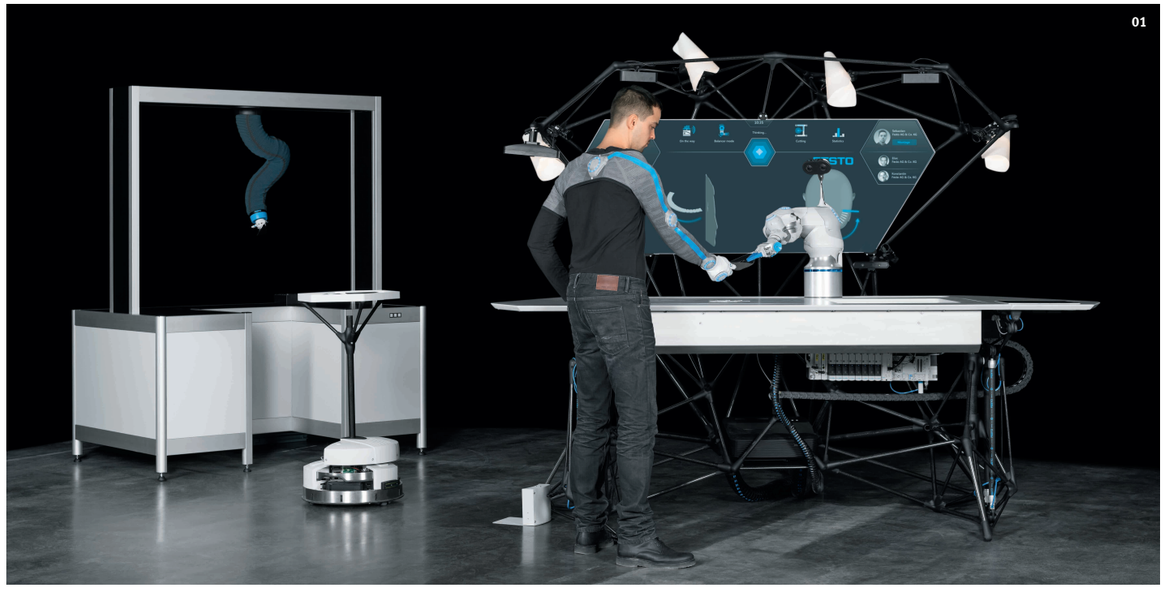
**BionicWorkplace**

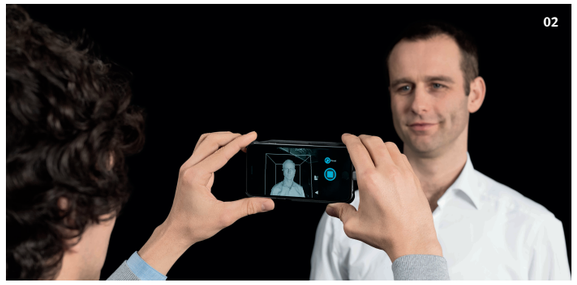
Self-learning workplace with artificial intelligence
for human-robot collaboration

FESTO

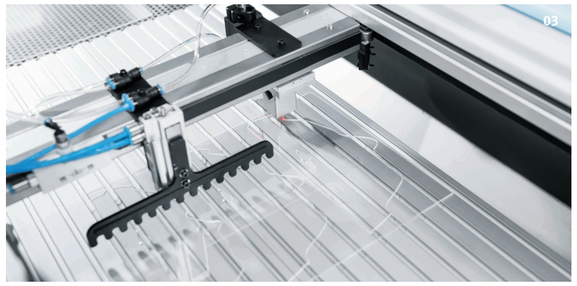
# BionicWorkplace
## Flexible production down to batch size 1




01: **Collaborative working environment:** the BionicWorkplace interacting with the BionicMotionRobot as a pick-and-place unit and a Robotino®.




02: **Changing requirements:** the scenario shows how a networked production system is able to react dynamically to individual customer requests.




03: **Modular concept:** besides the laser cutter, other applications can be integrated in the workplace for production in batch size 1.


04: **Customised end product:** individual items, like the 3D head models produced as an example, are becoming an integral part of the factory of tomorrow.

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.

A crucial role in this respect, besides the digital networking of entire installations, is also played by self-learning systems and robot-based automation solutions, which work hand in hand together with humans – like the BionicCobot, which Festo developed in 2017 as part of the Bionic Learning Network.

**Robot arm with human movement patterns**
The pneumatic lightweight robot is based on the human arm in terms of its anatomical construction and – like its biological model – solves many tasks with the help of its flexible and sensitive movements. Due to this flexibility and intuitive operability, the BionicCobot can interact directly and safely with people. The strict separation between worker and robot for safety reasons will therefore no longer be necessary in future.

**Artificial intelligence for efficient collaboration**
In the BionicWorkplace, it is precisely these collaborative abilities of the robot that are brought to bear. The flexible workplace is equipped with numerous assistance systems and peripheral devices, which are networked and communicate with each other. At the same time, artificial intelligence and machine learning methods turn the BionicWorkplace into a learning and anticipative system that continuously optimises itself. In this way, a human can directly interact with the BionicCobot and control it using movement, touch or speech. It is also possible to manipulate the system remotely.

In future there will be a call for the manufactured products to be as equally flexible as the place of work and the arrangement of the working environment. Due to its modular concept, the set-up and equipment of the BionicWorkplace can be easily and individually adapted, depending on the requirements and tasks. The following scenario shows how efficient and safe human-machine collaboration enables the manufacture of customised products down to batch size 1.

**Possible scenario for customised production**
For the manufacture of acrylic glass sections for an individual model of a head, a laser cutter is integrated in the worktop of the BionicWorkplace. For this purpose, the facial features of a person previously scanned using a smartphone with a depth-sensing camera are converted into a CAD model, which a software program then breaks down into separate slices. According to this 3D template, the laser cutter mounted on a planar surface gantry cuts the elements out of acrylic glass. The BionicCobot takes the slices from the cutter's cutting area and hands the worker the parts in the right sequence, who then puts them together piece by piece to make a unique model.

The constant automatic feed of material in this scenario is taken care of by a Robotino®, which autonomously shuttles between the stations and safely finds its way by means of a laser scanner. It is loaded by a refined version of the BionicMotionRobot, a soft robotics structure with pneumatic compartments and a 3D knitted textile covering. This construction thus combines all the key elements of robot technology.

**Support and relief for the human**
The BionicCobot supports the worker when doing monotonous and ergonomically strenuous jobs. It can also operate in areas that are dangerous for humans, like reaching into the laser cutter. The worker in turn performs the jobs for which they are better suited – when a high level of dexterity, agility and creative thinking are required.

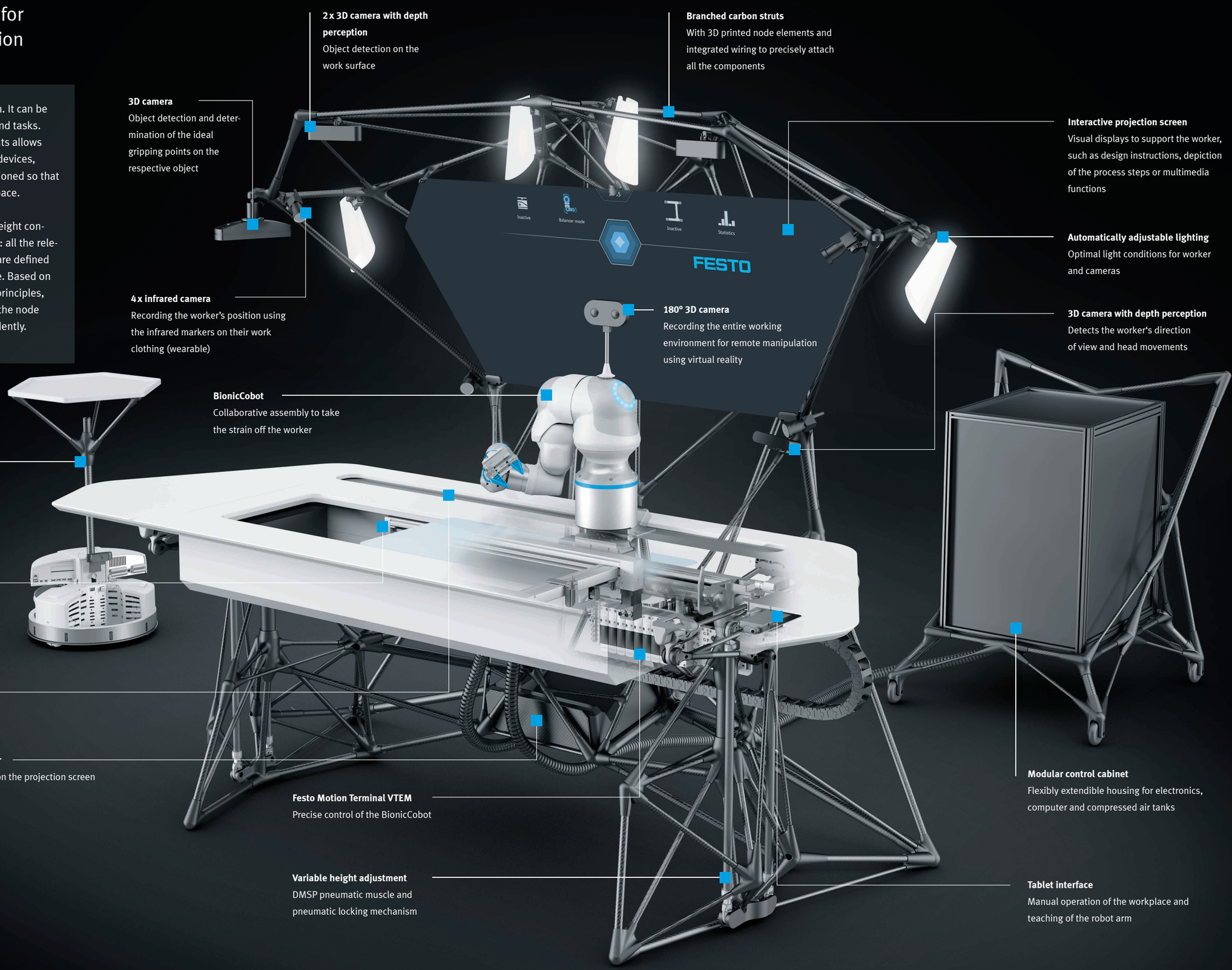
The whole workplace is ergonomically designed and can be individually adapted to people down to the lighting. Besides the BionicCobot, a key element is a large projection screen, which is placed at the centre of the worker's field of vision. It supplies the worker with all the relevant information and reacts dynamically with its contents to the relevant requirements.

**Recording the worker's position and working environment**
All around the projection screen, various camera systems are fitted, which constantly record the positions of the worker, components and tools. The system recognises the worker and their movements by their special work clothing.

# **BionicWorkplace**
## Self-learning workplace for human-robot collaboration

The entire workplace has a modular design. It can be adapted depending on the requirements and tasks. The branched design of its lightweight struts allows integrated cable routing to the peripheral devices, which are optimally coordinated and positioned so that they do not impair the worker's working space.

Due to the parametric design of the lightweight construction, the workplace is easily arranged: all the relevant attachment points and cable routing are defined during the planning stage of the workplace. Based on the parametrically designed construction principles, the CAD software is then able to generate the node elements and pipe pieces largely independently.




**2 x 3D camera with depth perception**
Object detection on the work surface

**Branched carbon struts**
With 3D printed node elements and integrated wiring to precisely attach all the components

**3D camera**
Object detection and determination of the ideal gripping points on the respective object

**Interactive projection screen**
Visual displays to support the worker, such as design instructions, depiction of the process steps or multimedia functions

**Automatically adjustable lighting**
Optimal light conditions for worker and cameras

**4 x infrared camera**
Recording the worker's position using the infrared markers on their work clothing (wearable)

**180° 3D camera**
Recording the entire working environment for remote manipulation using virtual reality

**3D camera with depth perception**
Detects the worker's direction of view and head movements

**BionicCobot**
Collaborative assembly to take the strain off the worker

**Robotino®**
Autonomous transport of material between BionicMotionRobot and BionicWorkplace

**EXCM planar surface gantry with laser cutter**
Production of individual workpieces according to the template of a CAD model

**Pneumatic linear axis DGCI**
Extra degree of freedom for the BionicCobot

**Projector**
Display on the projection screen

**Festo Motion Terminal VTEM**
Precise control of the BionicCobot

**Variable height adjustment**
DMSP pneumatic muscle and pneumatic locking mechanism

**Modular control cabinet**
Flexibly extendible housing for electronics, computer and compressed air tanks

**Tablet interface**
Manual operation of the workplace and teaching of the robot arm

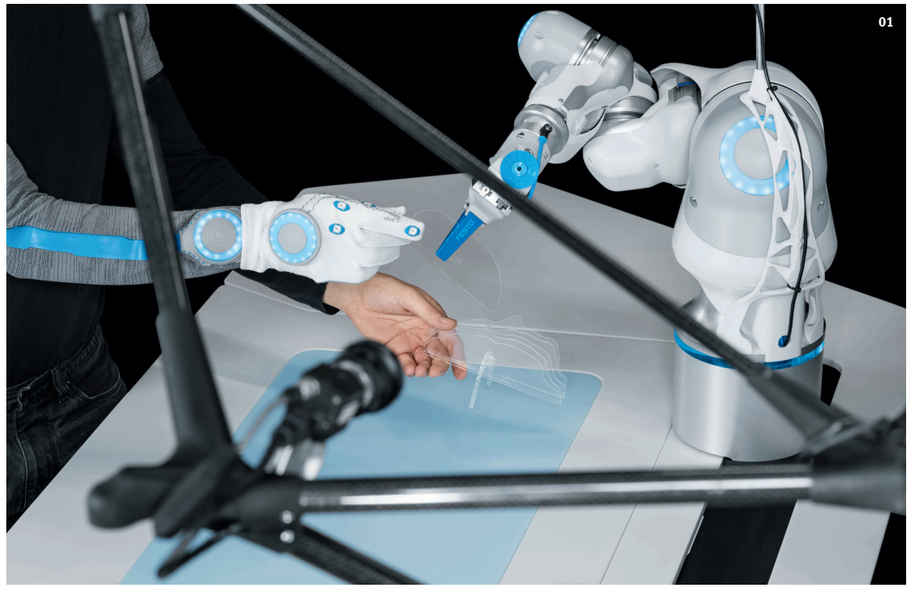
# BionicWorkplace

## Intuitive operating concepts and artificial intelligence

01: **Safe handling:** by means of the special work clothing, the system can adapt its actions to the position and movements of the worker.

02: **Workplace capable of learning:** with the help of artificial intelligence, the system processes the voice commands further and learns something with each new action.

03: **Controlled remote manipulation:** harmless working with the help of textile wearables and virtual-reality goggles from a safe distance.






The worker's special work clothing consists of a long-sleeved top, which is equipped with inertia sensors, and a work glove with integrated infrared markers. All the necessary cables are integrated in the fabric of these so-called wearables, so that they do not hinder the worker's movements.

The interaction of cameras and wearables allows the entire workplace to be handled safely and intuitively. With the help of the recorded sensor data, the BionicCobot is able to hand over objects to its human colleague with pinpoint accuracy and move out of their way if necessary – an essential requirement for direct collaboration between humans and robots.

**Camera systems for safe interaction**

A special 3D camera with depth perception registers the worker's direction of view and head movements. The system uses eye tracking to constantly check whether the worker's attention is on the workplace or whether it is dropping. If there is a hazardous situation, the BionicCobot can react immediately and adapt its behaviour.

If the person directs their eyes to a particular area of the projection screen, the content here is adjusted accordingly. If the robot is supposed to hand the worker a part from an unordered box, another camera supports it by working out the coordinates for the ideal gripping points on the object.

**Voice control and digital processing**

Another element of the intuitive operating concept of the workplace is voice control. Thanks to a corresponding software program, the system is able to interpret semantic details as well as the relevant linguistic context and to converse with the human in a natural way.

So that the BionicCobot can execute the required command, the voice recognition software turns the spoken sentence into text. To do so, it compares its frequency patterns with databases, where countless examples of words and their patterns are already stored. In the next step, the task is to understand the meaning of the sentence. For this purpose, the software sends the text to a language interface, which checks it for certain keywords.

**Machine learning optimises workflow**

Once the interface has identified the meaning of the sentence, it supplies a context object, which is a software code, with which the robot's control system can work. The clear handling instructions to the BionicCobot are then taken care of by a special, self-learning automation software program with artificial intelligence.

The intelligent software evaluates the contents of the context object and simultaneously processes all data and inputs recorded using sensors from the various peripheral devices. It uses all this information to derive the optimal program sequence and sends it using the robot's control system to the screen and the BionicCobot. The latter thus knows how and where it is supposed to move.

With every action solved, the system learns something new. This creates a so-called semantic map that grows continuously. Along the network paths, the stored algorithms constantly draw dynamic conclusions. As a result, a controlled, programmed and set sequence gradually turns into a much freer method of working.

**New application options with remote manipulation**

For remote manipulation purposes, a 180° 3D stereo camera records the entire working space, while the physically separated worker wears virtual-reality goggles with the textile wearables. The worker can use these to access and follow the images from the camera in real time. The robot can thus be controlled from a distance, for example, when handling hazardous substances or carrying out processes that are harmful to health. A worker could also control several systems at once in this way – even if these are spread out over factory facilities across the whole world.

**Learned knowledge building blocks applicable worldwide**

By means of intelligent workplaces capable of learning and the use of multifunctional tools, collaboration between humans and machines will be even more intuitive, simple and efficient in future. Knowledge building blocks and new skills, once learned, can be limitlessly shared and made available on a global scale. It would therefore be possible in future to set up workplaces as a worldwide network with local adaptations, in each case adjusted to the local individual tasks and customer requirements.


**Project participants**

Project initiator:
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Festo AG & Co. KG

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Timo Schwarzer, Micha Purucker, Philipp Steck, Gaetano Lopez,
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Artificial intelligence:
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Wearables:
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School of Textiles & Design, Reutlingen University
Felix Fuchs,
Felix Fuchs Design, Stuttgart

Eye scanner programming:
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Eyeware Tech SA, Martigny, Switzerland

Robotino® programming:
Haoming Zhang Cybernetics Lab IMA/ZLW & IfU,
RWTH Aachen University

BionicMotionRobot development:
with the support of pre-development,
Festo AG & Co. KG

**Technical data**

Integrated camera and sensor systems:
- 4× infrared camera
- 1× PickIt 3D camera
- 2× Orbbec Astra 3D camera for object detection
- 1× Orbbec Astra 3D camera for eye scanning
- 1× LucidCam 180° 3D camera

Software architecture:
- Software for speech input: IBM Watson
- Software with artificial intelligence: arago HIRO™
- Robot control system: Robot Operating System (ROS)

Festo products used:
- 1× electric planar surface gantry EXCM
- 1× Festo Motion Terminal VTEM
- 1× pneumatic linear axis DGCI
- 4× pneumatic muscle DMSP-20
- 4× pinch valve VZQA-C
- 1× Robotino® from Festo Didactic SE

Wearables sensor technology:
- In the top: combination of gyro sensor technology for rotary movements, acceleration and compass sensors
- In the glove: infrared markers

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50091 en 3/2018