Darwin on the Mountain – Evolution and Optimization

Englischer Filmkommentar

Variation and Selection *(1:50 min)*

Bionics is the fantastic science that seizes nature's ideas as a model for **new technologies**.
The term is a combination of the words **Biology** and **Electronics**. You may be asking yourself "what part does **biological evolution** play in the development of technologies"?

For over 4 billion years now evolution has been molding the life on our planet. Everywhere we look, whether in the water, on land or in the air, evolution has developed the countless shapes, structures and skills used to adapt to the challenges of life. It is in this fashion that it follows very simple principles recognized and named by **Charles Darwin** about 150 years ago.

Variations: the genetic variation. Genes define the appearance and abilities of individuals. The **genotype** of each offspring is a bit different in its mixture than that of its parents, or has been slightly altered by **genetic mutations**. This is why siblings are never a hundred percent alike and new variations evolve. In general considerably more offspring are conceived than survive and reproduce, allowing considerable variety in each individual.

Selection: a natural selection. Individuals that are better **adapted** to the conditions of their environment are most likely to **successfully reproduce**. They may be the better hunters, the faster runners, the more striking bachelors or the more inconspicuous type. The most successful of their kind reproduce and pass their genes onto the next generation. Engineers like to talk about a **billion-year optimization process**. Unfortunately, nature doesn't optimize the same way scientists do. Evolution doesn't pursue any higher goals. Those, who actually **adapted the most** will be shown by the number of offspring that managed to survive.

But how, you may ask, is Darwin's theory of the development of genetic variations and the survival of the fittest going to be of use in the improvement of technology?

Artificial Evolution in Scientific Research *(2:10 min)*

Engineers use nature to improve all kinds of different technologies. At the technical university of Berlin **Professor Ingo Rechenberg** realized that evolution worked far more elaborately than most of the commonly accepted optimization concepts and so developed a strategy that simulated evolution in its primary features. His **key experiment** illustrating this evolutionary strategy dates back to **1964**.

Researchers tested air resistance in a wind tunnel by using a zigzag surface, whose angles were adjustable, in an effort to reach the optimal aerodynamic form of a plain surface by a series of **random adjustments**. These researchers arbitrarily chose a starting arrangement of the plates segments, and all following arrangements were chosen by **coin-toss**. With every coin-toss an angle was adjusted only one step in the plus or in the minus direction.

There were five adjustable angles with 51 positions for each angle. That makes 345 billion possible adjustments. Skeptics found it much more realistic to win the lottery jackpot than to figure out that single optimal aerodynamic form out of 345 billion possibilities. They were convinced the experiment would take years because tens of millions of forms were to be implemented.

Rechenbergs' **artificial evolution** was of course not left to blind chance: it was found that the key factor in determining survival was that in the **direct comparison** of two generations. The only form to survive was the one better suited to the wind tunnel. It assured that the zigzag plate with the little random mutations was **consistently improved**. Instead of the feared tens of millions adaptions, it took only about 300 mutations to come near an almost perfect flow structure.

Only by the interaction of **random variations** and the **selection** of the **best adapted** form a robust optimization technique could be developed.

The Nested Strategy of Evolution *(2:00 min)*

Over the years Rechenberg created an **Evolution-Algebra** that not only compares one parental unit with its descendants, but also **simulated** a large **scale evolution** with multiple variations of descendants, parents and a total of populations. With a **nested strategy** of evolution it is possible to perform very complex optimizations.

That the result of the experiment with a zigzag plate would be optimal was already known from the start. But if for example you were to improve the wings of an airplane by using the wing of a stork as a model we would not know the outcome of the trial.

Optimization can be imagined like **climbing a mountain** in the fog. With every step, we feel as though we are going upwards, finding ourselves nearer the peak. Regardless of the number of steps we come, we can never know for certain how many steps remain. Does the next step lead us down the abyss? Or do we not make any progress at all? Would it be possible that we had made it up higher had we started the climbing at another spot?

The art of using the strategy of evolution is to find just the right step range for mutations. Taking too big steps we might skip the best result. Taking too little steps might never lead us to the optimum. This is why the strategy of evolution always takes numerous different ways into account for reaching the peak of a mountain.

The strategy of evolution has **many applications**. With the evolution of Darwin it is possible to construct perfect bridges, to design more effective cranes, to find the ideal bends for a pipeline, to create spectacular shapes for a special kind of steam-nozzle, to compose coffee blends that will stun even experienced coffee tester and also to optimize airplane wings.

Learning from the Stork *(1:50 min)*

Located at the end of the airplane wings there are little ears, called **Winglets**. They serve to minimize the risk of air swirls that arise in-flight. With the strategy of evolution we could use a trick learned from the birds. This **stork** spreads his wing tips to fly as economically as possible.
With the strategy of evolution we are able to improve the functionality of the winglets even further. It depends on the amount and the perfect alignement of the single winglets to each other.

Basically more winglets mean less aerodynamic drag. But practically this means an increasing instability of the single winglet. But after realizing this concept, it was easier to find an optimized technical solution. The **multi-winglet** became a **split-wing-loop**. Only by this little modification big jetliners could save 5 to 10 Percent of their fuel. That amazes even the stork.

Bionic is a way to a new consciousness that brings us to a closer combination of technology and nature. It includes hopes and expectations of technologies that are **future-orientated** and **compatible with nature**.