FreeMotionHandling
Autonomously flying gripping sphere

FESTO

FreeMotionHandling
Flying assistant system for handling in the air


01

Both flying and gripping have a long tradition in the Festo Bionic Learning Network. In the form of the floating FreeMotionHandling, the developers have now combined both topics in one technology platform for the first time. The indoor flying object consists of an ultralight carbon ring with eight adaptive propellers, at the centre of which is a rotatable helium ball with an integrated gripping element. Thanks to the intelligent onboard electronics and the indoor GPS used, the ball is able to manoeuvre in all directions, pick up objects independently and put them down at designated places.

Safe interaction between man and machine
No pilot is required to control the flying object. However, man and ball can interact safely with one another and without problems at any time. Unlike other indoor flying objects, contact is not dangerous even in the event of a collision. That opens up new prospects for the workplace of the future: the ball could act as a flying assistance system for people – for example, when working overhead, at dizzying heights or as a feeder system in spaces that are difficult to access.

Combination of several bionic principles
For this purpose, the engineers made particular use of two existing developments from the Bionic Learning Network: the gripping mechanism on the FreeMotionHandling is modelled on the universally applicable FlexShapeGripper, whose working principle is derived from the tongue of a chameleon. Its elastic gripper can wrap itself around the item being gripped in a flexible and form-fitting manner and even collect more than one object in a single process.

The flying helium ball itself is a further development of the eMotionSpheres. For its drive concept and for the first time, Festo designed adaptive propellers, which – thanks to their flexible membrane – can provide the same thrust in both directions of rotation. The knowledge gained from the work on the BionicOpter went into the design of the propellers. The developers took the wing principle of the artificial dragonfly a step further and transferred it to the drives, which are now used on the FreeMotionHandling as well.
Festo also used the flying manoeuvres of the eMotionSpheres to show how several flying objects move in an enclosed space in a coordinated manner and without colliding.

01: **Unique flying object:** besides the extended flying time, the helium ball also guarantees safe human–machine interaction

02: **Endless degree of freedom:** the freely orientable helium ball enables the item being gripped to be set down in the widest range of positions

03: **Sophisticated drive concept:** the four horizontal propellers, together with the helium ball, ensure the necessary uplift required

04: **Exact flying behaviour:** the four vertical steering drives are used to position the helium ball precisely in all possible directions

The propellers on the FreeMotionHandling are no longer located directly on the ball, unlike the eMotionSpheres. Just like the entire onboard electronics, the eight adaptive drives are fitted on the ultralight flying ring, which could thus also be used without the helium ball.

The ring consists of a delicate carbon structure, whose arched form guarantees a high degree of vibrational stability. Eight printed circuit boards are embedded into the structure, on which a total of four hoist and four steering motors as well as the integrated wireless and sensor technology are located.

Unique flying manoeuvres in all directions

Four of the propellers are attached horizontally in line with conventional quadrocopter technology. The other four drives are aligned vertically. Together with the drive on the helium ball, this clever combination enables dynamic flying behaviour in all spatial directions. It allows the flying object to be precisely positioned without tilting as well as the flying ring to rotate around its horizontal and vertical axis.

The FreeMotionHandling stands out not only due to its unique flying properties, however. By rotating the ball by up to 180 degrees, its gripping element can also be freely positioned in all spatial directions. Unlike standard quadrocopters, which are equipped with one gripper, not only can the ball control an object from above, but it can also grip it from various angles. Compared to conventional multi-axis kinematics, the FreeMotionHandling has a much greater degree of freedom.

Soft gripping of various objects

In order for the FreeMotionHandling to conveniently pick up different shaped objects, the developers also equipped the gripping element with an ultra-thin film, which is filled with helium. The gripper is able to draw objects in by means of a rope winch found inside the ball. The pressure in the sleeve makes it extend back out on its own, and the holding process in between is energy-free. In this way, the flying ball can also pick up several objects according to the last-in-first-out principle, transport them in its body and then dispense them at several different positions one after the other.

FreeMotionHandling
Autonomously flying gripping sphere with bionic drive

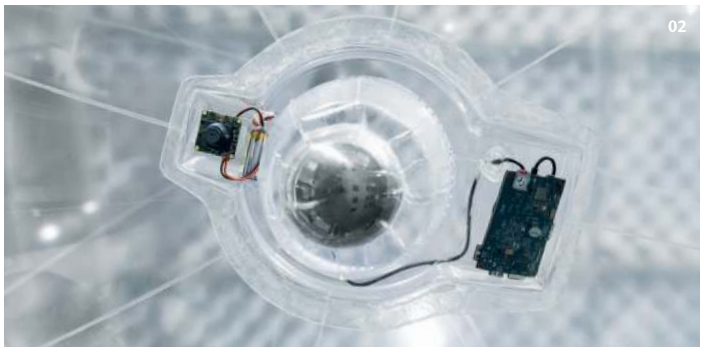
With the FreeMotionHandling, Festo presents an autonomously flying assistance system which can, for the first time, interact with people without any problems. Unlike other indoor flying objects, the handling system does not have to keep at a safe distance and can also stay in the air for much longer.

The sophisticated concept consists of a helium-filled ball with integrated gripper and an ultralight flying ring with bionic drives. Due to the profile change on their flexible membrane, the adaptive propellers can generate the same thrust going forwards and backwards.

FreeMotionHandling

Self-learning system for the future working world


01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Exact positioning using indoor GPS

In order for the FreeMotionHandling to fly stably and with process reliability, a permanent communication system is necessary. The pinpointing of the flying object is ensured by the wireless sensor technology on board combined with the installed guidance and monitoring system, which has already proven itself on the Festo eMotionSpheres and eMotionButterflies.

An important part of this indoor GPS is a camera system, as could also be used in the factory of the future. Several infrared cameras installed in the space record the FreeMotionHandling using eight infrared LEDs, which are attached to the flying ring as active markers.

The cameras transmit the position data to a central master computer, which acts like an air traffic controller and coordinates the ball from outside. They are set up so that they map out the space as a whole and each flying object is recorded by at least two cameras at all times. Due to their special filters, they only capture infrared light and are not sensitive to other light.

In this respect, the camera system measures the exact actual position of the flying object 160 times per second, upon which the computer readjusts each deviation. The flight path planning is therefore constantly updated. Besides the position, the system also directly determines the orientation of the gripping sphere. In addition, the speeds and accelerations are recorded.

Precise object detection using onboard cameras

Once the ball approaches the object being gripped, it takes over its flight-path planning independently, but with the aid of two integrated cameras: the first camera is located in the gripper and the second one directly on the outer sleeve next to it. The handling system thus perceives its environment even during the gripping process and can react to it in any given situation. Besides the item being gripped, the ball also detects possible obstacles on the ground that it can avoid.

After being put into operation, an external control system is no longer required. The constant information exchange guarantees the process stability of the entire system. It is possible, however, to monitor all the parameters wirelessly and to make a regulating intervention.

01: **Intelligent monitoring:** with its installed infrared cameras, the indoor GPS is used to pinpoint the ball in an enclosed space

02: **Integrated camera technology:** using the camera on the outer sleeve, the handling system detects its surroundings even during the gripping process

03: **Autonomous object detection:** the camera in the gripper enables the system to identify objects and pick them up safely

04: **Flying assistance system:** conceivable application scenarios include working overhead, at dizzying heights or in spaces that are difficult to access

To enable the FreeMotionHandling to independently identify the objects it is looking for and then grip them safely, the developers rely on another scientific phenomenon.

A mini PC is located on the outer sleeve of the ball and constantly analyses the signals from the two onboard cameras. By means of neural networks, its intelligent software is trained in advance to detect the objects to be gripped in any light and from all possible perspectives by itself.

Object detection by means of machine learning

For this particular purpose, a large number of images of the target object are transmitted to the system in various sizes, views and lighting conditions, which it saves as an array of positive examples. Just like the human brain, the computer can link the individual empirical values to generate a coherent overall image and subsequently use it to extract the key features of the object in question. Once the system has collected sufficient positive samples, it can then recognise and handle the learned object or comparable items in all situations.

Taking the strain off people

With the ability to be able to react independently to its surroundings, the FreeMotionHandling already meets one possible criterion for the workplace of the future. Self-learning subsystems and other intelligent components are taking on an increasingly important role in production. With Industry 4.0, humans and technology are working even closer together.

An important element for future production facilities are human assistance systems that can adjust flexibly to a wide range of production scenarios. In this respect, the technology is able to react at all times to interventions by humans and other variable parameters. Machines are becoming increasingly harmless to people and also help to take the strain off them during their daily work.

The concept of FreeMotionHandling could therefore be used anywhere and in all kinds of situations where people require additional support from machinery – for instance, when doing ergonomically one-sided tasks in assembly, during sorting as well as in warehousing.

Technical data

Flying object:

- Diameter: ..... 137 cm
- Outside diameter ..... 180 cm
- Total weight (without helium): ..... 1400 g
- Total weight (with helium): ..... 50 g
- Weight of flying ring: ..... 740 g
- Maximum payload: ..... up to 400 g
- Maximum flight time: ..... 40 min. (without payload)
- 2 onboard cameras
- 6 rechargeable batteries
- 1 onboard computer
- 4 steering motors
- 4 hoist motors
- 8 propellers
- 8 infrared LEDs as active markers

Installation:

10 infrared cameras
Frame rate: ..... 160 images per second
Exposure time: ..... 250 µs

1 central master computer
Analysed pixels: ..... 3.7 billion pixels per second

Project participants

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