AirPenguin

A group of autonomously flying penguins

Info

Flying through the sea of air with collective behaviour

Penguins are fascinating creatures which have lost their ability to fly in the course of their phylogenetic development as marine birds. With the AirPenguins, the engineers have created artificial penguins and taught them “autonomous flight in the sea of air”. The knowledge acquired from this research project of Festo’s Bionic Learning Network is to be put to use for future requirements in the automation of production processes.

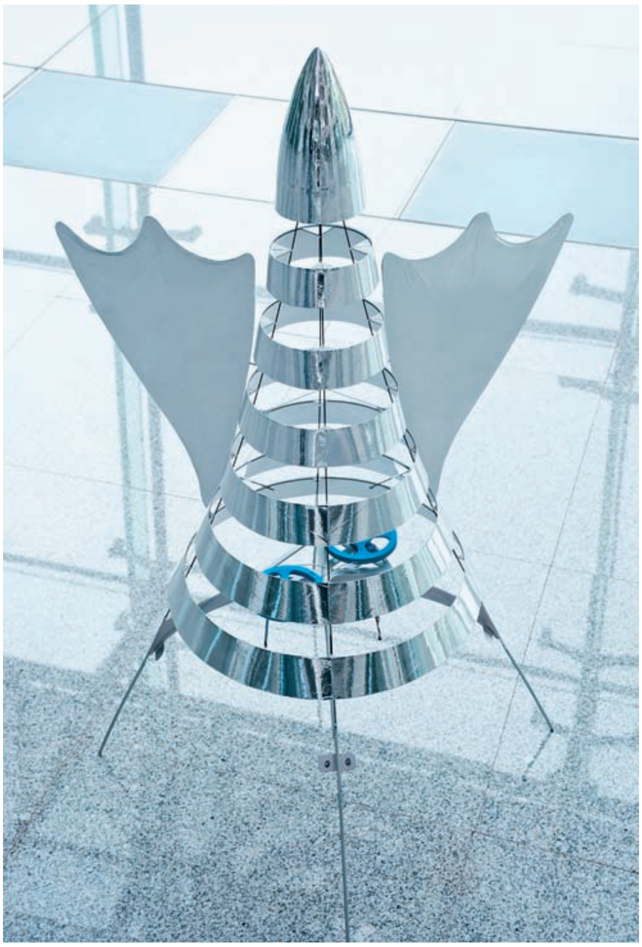
AirPenguin –
technology-bearers for adaptive flapping-wing mechanisms

The AirPenguin is an autonomously flying object that comes close to its natural archetype in terms of agility and manoeuvrability. It comprises a helium-filled ballonett, which has a capacity of approx. 1 cubic metre and thus generates approx. 1 kg of buoyant force; at each end of the ballonett is a pyramid-shaped flexible structure of four carbon fibre rods, which are connected at joints by a series of rings spaced approx. 10 cm apart. The rings together with the carbon fibre rods yield a 3D Fin Ray® structure that can be freely moved in any spatial direction. The Fin Ray® structure was derived from the anatomy of a fish’s fin and extended here for the first time to applications in three-dimensional space.

Each pair of spatially opposed carbon fibre rods is connected via bowden wires and a double pulley, and can be extended and retracted in contrary motion by means of an actuator. This gives rise to rotation free of play both at the tip of the AirPenguin’s nose and at the end of its tail. By superimposing two perpendicular planes of rotation, any desired spatial orientation can be realised.

A strut to which the two wings are attached passes through the helium-filled ballonett. This new type of wing design can produce either forward or reverse thrust. Each wing is controlled by two actuators: a flapping actuator for the up-and-down movement of the wings, and a further unit that displaces the wing strut to alter the pressure point of the wings. There is also a central rotational actuator for the two flapping wings that directs their thrust upwards or downwards, thus making the AirPenguins rise or descend. All three actuators are proportionally controlled. This makes for continuously variable control of the flapping frequency, forward and reverse motion, and ascent and descent.

The entire wing complex comprises a strut with flat flexible wings of extruded polyurethane foam. The wing strut, which is supported at the pivot point of the torso, can be moved either towards the front or rear edge of the wing. Displacing the strut towards the front, for example, causes the wing’s pressure point to migrate forwards. The pressure of the airstream bends the cross-section of the wing in such a way as to produce a profile that generates forward thrust. If the wing strut is moved towards the rear edge of the wing, the pressure point is likewise moved to the rear, and the AirPenguin flies backwards. With this design a self-regulating, wing pressure-controlled, passively twisting adaptive wing has been realised for the first time.



Rear section with 3D Fin Ray® structure

**AirPenguin –
autonomous self-regulating systems with collective behaviour**

The AirPenguins are also equipped with complex navigation and communication facilities that allow them to explore their “sea of air” on their own initiative, either autonomously or in accordance with fixed rules.

The underlying project: A group of three autonomously flying penguins hovers freely through a defined air space that is monitored by invisible ultrasound “transmitting stations”. The penguins can move freely within this space; a microcontroller gives them free will in order to explore it. The microcontroller also controls a total of nine digital actuators for the wings and for the head and tail sections. By means of XBee, based on ZigBee, large volumes of data can be transmitted between the penguins and the transmitting stations by 2.4-GHz band radio. The penguins recognise each other on the basis of their distances to the transmitting stations. The rapid, precise control allows the AirPenguins to fly in a group without colliding, while also mastering height control and positional stability. As an alternative, they can act synchronously as a group. A comprehensive central surveillance system provides security in case of sensor failure and reports low energy supply. Whenever necessary, it prompts the penguins to return to the charging station.

Technology-bearers for the automation technology of tomorrow

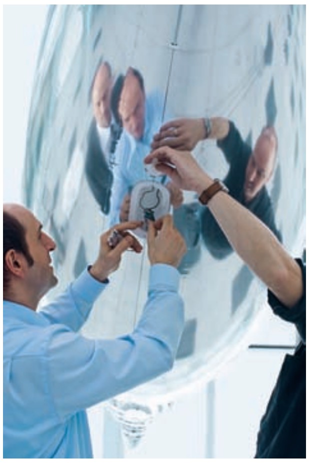
If the 3D Fin Ray® structure of the head and tail sections is transferred to the requirements of automation technology, it can be used for instance in a flexible tripod with a very large scope of operation in comparison with conventional tripods. Fitted with electric drive mechanisms, the BionicTripod from Festo for example makes for precise, rapid movements, just like the AirPenguin.

Autonomous, versatile, adaptive self-regulating processes will acquire increasing significance in future for automation in production. The animal kingdom can provide insights here which, when implemented by resourceful engineers, lead to astounding new applications.

The ongoing development of sensor and control technology is thus also being promoted along the road to decentralised, autonomously self-controlling and self-organising systems thanks to inspiration from nature. The transfer to automation technology is also to be found by analogy in regulating technology from Festo, for example in the new VPPM and VPWP proportional-pressure regulators for servo-pneumatics.

Technical data

Overall length:	3.70 m
Max. torso diameter:	0.88 m
Helium volume:	0.980 cbm
Wing span:	2.48 m
Weight:	1.0 kg
Control of wings, head and tail segments:	9 digital actuators, range 180°
Materials	
Buoyancy body:	aluminium-metallised foil, 22 g/qm
Head and tail segments:	3D Fin Ray Effect® structure of carbon-fibre rods
Wings:	extruded polyurethane foam
Wing strut:	carbon-fibre rod
Accumulator battery for wing drive and torso orientation:	Li-Po battery, 2000 mAh, 4.2 V
Receiver sensors:	32-bit microcontroller @ 50 MHz MCU 2x LM3S811 64 kbyte flash, 8 kbyte RAM
Altitude measurement:	SCP 1000 pressure sensor
Distance measurement:	ultrasound receiver capsules
Measurement of rotation rate about vertical axis:	Lisy 300-AL gyroscope
Directional and positional sensors:	positionally compensated 3-axis compass with accelerometer
Temperature measurement:	temperature sensor
2.4 GHz radio transmission:	based on ZigBee
Current and voltage monitoring for Li-Po cell	
Overvoltage protection:	DS2764 Li-Po protector
Charging controller for Li-Po cell:	Max1555 charging controller
Accumulator battery:	Li-Po battery, 2000 mAh, 4.2 V
Base stations/ transmitting stations:	32-bit microcontroller @ 50 MHz MCU LM3S811 64 kbyte flash, 8 kbyte RAM
Altitude measurement:	SCP 1000 pressure sensor
Distance measurement:	ultrasound transmitters
Temperature measurement:	temperature sensor
2.4 GHz radio transmission:	based on ZigBee
Current and voltage monitoring for Li-Po cell	
Overvoltage protection:	DS2764 Li-Po protector
Charging controller for Li-Po cell:	Max1555 charging controller
Energy reserve for approx. 50 h continuous operation:	Li-Po battery, 2000 mAh, 4.2 V
Brands:	Fin Ray Effect® is a brand of EvoLogics GmbH, Berlin, Germany



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