BionicMobileAssistant
Mobile robot system with pneumatic gripping hand

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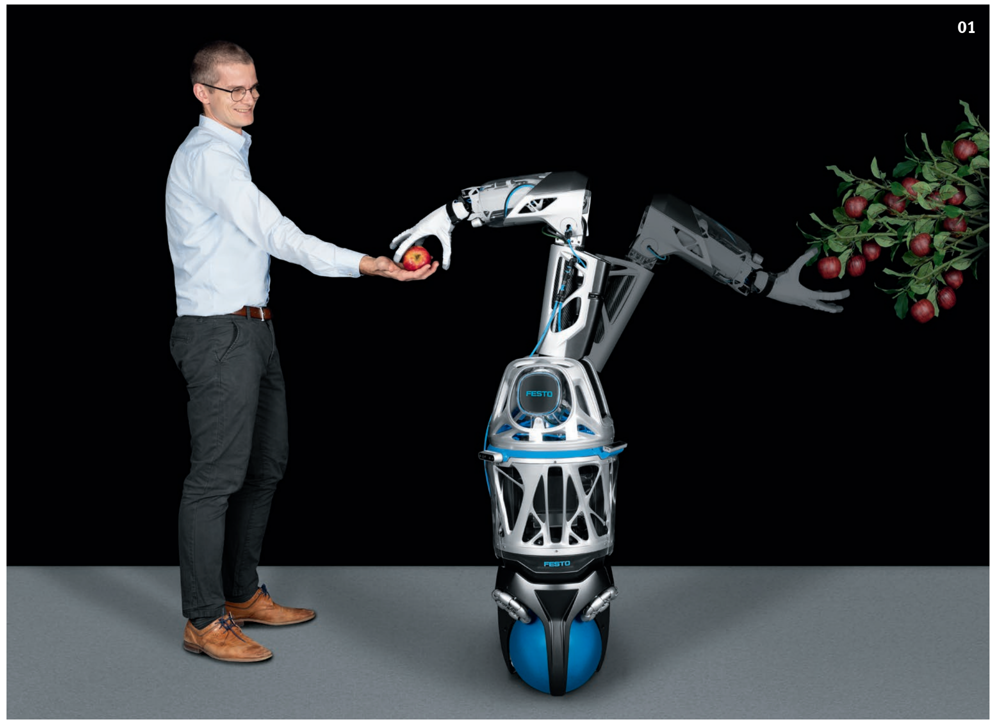
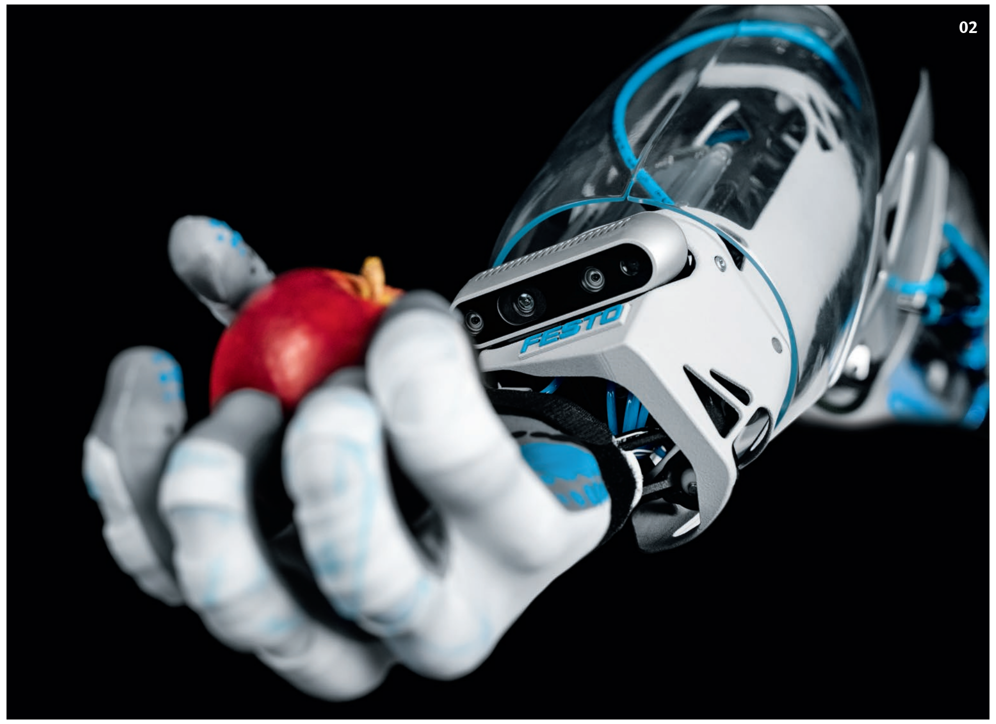
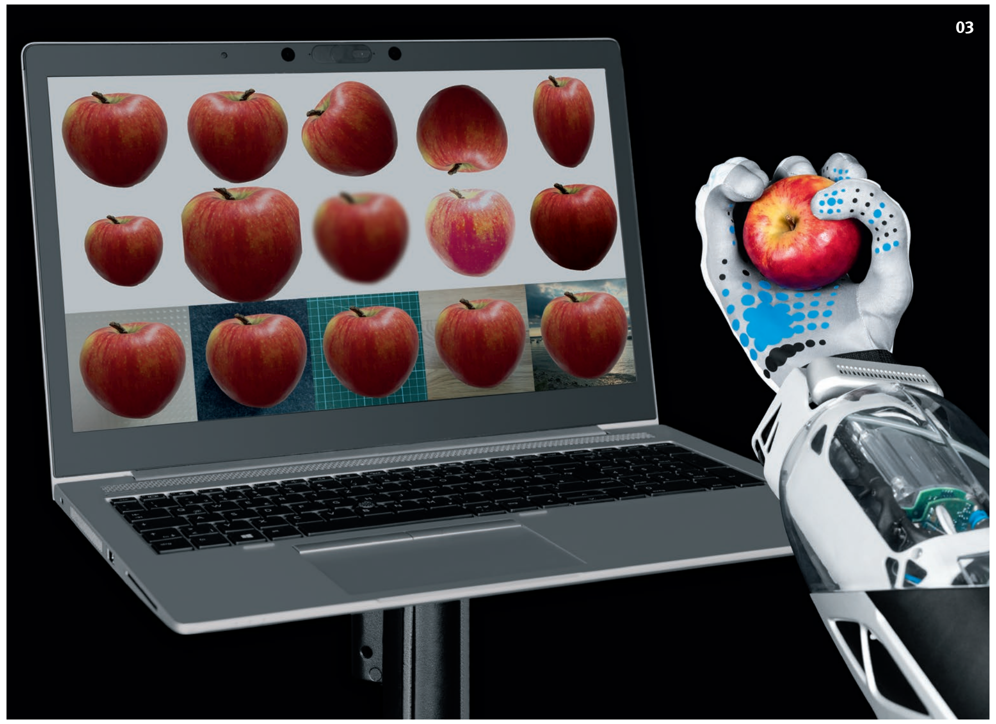
01: **Reliable assistance system:** ballbot, DynaArm and BionicSoftHand 2.0 in action

02: **Visual object detection:** a depth camera on the wrist

03: **Digital learning:** data augmentation for training the neural network







A changing industry requires a new way for humans, machines and data to interact. In the future, workers and robots will work together more and more closely. For this reason, Festo has been looking intensively into systems that could, for example, relieve people of monotonous or dangerous activities and at the same time pose no risk. Artificial intelligence plays a central role as an enabler.

In the Bionic Learning Network, a research alliance between Festo and universities, institutes and development companies, the BionicMobileAssistant is a robot system that moves autonomously in space and can recognise objects, grip them adaptively and work together with humans.

Modular assistance system
The entire system, which was developed in cooperation with ETH Zurich, has a modular structure and consists of three subsystems: a mobile robot, an electric robot arm and the BionicSoftHand 2.0. The pneumatic gripper is inspired by the human hand and was first presented in 2019.

BionicSoftHand 2.0: based on the human hand
The human hand – with its unique combination of force, dexterity and fine motor skills – is a true wonder of nature. An important role is played by the thumb, which is positioned opposite the other fingers. This so-called opposability enables us, for example, to clench a fist, to grasp tweezers precisely and to also do delicate work.

Pneumatic kinematics with 3D textile knitted fabric
So that the BionicSoftHand 2.0 can carry out the movements of the human hand realistically, small valve technology, sensor technology, electronics and mechanical components are integrated in the tightest of spaces.

The fingers consist of flexible bellows structures with air chambers, covered by a firm and at the same time pliable textile knit. This makes the hand light, flexible, adaptable and sensitive, yet capable of exerting strong forces. The pneumatic fingers are also still controlled via a compact valve terminal with piezo valves, which is mounted directly on the hand.

Further development with an optimized radius of action
In order to extend the range of the thumb and index finger, the developers have significantly increased the lateral swivel space of both fingers. This means that they can now work together optimally and grip very precisely. Thanks to a 3D-printed wrist with two degrees of freedom, the hand can now also move back and forth as well as to the left and right. This means that gripping with a narrow radius is also possible.

Finely tuned gripper with fingertip sensitivity
For more stability in the fingers, the air chambers now contain two structural elements that act as bones. A bending sensor with two segments per finger determines the positions of the fingertips. In addition, the hand wears a glove with tactile force sensors on the fingertips, the palm and the outside of the robot hand.

This allows it to feel the texture of the object to be gripped and adapt its gripping force to the object in question – just like we humans do. In addition, a depth camera is located on the inside of the wrist for visual object detection.

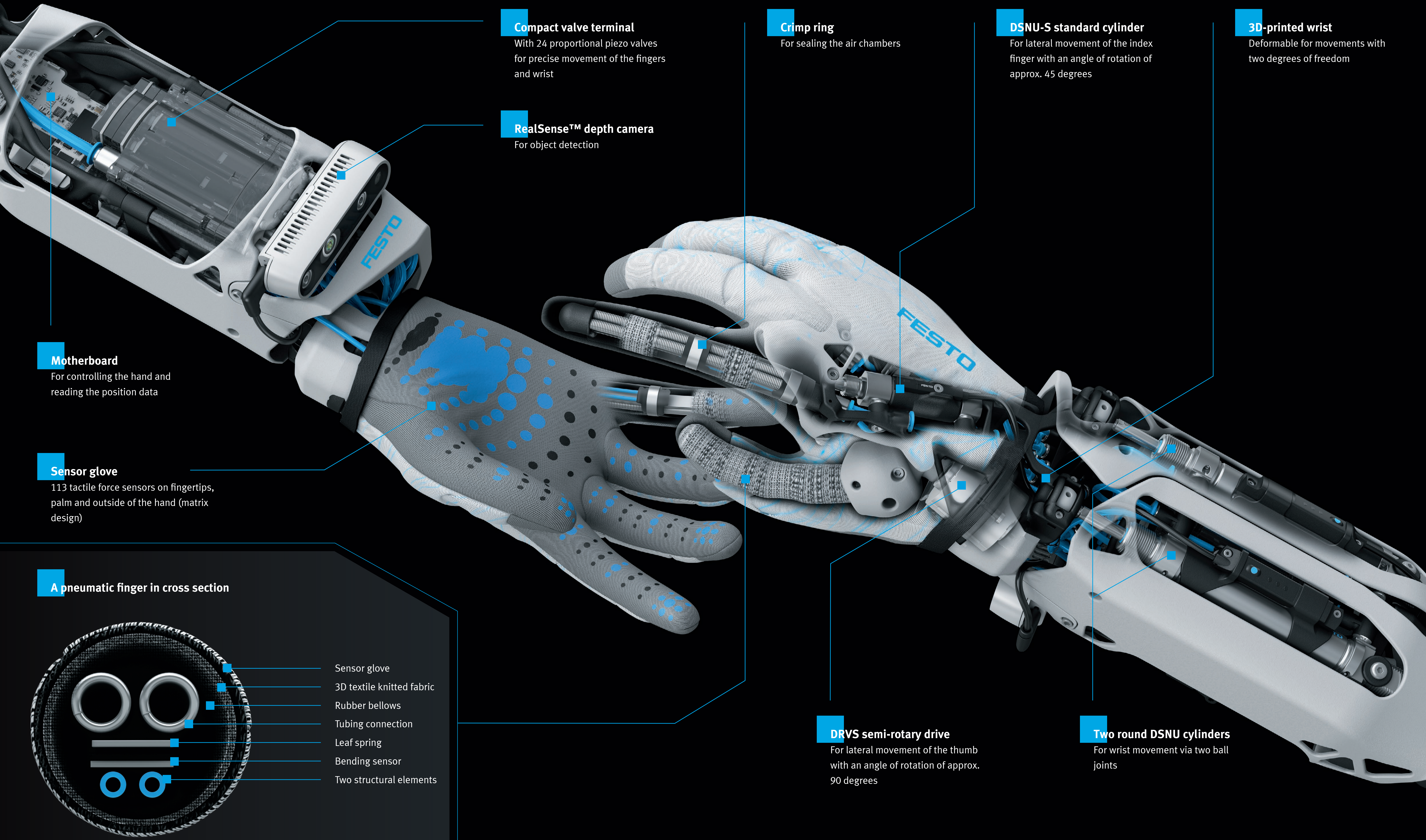
Object detection by means of a neural network
With the help of the camera images, the robot hand can recognise and grip various objects, even if they are partially covered. After appropriate training, the hand can also assess the objects on the basis of the recorded data and thus distinguish good from bad, for example. The information is processed by a neural network that has been trained in advance with the help of data augmentation.

Extensive data sets through data augmentation
In order to achieve the best possible results, the neural network needs a lot of information with which it can orient itself. This means the more training images are available to it, the more reliable it becomes. Since this is usually time-consuming, automatic augmentation of the database is a good idea.

This procedure is called data augmentation. By marginally modifying a few source images – with different backgrounds, lighting conditions or viewing angles, for example – and duplicating them, the system obtains a comprehensive data set with which it can work independently.

BionicSoftHand 2.0

Highly integrated soft robotic components



A pneumatic finger in cross section

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01: **Reliable manoeuvres:** even if pushed, the ballbot will balance and not fall over.

02: **Optimum traction:** the three omniwheels are also driven by one DynaDrive each.

03: **Autonomous navigation:** orientation in space with the help of a second camera

04: **Modular concept:** the BionicSoftHand 2.0 on the BionicCobot

For the BionicMobileAssistant, the BionicSoftHand 2.0 is combined with a mobile ballbot and a lightweight, electric robot arm – the DynaArm. Thanks to model-based force control and control algorithms to compensate for dynamic effects, the arm can react well to external influences and thus interact very sensitively with its environment.

Dynamic robot arm
With the DynaArm, fast and dynamic movements are possible. This is ensured by its lightweight design with highly integrated drive modules weighing only one kilogram. In these so-called DynaDrives, the motor, gear unit, motor control electronics and sensors are installed in a very small space.

High power density
In addition, the robot arm has a high power density which, with 1 kW at 60 Nm drive torque, far exceeds that of conventional industrial robots. It is controlled by the ballbot via an EtherCAT communication bus. Thanks to its modular design, the DynaArm can be quickly put into operation and easily maintained.

Mobile robot application with special drive
For the ballbot, the developers rely on an ingenious drive concept: the robot balances on a ball driven by three omniwheels. This allows the BionicMobileAssistant to manoeuvre in any direction. The robot only touches the ground at one point at a time and can therefore navigate through narrow passages. In order to maintain its balance, it must move continuously.

The planning and coordination of the movements are carried out using planning and control algorithms that are stored on a powerful computer in the body of the ballbot.

The stability of the mobile robot is purely dynamic – in case of external influences, the ballbot can quickly set the ball in rotation and thus keep its balance. Using an inertial measuring unit and position encoders on the wheels, it records its movements and the relative inclination of the system. Based on this data, an optimisation program calculates how the robot and arm must move to bring the hand into the target position and stabilise the robot at the same time.

Mobile use at changing locations
The whole system has its entire power supply on board: the battery for the arm and robot sits inside the body. The compressed air cartridge for the pneumatic hand is installed in the upper arm. This means that the robot is not only mobile, it can also move autonomously.

The algorithms stored on the master computer also control the autonomous movements of the system. With a view to the future, they plan how the arm and the ball must move in order to reach certain target points while maintaining balance. With the help of two cameras, the robot orients itself independently in space: one camera searches for predefined fixed points in the environment to position itself autonomously, while a second camera uses the ceiling structure to estimate movement.

Its mobility and autonomous energy supply enable the BionicMobileAssistant to be used flexibly for different tasks at changing locations – in line with the constantly changing production environment.

Versatile application possibilities
The BionicMobileAssistant would be predestined for use as a direct assistant to humans, for example as a service robot, as a helping hand in assembly or to support workers in ergonomically stressful or monotonous work.

Furthermore, the mobile robot system could be used in environments where people cannot work, for example due to hazards or limited accessibility. This would be conceivable above all for maintenance activities or repair work, the measurement of data or visual checks.

Hand in hand with humans
Thanks to its modular concept, the BionicSoftHand 2.0 can also be quickly mounted and commissioned on other robot arms. Combined with the BionicCobot or the BionicSoftArm, the gripper forms, for example, a completely pneumatic robot system that can work hand in hand with humans due to its inherent flexibility – an aspect that is becoming increasingly important in everyday factory life.

Technical data

BionicSoftHand 2.0

- Degrees of freedom of the hand: .... 11, including wrist
- Weight of the hand: .... 1,295 kg
- Maximum load capacity: ... up to 4 kg (depending on orientation)
- Operating pressure manual or swivel modules: .... 5 or 6 bar
- Pneumatic drives: .... 1 DRVS semi-rotary drive,
  .... 3 DSNU/DSNU-S cylinders
- Valve technology: .... 12 piezo cartridges from the VTEM
- Computer vision: .... 1 Intel® RealSense™ depth camera

Material:

- Textile fingers: .... technical 3D-knitted fabric
- Bellows: .... EPDM with shore hardness of ~45
- Housing and wrist: .... 3D-printed polyamide
- Airflow plate: .... epoxy resin

Sensor technology:

- 10 bending sensors for finger position, 1 inertial sensor
- 113 tactile force sensors inside the glove (matrix design)
- 14 pressure sensors in the airflow plate

DynaArm

- Total weight (including BionicSoftHand 2.0): .... 8 kg
- Payload: .... 8 kg
- Range: .... 850 mm
- Angle of rotation: .... 180 ° in each joint
- Degrees of freedom: .... 4 swivel joints
- Drives: .... 4 V2 DynaDrives with 48 V, 32 A, 980 W

Ballbot

- Total weight: .... 21,9 kg
- Battery: .... LiPo battery, 48 V
- Drives of the omniwheels: .... 3 V2 DynaDrives
- Sensor technology: .... 1 inertial measurement unit (IMU),
  .... 2 Intel® RealSense™ depth cameras

Project participants

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