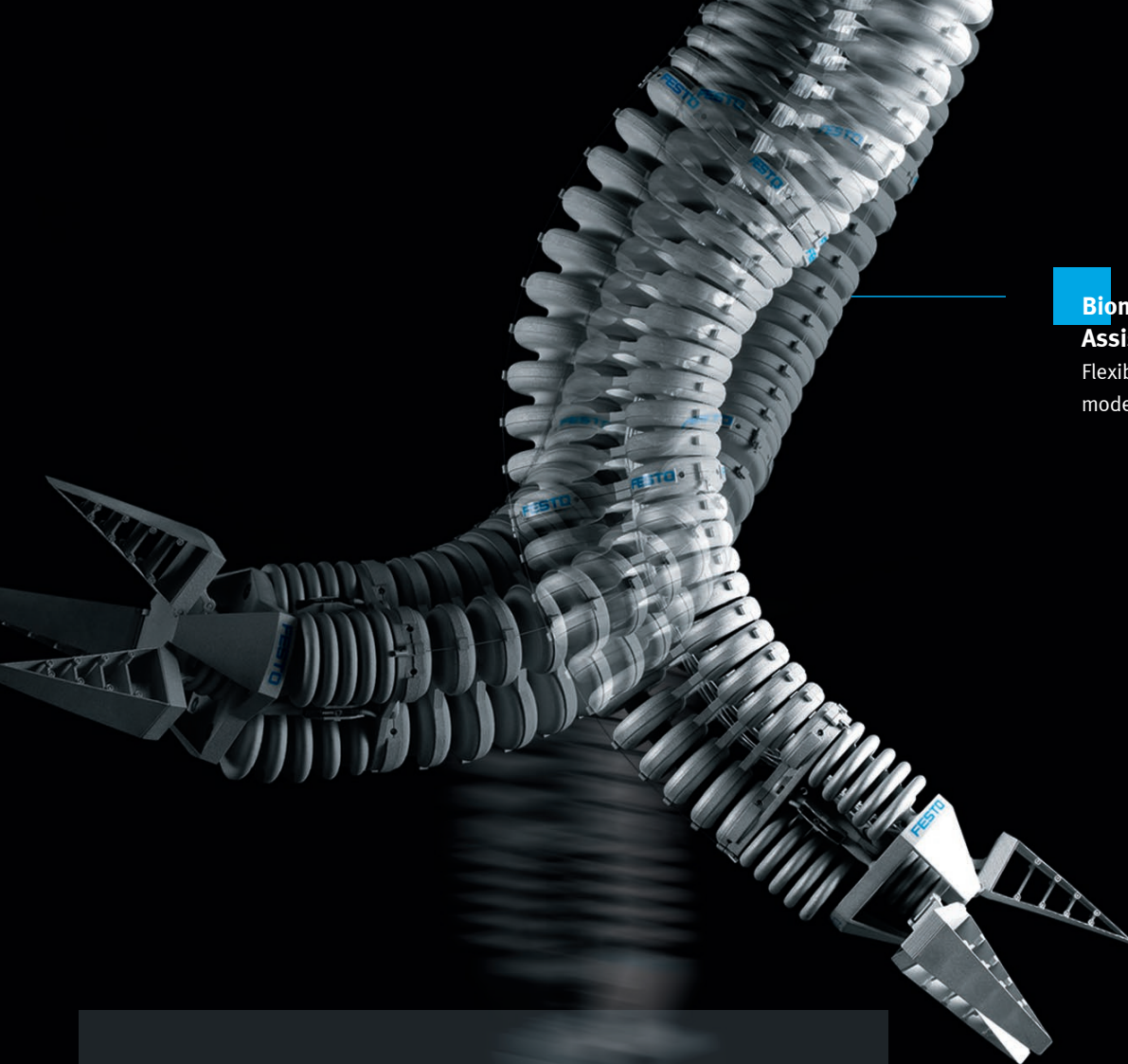
These open working spaces will primarily require robots that can be flexibly adapted and independently adapt to different products and scenarios.

Multiple application possibilities

The modular robot arm can be used for a wide variety of applications, depending on the design and mounted gripper. Thanks to its flexible kinematics, the BionicSoftArm can interact directly and safely with humans. At the same time, the kinematics make it easier for it to adapt to different tasks at various locations in production environments: the elimination of costly safety devices such as cages and light barriers shortens conversion times and thus enables flexible use – completely in accordance with adaptive and economical production.

Intuitive operation on the tablet

The BionicSoftArm is operated intuitively via the Robotic Suite. The graphical user interface was developed specifically for Festo's bionic lightweight robots and was used for the first time in the BionicCobot. With a tablet, the user can quite easily teach the actions and set their parameters. At any time, the defined work steps can be arranged in a timeline in any order by dragging-and-dropping. In doing so, the complete motion sequence is virtually depicted and simulated at the same time.



Bionic Handling Assistant

Flexible gripper arm which is modelled on an elephant's trunk

BionicSoftArm

Pneumatic lightweight robot with natural movement patterns

Natural role model and bionic predecessors

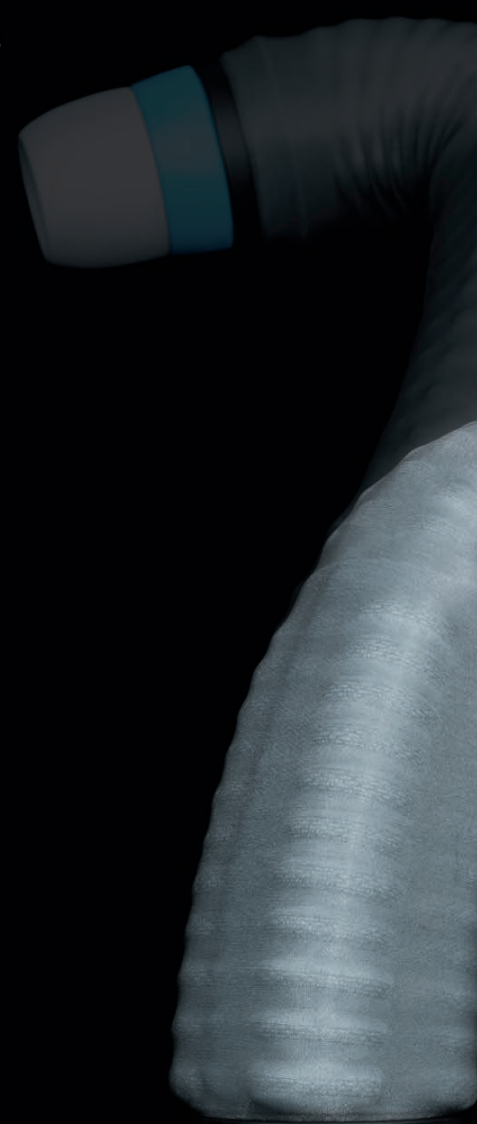
Like its two predecessors – the Bionic Handling Assistant (2010) and the BionicMotionRobot (2017) – the BionicSoftArm is inspired by the elephant's trunk in its movements and functionality. Whether supple and gentle or powerful and dynamic, elephants can not only lift heavy loads with their trunks and move them flexibly, they can also grip objects sensitively and precisely.

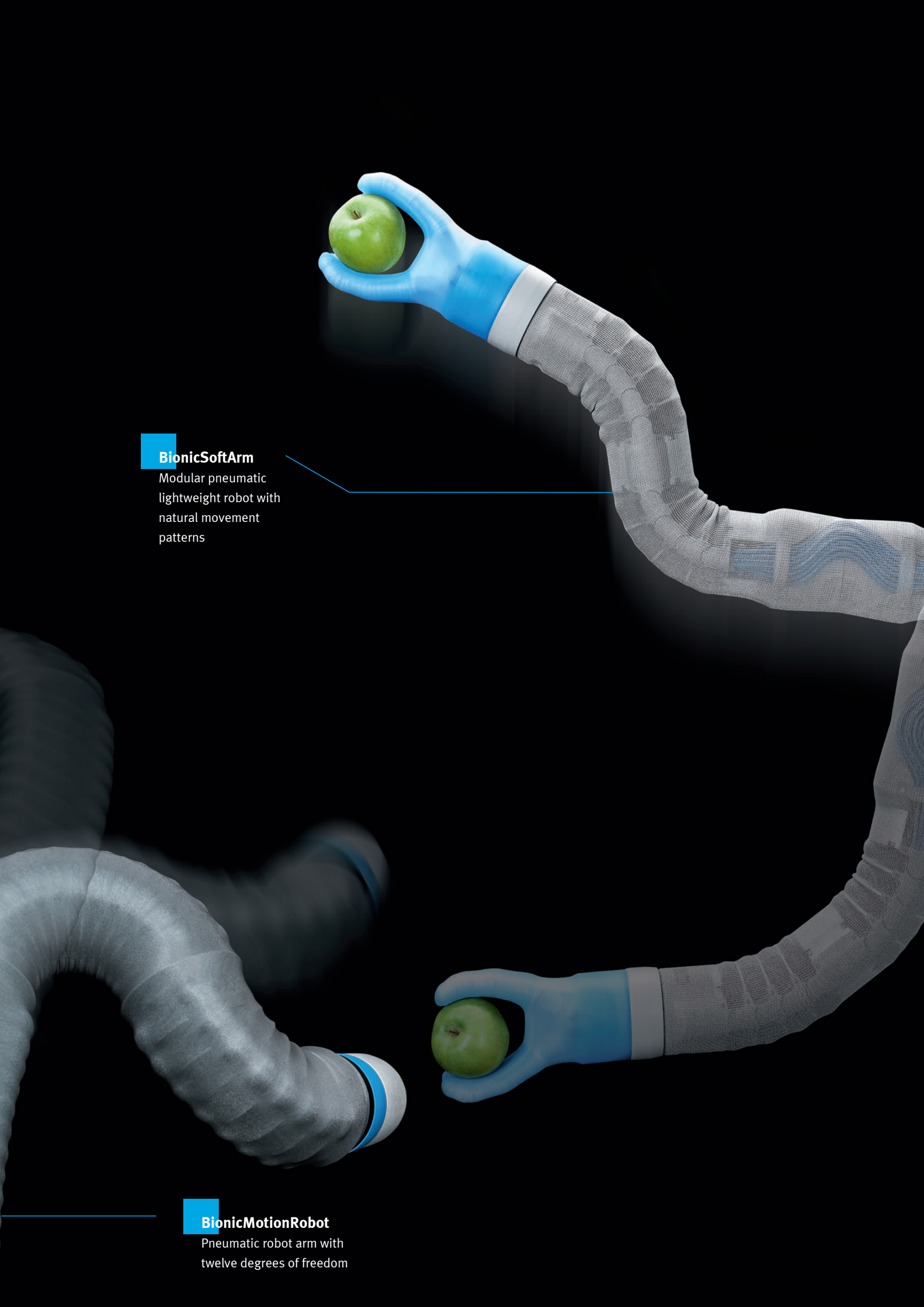
Technical implementation

With its pneumatic bellows structures, the BionicSoftArm effortlessly masters the flowing motion sequences of its natural role model. Depending on the desired action, the bellows can bend freely and stiffen as required. For this purpose, they are sheathed with a special 3D textile knitted fabric that allows expansion of the bellows structures in the desired direction of movement and simultaneously limits them in the other directions.

Industrial benefits

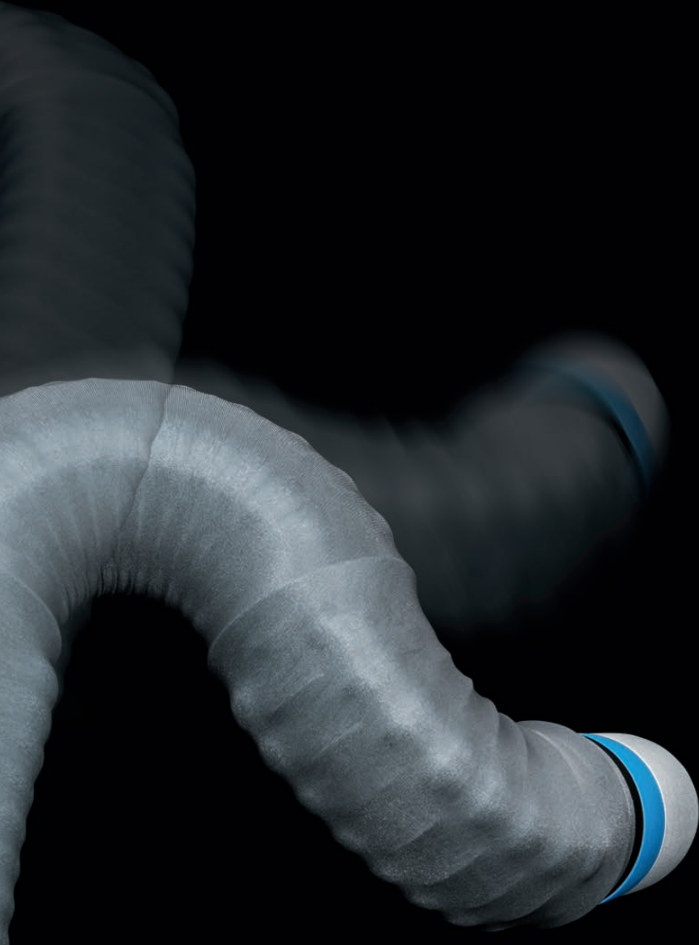
The natural-looking movements of the bionic robot arm create a sense of familiarity for the user, which increases acceptance for direct collaboration. In the event of a collision, the pneumatic kinematics automatically ease off and do not pose any danger to humans. This inherent flexibility of the system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



The image features two BionicSoftArm robots against a black background. Each robot has a grey, segmented, flexible arm and a blue, two-fingered hand. One robot is positioned in the upper right, holding a green apple. The other is in the lower right, also holding a green apple. A third, partially visible arm is on the left. A thin blue line connects the text to the upper robot's arm.

BionicSoftArm

Modular pneumatic
lightweight robot with
natural movement
patterns

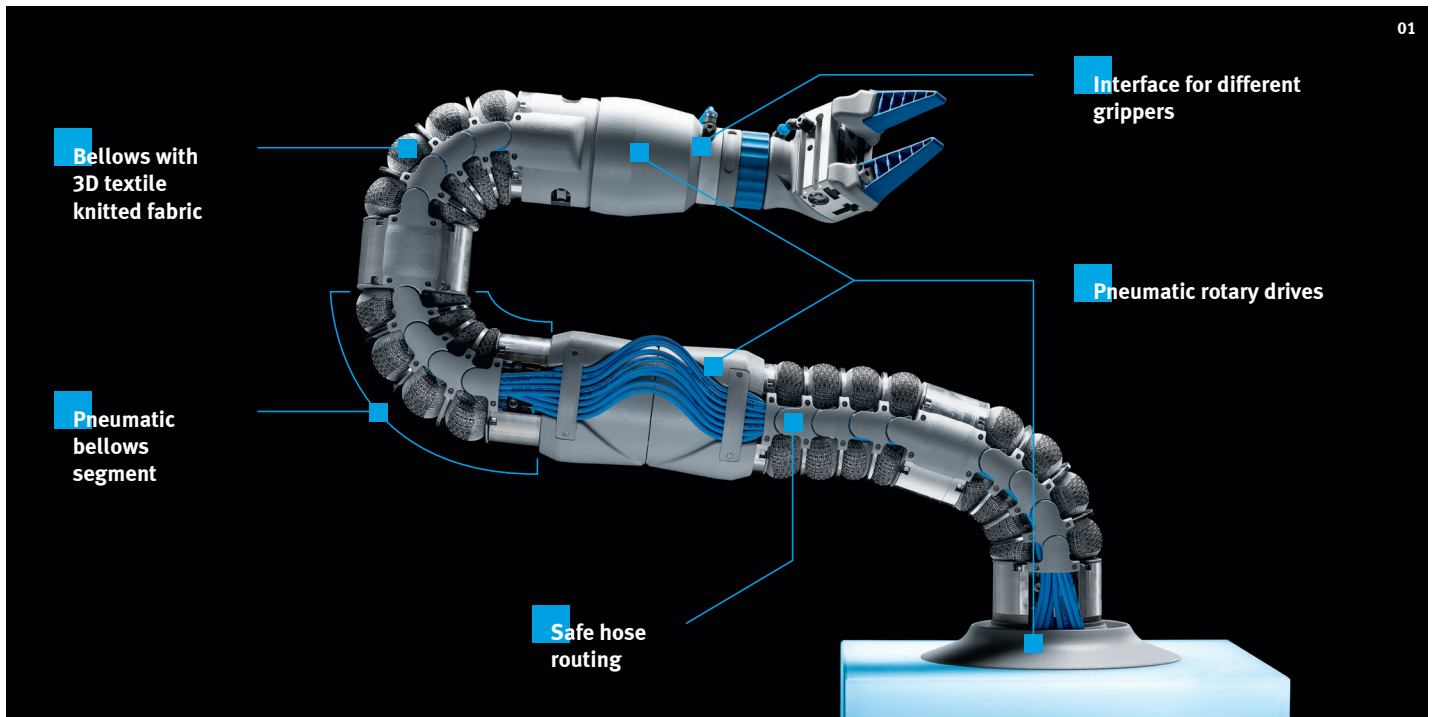
A close-up of a BionicMotionRobot arm, showing its grey, segmented, flexible structure and blue accents.

BionicMotionRobot

Pneumatic robot arm with
twelve degrees of freedom

BionicSoftArm

Modular system with a wide range of applications



The pneumatic segments of the BionicSoftArm each have two bellows and a degree of freedom to keep the closed-loop control technology as simple as possible. However, by combining several bellows segments and rotary drives, its range of motion can be extended almost arbitrarily.

This modular system enables a variable layout – from a simple handling system to a fully-fledged multi-axis robot. In its largest possible version with seven pneumatic actuators, the modular robot arm has seven degrees of freedom.

Targeted motion dynamics through 3D textile knitted fabric

The bellows are made of sturdy elastomer. Each one of them is covered with a special 3D textile knitted fabric which consists of two layers. A soft knitted fabric lies directly on the bellows to protect them from friction and wear. The high-strength fibres 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 entire kinematics can be exploited.

The hoses for airflow are laid on the outside of the robot so that they do not disturb or get squashed when the arm moves. A textile cover pulled over the arm protects the tubing from damage and keeps it in place.

Position-accurate movements thanks to digitised pneumatics

The control and regulation of complex kinematics is made possible by the Festo Motion Terminal VTEM. Through the internal control algorithms of its 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.

The movements of the BionicSoftArm are position-controlled, which is achieved with a model-based approach. Every part of the robot is a model. The required parameters are either calculated or determined using parameter identification. The necessary control algorithms run in real time on the Festo Motion Terminal. The condition of the BionicSoftArm is continuously monitored through pressure and absolute position sensors throughout the entire robot using the Motion Terminal.

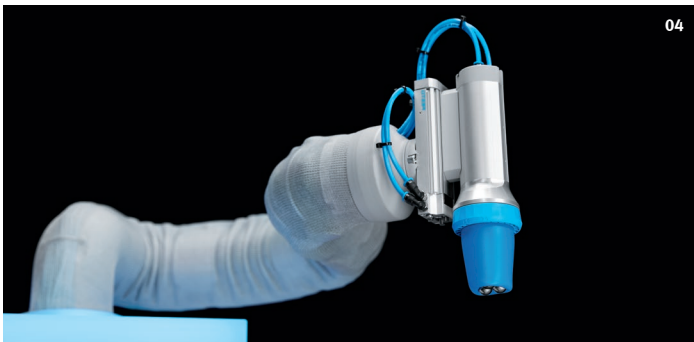
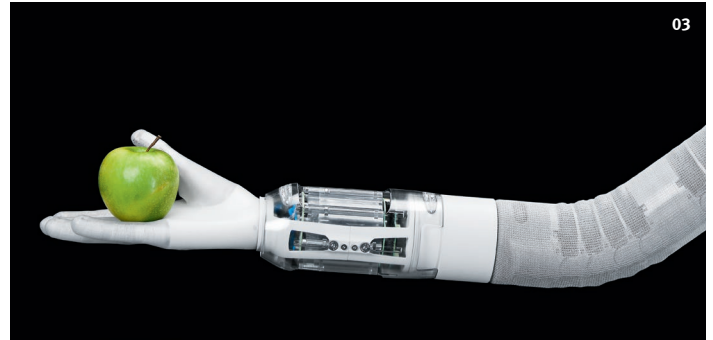
01: **Largest possible version:** the BionicSoftArm with seven pneumatic actuators and just as many degrees of freedom

02: **Adaptive pincer gripper:** with four pneumatic gripper fingers from BionicSoftHand

03: **BionicSoftHand:** solving tasks independently thanks to artificial intelligence

04: **DHEF adaptive shape gripper:** as adaptable as a chameleon's tongue, developed from the FlexShapeGripper

05: **DHAS adaptive gripper fingers:** inspired by the behaviour of the fishtail fin, developed from the FinGripper



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.

On the basis of these coordinates and the incoming sensor data, the Motion Terminal can control the respective pressure in the pneumatic actuators and thus determine the positions of the individual segments and axes.

Adaptive grippers for a wide range of applications

The wide range of applications of the modular robot arm can be further expanded by combining it with various bionic grippers. Due to their adaptivity and flexibility, a wide variety of objects and shapes can be accommodated. One of these grippers is the BionicSoftHand. Like the BionicSoftArm, it consists of flexible, pneumatic bellows structures and soft materials. This provides the worker with a versatile gripper which is also capable of learning through artificial intelligence.

With its flexible, pneumatic design, the BionicSoftHand differs from electric or cable-operated robot hands and makes inexpensive production possible. Thanks to their modular design, there are also gripper variants with three or four gripper fingers – for example, an adaptive pincer gripper. At present, these grippers are still bionic concepts that could be used in production in the future.

From the bionic concept to series product

Festo is one step further with the DHEF adaptive shape gripper and the DHAS adaptive gripper finger. Based on the natural role model, both grippers were first designed as prototypes within the framework of the Bionic Learning Network and then developed into series products.

While the DHEF adaptive shape gripper is predestined for pick-and-place applications, the DHAS adaptive gripper fingers are frequently used for handling sensitive and differently shaped gripping objects – for example, in food processing. Both grippers thus impressively demonstrate how bionics can give new impetus to automation.



Technical data

- Diameter: 80 mm
- Length of bellows segments: 150 mm
- Length of rotary drives: 150 mm
- Maximum overall length: 1050 mm
- Maximum degrees of freedom: . . . up to 7
- Dead weight of bellows segments: . . 500 g
- Dead weight of rotary drives: 750 g
- Working pressure: up to 6 bar
- Repetition accuracy: 5 mm

Software architecture:

- User interface: Festo Robotic Suite
- Calculation and path planning: . . . Robot Operating System (ROS)
- Control and regulation: Festo Motion Terminal VTEM

Sensor technology:

- Sensitec FreePitch sensors AA700, based on anisotropic magnetoresistance (AMR)
- Heidenhain EBI 1135 encoder
- Fujikura XFGM pressure sensors

Actuator technology:

- Pneumatic bellows segments made of natural rubber with high-strength 3D textile knitted fabric
- Modified rotary axes based on the DRVS semi-rotary drive

Project participants

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