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That GOLEM from the computer

Researchers dream about machines, which sketch themselves. In the computer the technical evolution makes its first steps successful. Ä Von
Niels Boeing



Click on the picture - and you see, how the Blockpusher principle functions!

© Diagram: Anne Gerdes/Foto: Getty image

Since beginning of the industriellen engineers machines, which decrease to humans work, invent revolution not rarely so thoroughly that whole branches of profession become redundant. Only itself engineers could not replace so far. Still the draft of machines is an art, which can be not completely automated. In addition, that is to change. Some researchers want to solve, what the US Robotiker Hod Lipson the "Metaproblem of the engineering sciences" calls: "a machine build, which can sketch

and build independently different machines".

Lipson is a representative of the evolutionary robotics in such a way specified. The quite recent branch of research wants to lend abilities, which were reserved so far the organic life to the machine realm. Machines are to grow, mutate, to a changed environment to adapt and multiply.

"we want to let the evolution for us work", say Rolf Pfeifer, which the AILab, which leads laboratory for artificial intelligence, at the University of Zurich. "our large weakness as human designers is that we have prejudices. A computer however, which uses genetic algorithms for example, does not have prejudices. That can develop solutions, on which we would not come."

The basic principles of the evolution, mutation and selection, made researchers already decades ago for technical problems usable. The citizen of Berlin bionics engineer Ingo computing mountain developed his "evolution strategy" in the sixties in wind tunnel experiments. By letting the form of a bearing area mutate again

and again and only the best variants re-using, he found that solution for smallest air resistance.

Announcement

Scientists such as Lawrence Fogel and John Holland devised different beginnings for "evolutionary algorithms", with which the programs optimal for a certain problem are found. Owing to advanced computer technology the US computer commercial artist Karl windshield frame section could demonstrate then for the first time virtual natures in a computer world, whose shape and control program developed themselves further in the course of several generations, in order better to run or to jump be able to 1994.

Until in a simulation evolvierte robots developed, it took still several years – up to the GOLEM project of Hod Lipson and Jordan pole lacquer. The acronym GOLEM stands for "genetic organized life-similar elektro-Mechanik". Differently than in the old Jewish myth of the Golems erschaffenen made of loam, the robot creations developed not from the hands of a toepfers, but in a 3D-Drucker.

Lipson and pole lacquer wrote first a program, to shape and controlling of the simulated robot on a virtual surface describe. Possible elements were connecting props with joints, a kind hydraulic linkage, which can produce movements, and artificial neurons. Everyone of 200 robots in the starting population got coincidental initial equipment. Some copies submitted of a mutation the two in addition: Connecting props were shortened or extended according to the coincidence principle, strengthened or weakened the activity by neurons.

Now Lipson and pole lacquer tested themselves, like far the bundles of – developed in such a way; Initial at the beginning of plus Mutanten – within a certain time on the surface to move could. The further they came, the more largely the researchers estimated the "Fitness" the robot. Afterwards so many were removed from the weaker that a new generation remained remaining by 200 virtual robots. Up to 600 of such evolution steps the population went through. "with it astonishing different forms" developed, say Lipson. "surprisingly it was also that many were symmetrical, although this characteristic in the experimental assembly was not recompenced."

At the end the three were selected to fit-test to the
Materialisierung: Lipson and pole lacquer printed out their

connection parts in a 3D-Drucker as plastic parts, which assembled them in accordance with the arrangement with hydraulics and the electronic control, evolvierten in the computer. The strange creatures, that crept then actually as simulated in the computer over the soil, reminded of primitive urzeitliche creatures.

But also the GOLEM Kriecher had still two substantial restrictions. "during the development of the structural drawing to the new shape the system was isolated", says Rolf Pfeifer. Their reciprocal effect with the environment was missing as in the nature, in which organisms must constantly react to their environment. And they could not grow yet correctly. "in the current phase of the evolutionary robotics we try to code also the growth of the machines."

From random numbers have it and its former graduate student Josh Bongard – in the meantime professor at the University of Vermont – a Genom sketched, which lets spherical cells of a simulated robot develop. Depending upon numerical value the cells are divided and equipped with neurons, sensors or engines. The Genom is regularly mutated thereby. The task, at which the creature is to grow, is, to push a right parallelepiped on one level as far as possible.

The simulation starts with only one cell. After more than 80 evolution steps the "Blockpusher" grew on 50 cells. A Tentakel from the trunk was formed, that against the right parallelepiped to press knows – a differentiation of the shape into different parts of the body, as it occurs with organisms since ever. The Blockpusher cannot be converted so far into material robots. But in the European Union project Pace work Pfeifer and other researchers to create on chemical basis artificial, programmable cells which can go through a genuine evolution.

The Italian researchers Stefano Nolfi and Raffaele Bianco pursue a similar beginning, which in addition, the interaction with the environment wants to include. They use a swarm from, sensor-steered minirobots with a diameter of approximately 10 centimeters, isolated first, which can be connected to larger units. In its on-board price increase is a software with an artificial neural net, which serves as digital Genom.

In this digital hereditary property also a self disconnection is programmed, which can occur after each time interval of 100 milliseconds with a probability of 0,013 per cent. a robot "dies", it from the testing ground is taken and with a mutated Genom again put in. Thus the genetic equipment of the devices around-tearing

on roles is permanently changed.

Differently than with the GOLEM creatures or the Blockpushern the robots do not have a concrete task to solve, but simply only survive. One on the other, that is explained to percussions two as the winner, who hits with larger force. It actually couples the being subject and transfers its software into its control – the stronger Genom, which made a wuchtigere movement possible, increases thus. If the two-bottom plate meets a third robot and wins again, this is attached to the end. In this way gradually ever larger arrangements can form, which not necessarily like a course is in straight lines line together coupled. Formations also broken are possible, which survive, if they coordinate their movement better than others.

"our goal is long-term, a hardware evolution with open exit", says Nolfi. Also the Italian evolution existed so far only in simulated form, is to be realized however soon with the micro robots of the European Swarm offer project. Nolfi is confident that that will succeed: "we could convert other experiments successfully with the simulator routine already with the Swarm Bots."

During Pfeifer and Nolfi above all the possibilities of mutation, selection and growth in the machine realm examine, work Hod Lipson in the meantime of mastering the fourth important characteristic from organisms to: independently to multiply, "make a replication themselves". The first important impulse for this the Hungarian-American mathematician gave to John von Neumann more than 50 years ago. After it had carried innovative theoretical work out for the architecture of digital computers in the forties, it developed the cellular automat in such a way specified in a mathematical thought experiment.

The cellular automat was a two-dimensional object in a kind chessboard world. Rules were given to its elements, according to which they could add further elements. The astonishing: With suitable rule set the automat could produce a copy of itself. By Neumann this model used, in order to show that the combination of a universal construction apparatus and a universal computer has a remarkable characteristic: "self reproduction", says Neil Gershenfeld, physicist at WITH Media lab.

Which in the cellular automat only one concept is, Lipson demonstrated in the past year with a simple robot, which from four wuerfelfoermigen components, which "Molecubes" exists. Those have two halves, which are against each other rotatable owing to an

electric motor in the diagonal. A micro CONTROLLER in each cube knows the possible movements just like the form of the entire robot. If one starts it, he bends and looks for themselves for a new Molecube. That it takes up then, winds themselves, divides, seizes a further cube, adds it cubes already put down, connects themselves again with them to – a procedure confusing which can be looked at, at whose end two robots stand on the table.

This arrangement was still quite simple, particularly since the Molecubes was programmed on it, to look in two determined places for further cubes. "in another attempt we let develop a robot during an evolution process at all only the ability to the Selbstreplikation", say Lipson. "with it interesting constructions, which learned rather spontaneously to multiply itself developed however only in a simulation." Now Lipson wants to repeat these experiments with some hundred smaller units, not more largely than 0.4 millimeters, material.

In order to create machines, which can build other machines, it is not sufficient however to build these from a sentence from modules already prefabricated to. They would have to be able to make if necessary in principle new modules of raw materials themselves. Therefore Lipson works at the same time also on the advancement of a universal "Fabricators" (*TIME* NR. 38/06), with which such elements expressions leave themselves.

The equipment, which it and its for colleagues built, is not only able to manufacture plastic parts as also in the industriellen rapidly the prototyping happens. It can print layers, which serve as electronic components with the help of a metallionenhaltigen synthetic resin. If one sets under tension, they become bent and with them also surrounding plastics, it develops a construction unit, which is called in the robotics actuator. "we did not only print the first actuator, but recently also, Lipson says a transistor". Even a flat battery can be manufactured with the 3D-Drucker in the meantime. "with it we have already important components together." It prophesied, in one year it knows complete functional devices expressions.

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Also Stefano Nolfi believes that first reproductionable hardware could become already in the near future reality. "up to making a replication machines, which develop also still different shapes and behaviors during an evolution process, it is however still another

