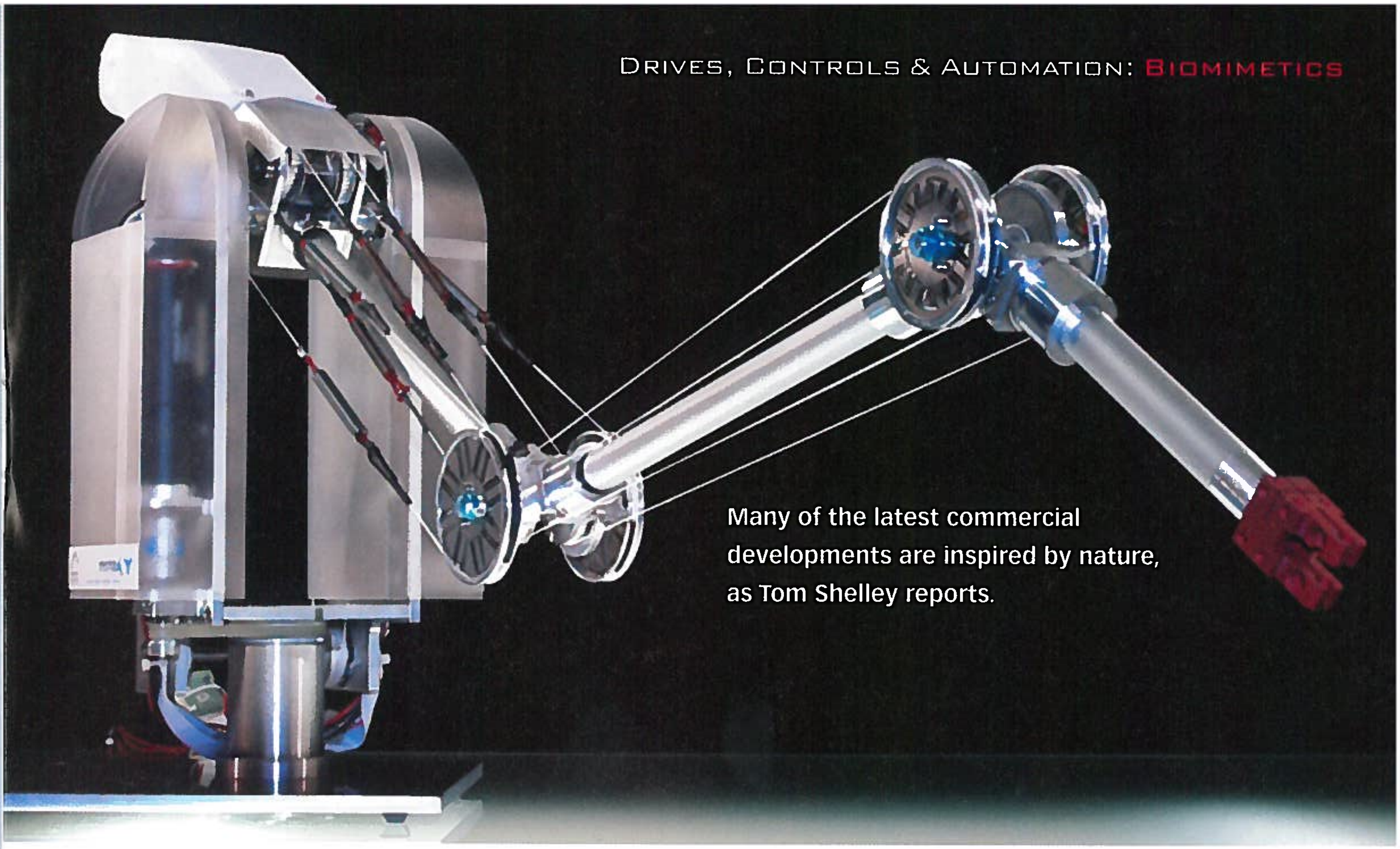

Many of the latest commercial developments are inspired by nature, as Tom Shelley reports.

Plants and animals offer models for efficient movement

A robot arm inspired by human anatomy that is exceptionally light and uses a tenth of the energy of conventional designs caught the eye at this year's Hannover Fair as well as flower-inspired mechanisms, animal-inspired manipulators and rat-inspired robots.

The robotic arm employed antagonistic tensions, similar in operation to human muscles and tendons, while the blind operating mechanism was derived from studies of what happens when birds land on the blooms of the bird of paradise flower, Strelitzia Reginae, causing a structure that distorts to enable contact between the bird and pollen-bearing stamens.

Simon Poppinga, from the plant biomechanics group at the University of Freiburg explained that plants avoid the need for hinges, yet can construct mechanisms that achieve rapid changes in orientation. These can be imitated by making use of fibre-reinforced polymers of high tensile strength and low bending stiffness to produce useful mechanisms.

In the flower, two petals form a perch. When a bird lands, the petals bend downwards and at the same time, flick open to expose the pollen bearing stamens to the bird. The mechanism was studied by cutting away all parts of the plant that were not required to produce the movement and studying it, and constructing a physical model that demonstrated the same kind of mechanical behaviour. This was then analysed using finite element analysis, and led to the development of the 'Flectofin', by Simon Schleicher and others at the Institute of Building Structures and Structural Design at the University of Stuttgart. The mechanism is described as depending on torsional buckling of a shell component as a result of uniaxial bending of an attached beam.

The actual device is made of glass reinforced plastic laminate, and the fin rotates through 90° when the rib on which the fin is mounted is bent slightly. The bending can be accomplished by applying external force, or by employing thermal expansion. The device is currently being tested and evaluated in prototype shading façades for buildings, but also offers potential for use in air control vanes in heating and ventilation systems, valves generally, micro engineered silicon devices and aircraft control surfaces. For its initially identified market for shading buildings, it has been computer modeled in designs from 1m to 14m long. A large mockup is currently being developed for endurance tests, and a system is to be implemented in the theme building at the 2012 Expo in Korea. Performance is optimised, as in plants, by adusting fibre orientation and thickness within the structure. The developers note that in the turned state, the double curved surface that is developed generates enough stiffness to withstand wind loads.

The developers claim to have identified nearly 100 plant movements with a potential to be transferred into mechanical engineering products. Plants have evolved all kinds of structures to ensure that they maintain integrity in spite of severe external load conditions. These usually incorporate natural means to avoid stress concentrations.

Simon Poppinga is currently engaged, along with others, in a study of the mechanics of the underwater suction traps in bladderworts. These are of interest because they typically operate in about 0.5ms, although it has to be pointed out that they are only a few mm across. The way they work is that during the course of about an hour, glands pump water out of the trap interior, so that elastic energy is stored in the trap body owing to lowered internal hydrostatic pressure. A flexible door with protruding hair closes the entrance watertight. A small animal touching trigger hairs results in: the door opening, the wall relaxing and water and the prey animal being sucked into the trap. Maximum measured fluid acceleration is 600g. The door changes from convex to concave when contact between the prey animal and the hairs triggers a buckling wave. Poppinga has not yet identified a practical application for the underlying mechanics, but feels there must be one somewhere.

Festo has for some years been studying biologically inspired mechanisms for robotics. Apart from the flapping winged robotic seagull which the company had flying round its stand at this year's event, we were shown autonomous mobile robots with the company's biologically inspired 'Fin Ray' grippers on elephant trunk inspired arms. The grippers are particularly good at grasping delicate objects. Examination of the flying bird showed that it flapped its wings thanks to a three-part, mechanical crank mechanism. The wings were in two parts, with an 'arm' wing to generate lift, and a hind wing behind a trapezoidal joint to generate thrust. While constituting a considerably achievement, in designing a mechanical flapping wing bird that can autonomously fly, take off and land, nobody was able to advise us of any practical usefulness for the technology.

Design Pointers

- Fins can be made that flick round by applying slight bending to a beam, taking their inspiration from Bird of Paradise flowers
- Robots arms with a small fraction of the weight and power consumption of conventional constructions use antagonistic tensions on cables, in an analogous method to that use of move the human arm
- Rats, bats, and dinosaurs have are also currently inspiring novel engineering designs

Of immediate practical usefulness however, is the 'BioRob' robotic arm that has been developed by Tetra. By using antagonistic tensioned cables to move its various parts, it is at the same time, much lighter in weight than a conventional robot arm, and consumes much less energy, one tenth as much, according to Christian Trommer, the company's head of division lightweight Mechatronics. For the same reasons, we know that NASA has also studied related mechanisms for use in space (Eureka June 2010). With four joints, the company's model X4-SR has a total weight of 5kg, including control units, yet can lift 2kg with its 700mm long arm, or deliver a contact force of 25N. Nominal power consumption is 15W. Each joint is actuated through a DC electric motor. Joint position feedback is from an encoder on each motor and another absolute encoder in each joint. Interface is by EtherCAT from a PC and the design is protected by patent.

The robot, being low powered, is exceptionally quiet running, and one of its application areas is medical. Its low weight also allows it to be used in other novel applications, such as on a helium balloon, for ceiling and wall inspection in buildings, and also performing light tasks, such as marking cracks and cleaning. This does away with the need to erect scaffolding, which is liable to be both time consuming and expensive, as well as possibly damaging the floors of old constructions.

Still in the research stage is the 'RatNic' climbing robot rat, which uses claw analogues for gripping pipes and cables as it climbs, light weight elastic legs, and a construction based on a rat's skeleton. The small robot, which is rat sized, is designed to carry sensors such as cameras, temperature and humidity and gas sensors, into high corners of buildings. Weight of the development prototype is 1.1kg and it can crawl through a 150mm diameter pipe.

Slightly more down to earth, around the back of the stand exhibiting the BioRob, we encountered Fatih Bagkesen, from the Institute for Textile Technology and Process Engineering Denkendorf, who showed us how only 0.2bar air, blown into a structure, could reverse its curvature.

http://itke.uni-stuttgart.de
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