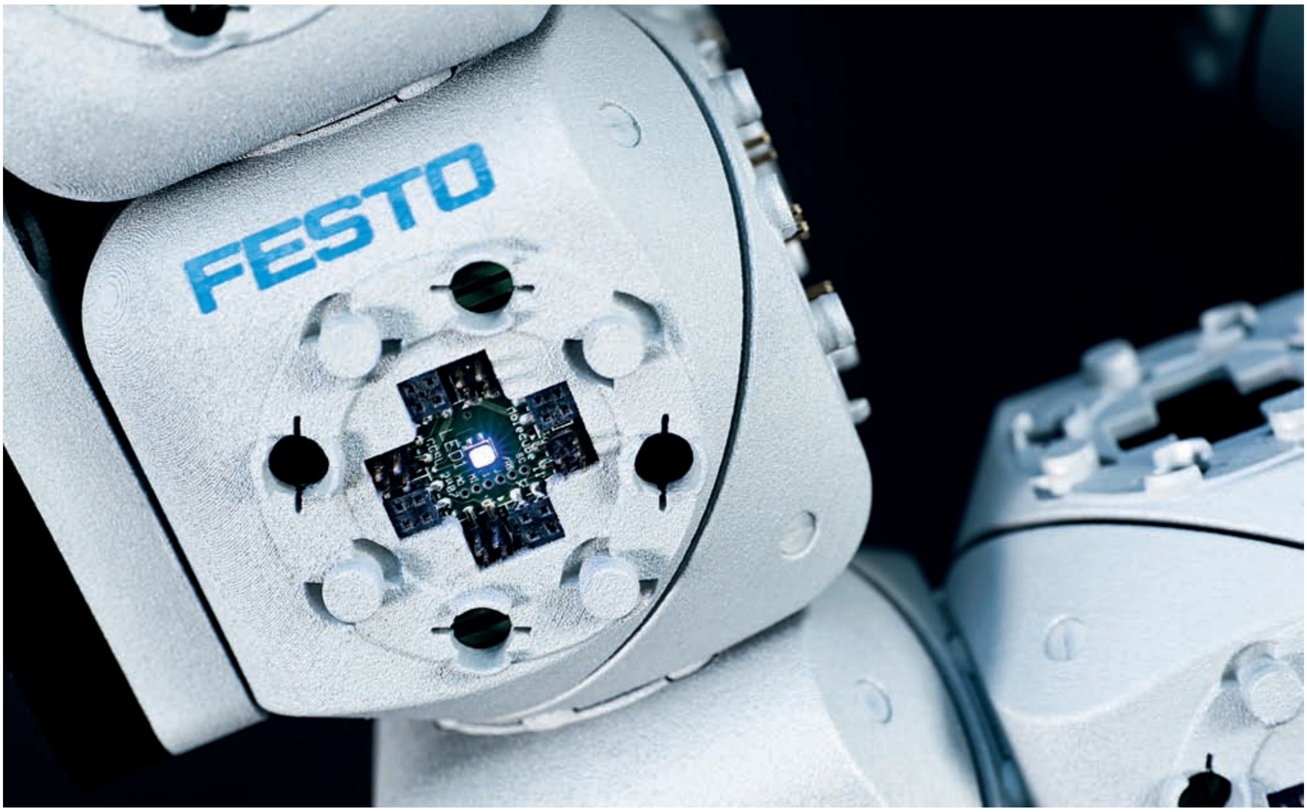
Molecubes

A programmable
robot system

Info

Modular learning



Modularisation – a principle of nature

Modularisation is a basic principle of living nature: organisms consist of molecules and cells that use genetic programming in order to group together to form organs. Cell division and modularisation are the two mutually opposed aspects of reproduction in living systems.

Modularisation is also the basis of the design of complex technical devices and machinery in all disciplines, from electrical engineering, mechatronics and robotics to IT and traffic systems.

Learning, i.e. the application-oriented acquisition of knowledge, is also subject to design processes. Existing and newly acquired "knowledge modules" are modularly networked. Because of the complexity of the human brain, learning can only be externally controlled to a limited extent. The reinforcement or rejection of an organism's own positive or negative "experience modules" appears to be the most efficient principle for sustainable learning; this learning by trial and error can best be observed among small children.

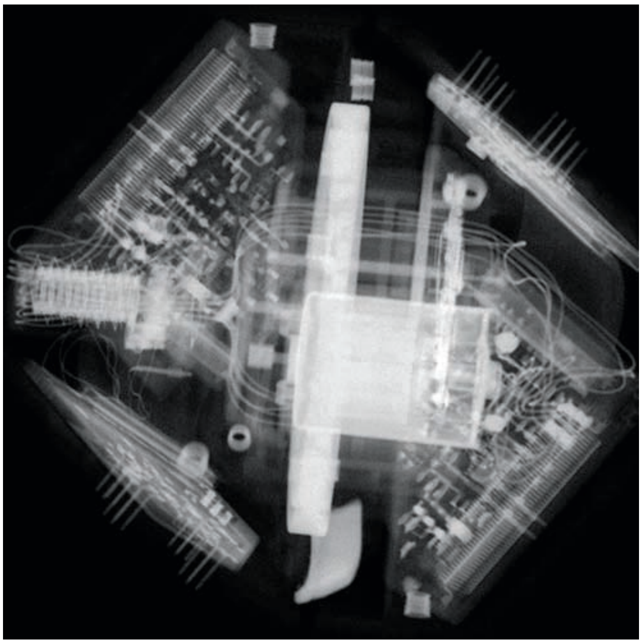
Molecubes – learning by experimenting and programming

This project is a further development of the "Molecube Systems" of Cornell University, Ithaca, USA, in the third generation. The geometrical basis of this system is a cube, to which further Molecubes can dock in all six directions like the molecules of a chemical compound. The two halves of a Molecube module rotate about the axis defined by two diagonally opposite corners. By linking together several Molecube elements, a practically unlimited number of spatial movement variants for the entire system can be realised. The end modules can also take the form of Molecubes with grippers, cameras or drive shafts.

The configuration newly formed by the docking of a further element is directly communicated to all Molecubes within the system; this ensures that the energy supply and the transmission of signals from Molecube to Molecube is maintained.

From reality to virtuality

The rigorously systematic approach of translating the mechanical configuration into corresponding data structures now also paves the way from the concrete structure to virtual reality – or in the language of the Massachusetts Institute of Technology (MIT): from atom to bit. Wireless data transmission enables the real configuration of the Molecubes to be replicated in a data model on a personal computer.



X-ray image of a molecube

Molecube with gripper

The Molecubes can be programmed in four different ways, ranging from manual to fully automated programming:

High-level programming
The interface for numerical calculations on the basis of matrices, similar to the MATLAB program, allows programming with direct drive commands, sensor signals, and the application of internal variables and of data flow control commands. At this level, elementary programming experience can be acquired through direct feedback. The source code is available e.g. for study units via compilers that can convert the source language into a target language, or for extension by experienced users.

Direct programming
Via the ARM-processor interface, experienced users can program the robot directly in the programming language C++. A library enables direct communication with all sensors and actuators.

Machine learning
With this interface, fully automatic programming by means of mechanical learning processes at the highest level for research purposes is possible. Reinforcement learning and evolutionary algorithms are the key words in this context.

Graphic emulation
Realistic graphic and physical emulation allows the robot to be tested and operated virtually. In virtual reality, the user can control geometric and physical parameters and for instance monitor a robot's collision behaviour. The simulation data can be exchanged between several robots, e.g. for studying cooperative or competitive behaviour.

Towards the learning module

This study demonstrates the general feasibility of such a versatile system. The positive experience gained with students of the Molecube Community at Cornell University and further universities throughout the world validates the chosen approach.

The task of the next Molecubes development phase will be to drive forward mechanical and electronic integration. The objective here is to reduce the volume of the Molecubes even much further by means of technologies from Festo.

With the Molecubes project, Festo is demonstrating a possible future learning environment that combines direct experience with the latest opportunities provided by modular software and robotics technology. Constructing and programming robots at first hand enhances experience and facilitates instruction in automation, and represents hands-on technology for youths and all interested specialists.

Learning from practical experience

Versatile systems machinery and product design has long been part of Festo's repertoire. The new CPX-CEC and PC Worx control units, with a universal programming interface in accordance with the IEC 61131-3 standard and a modular electric periphery such as CPX, can dock as easily as molecules when a task list undergoes modification.

Technical data

Edge length of a Molecube:	66 mm
Weight:	200 g
Torque:	4.85 Nm
Rotation angle:	continuous
Rotation speed:	max. 17 per minute
Processors:	2 x ATMega16
Servo controller:	AX-12 with ATMega8
Internal communication:	single wire, max. 1 Mbps
External communication:	USB and Bluetooth
Simulation:	AGEIA PysX engine
Graphics rendering:	OGRE

Project partners

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