

eMotionSpheres

FESTO



**Collision-free
motion of autonomous
systems in an area**

Flying objects with bionic drive – individual and collective



The eight white spheres fly in all directions above the heads of those watching, before the random movements develop into an organised formation, first making a circle and then a figure of eight. Suddenly, one of the spheres detaches itself and the others follow it like pearls on a string. The perfect line turns into a sine curve in the air until the spheres form a circle again.

The flight manoeuvres at a ceiling height of three to six metres are part of an elaborate choreographed sequence, which Festo presents under the name eMotionSpheres.

Unique and highly efficient drive system

Each of the eight spheres has a diameter of 95 cm and is filled with helium. They are each driven by eight small propellers, which are attached to their outer shell. The drives are adaptive and supply the same efficient thrust in both a forward and reverse direction, thus representing something totally new when it comes to flying objects. Together with the camera system and an intelligent control system, they are capable of the widest range of flight manoeuvres – even without human pilots.



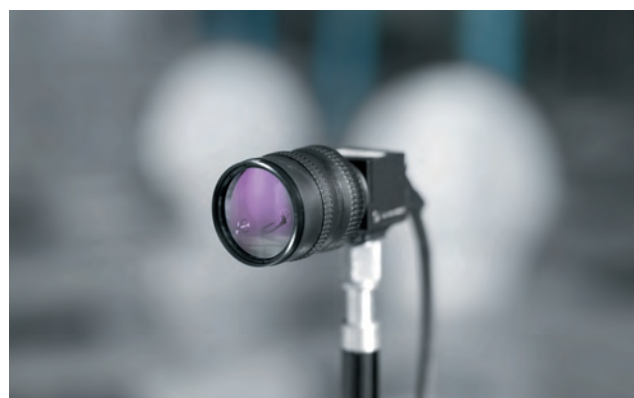
Absolute novelty: the adaptive propeller of the ultralight flying objects

Indoor GPS for exact localisation

Festo uses the installation to show a guidance and monitoring system, as could be applied in the networked factory of the future. Ten infrared cameras installed in the room record the spheres via their active markers (four infrared LEDs) and pass on the position data to a main computer.

On the computer there are preprogrammed paths, which specify the spheres' flight paths when flying in formation. Thanks to additionally stored behaviour patterns, the spheres can however also move autonomously through the space. There are no collisions even in chaotic situations as they move out of each other's way. The spheres can also be controlled individually by people and, because of their process reliability, consistent lightweight design and flexible propellers, they are not dangerous.

The knowledge gained from the work on the BionicOpter went into the design of the adaptive propellers. The developers pursued the wing principle on the artificial dragonfly and transferred it to the unique drives used by the spheres.



The most modern infrared technology: exact positioning of the spheres



Pioneering role model: the BionicOpter wing principle transferred to the drive technology of the eMotionSpheres

Adaptive propellers with profile modification

Just like the wings on the BionicOpter, the spheres' propellers are made of a sturdy frame covered with a flexible membrane. The laser-sintered frame is twisted once, thus making a figure of eight.

As the film is not under complete tension, it inflates on one side or the other, depending on which direction the propeller is turning. This creates a passive effect, which also occurs on the flapping wings of the artificial dragonfly.

Identical thrust performance in both directions

On each sphere there are eight of these adaptive propellers, which act as drives. They supply up to 42 g of thrust both forwards and backwards and are thus equally efficient in both directions.

Until now, that has only been found in very few applications, for example in the heavy rudder propellers on ships. In flying objects, this efficient combination of equal thrust performance in two directions is even a genuine first. As the propellers weigh less than one gram, the direction can be changed almost without any delay.

The eight drives are attached along the equator of the spheres, four of them aligned horizontally. They enable the spheres to fly, climb or descend quickly up and down. Thanks to the four vertical propellers, the spheres can move horizontally in all directions and rotate about their vertical axis.

Precise steering and control

Four of the propellers are screwed anticlockwise and the other four clockwise, with an anticlockwise drive always being located opposite a clockwise one. In this way, the torques are neutralised and the spheres can be steered in any spatial direction to an accuracy of one centimetre. The spheres themselves are controlled locally by the activation of the eight motors.

The corresponding onboard electronics with 12 processors are installed in the spheres, as are the radio unit, the battery and four power LEDs, which light up to help the choreography in an optical manner. The four infrared markers used for communicating with the cameras are embedded in the shell, which is made of a PE/PP film.



Horizontal propellers: vertical flying, climbing and descending



Vertical propellers: horizontal flying, accelerating and braking



Intelligent monitoring: the system enables both the formation and individual flight of the spheres

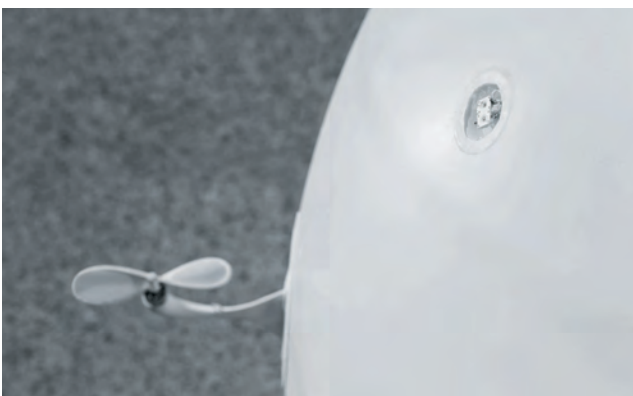
Exact positioning thanks to infrared technology

The ten cameras are positioned so that they map out the flight area as a whole, and each sphere is recorded by at least two cameras. Due to their special filters, the cameras only capture infrared light and are not sensitive to other light. By means of the four infrared LEDs on the outside of each sphere, they detect their position and orientation in the space and, additionally, can tell the optically identical flying objects apart.

Large spatial coverage with low power consumption

Whilst passive reflectors first have to be illuminated, the active markers on the spheres emit the infrared light by themselves. The light only has to cover the distance between the sphere and camera. Compared to passive markers, a larger space can therefore be recorded with the same number of cameras.

The markers are not permanently lit, but instead flash for only a millisecond. This makes them extremely long-lasting and energy efficient. Synchronised with the flashing, the cameras record an image that they send to the main computer.



Active markers: infrared LEDs for communication with the cameras

Fast calibration of the system

In order to know where a flying object is located in the space, the computer must first know the positions of the cameras. The necessary calibration of the system can be carried out quickly and easily. To do so, a manually controlled sphere with a measuring cross flies through the space freely for about 15 minutes and is recorded by the cameras whilst doing so. The recording process enables the main computer to recalculate the exact locations and alignments of all the cameras in the coordinate system.

From here on, it acts like an air traffic controller, coordinating both the manoeuvres and the free movements of the spheres. No direct communication takes place between the spheres in this respect.

Long flight times due to autonomous charging

Depending on the flight speed, buoyancy and manoeuvres that are flown, the average flight time of a sphere comes to two hours. As the spheres stop at their charging stations regularly and autonomously, they can be used as flying objects for several days without a person having to intervene.



Autonomous charging principle: independently calling in the charging stations



Large spatial coverage: predestined for use as an indoor GPS to prevent collisions in the workspace of tomorrow

Networking the real and virtual worlds

In thoughts about production of the future, networking is omnipresent; real and virtual worlds are continuing to grow together. Furthermore, intelligent and flexible components will be increasingly used. Festo is working holistically on the fundamental technologies, and at the same time has an eye on how humans and machines work together.

With the eMotionSpheres, Festo is already showing how several objects can be coordinated without colliding in a three-dimensional space thanks to multifaceted networking. The objects and their surroundings are recorded using camera technology and depicted virtually on a computer. The actions calculated from this process are sent back to the objects, where they are locally implemented.

This guarantees safe interaction between the spheres and people, which creates new prospects for the workspace of the future. Unlike other indoor flying objects, the spheres therefore do not have to be shielded and can also stay in the air for much longer.



Safe handling: harmless interaction between humans and technology

Monitoring and guidance system for tomorrow's factory

The installation could find a concrete application in future factory buildings. It could be conceivably used as a monitoring system which pinpoints the positions of products in the factory, analyses them and thereby improves the production process. In the field of logistics, the system could be put to use as a way of monitoring the function of small robots or forklifts. Generally speaking, it could also be conceivably used as a guidance system – whether for people working in factories or for visitors at trade fairs, museums or large indoor events.

Objects are already tracked in industry using RFID technology. In this case, a code is transferred from a transponder attached to the marked object to a scanner via electromagnetic waves. With the eMotionSpheres, Festo is pursuing a concept in which the objects are not only recorded, but also actively react to different situations and can even move around autonomously. Other benefits are the comparatively large spatial coverage, the energy-efficient way that the markers work and the ability to quickly put the system into operation.



Networked overall system: the merging of the virtual and real worlds



Technical data

- Installation: 10 infrared cameras, 1 main computer
- Shell:
 - Diameter: 95 cm
 - Material: 7-layer, bidirectionally stretched PE/PP film
 - Thickness/weight: 25 μm / 27 g/m²
 - Active markers: 4 infrared LEDs

Integrated components:

- 1 main processor, 8 processors to control the motors, 1 processor for the wireless time synchronisation, 1 processor for HOTT decryption, 1 processor for communication using ZigBee
- 8 brushless motors for activating the propellers
- IMU (inertial measurement unit): 3 gyroscopes, 3 acceleration sensors, 3 magnetometers
- Optical flashlights: 4 power LEDs (2 white and 2 blue)
- Battery: 2 Li-poly cells with permanent condition monitoring of the charging procedure and charging status

Propellers:

- Material: sintered nylon and translucent PE film
- Film thickness/weight: 5 μm / <1 g
- Thrust performance: in forwards and reverse directions over 42 g at 7.8 V and 2.2 A



→ Film

Project participants

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