PHANTOM

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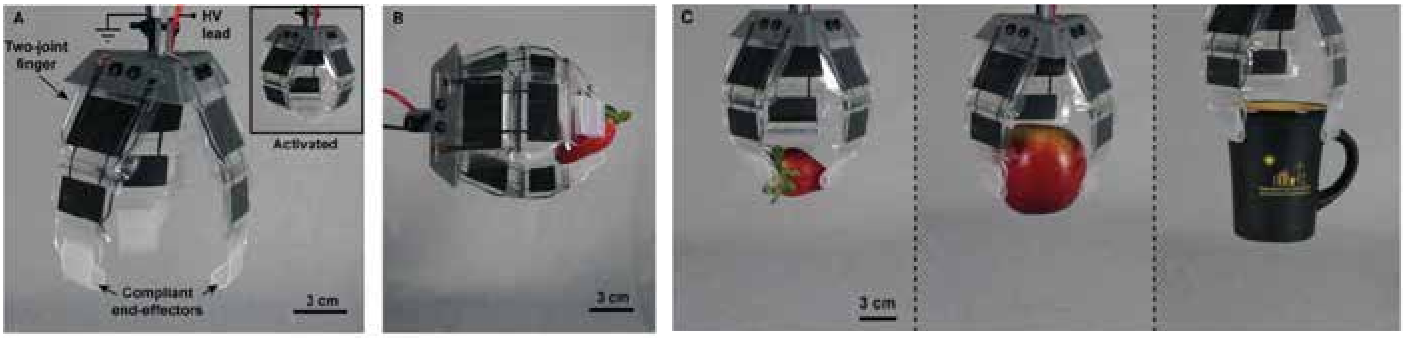
CASE STUDY

Bionic Technology Analyzed Precisely

Ultrahigh-speed camera used in complex fundamental research, analyzing bionic joints with 300,000 frames per second.

To realize future visions such as robotic humanoid with artificial joints and muscles, complex fundamental research is necessary. The Max Plank Institute for Intelligent Systems (MP-IS) in Stuttgart, Germany, has dedicated itself to this research using a Phantom Ultrahigh-speed (UHS) Camera for precise observation and versatile analysis of these complex processes.



Several joints can be arranged one behind the other like a finger - and combining multiples of them can form a hand. This can be used to lift a strawberry, an apple or a coffee cup.

VISION RESEARCH / AMETEK®

In order to breathe life into bionic joints, small plastic bags filled with liquid (e.g. vegetable oil) are set in motion electrostatically. The strength and form of the electrical voltages applied determine the strength, type and form of movement. To imitate the complex mechanical processes of the human hand several joints can be arranged in a geometric shape, one behind the other, similar to a human finger. This control is important as there is an enormous difference between grasping a raw egg and an object weighing several kilograms.

Experimental setup with Dr. Philip Rothemund, Postdoctoral Researcher at the Max Planck Institute for Intelligent Systems (MPI-IS): "In basic research you constantly come across new questions, aspects and requirements. The ultrahigh-speed camera used in our analysis offers a very high level of performance and wide range of functions."

(MPI-IS) in Stuttgart has been working on bionic joints research for over a year. The CMOS camera Phantom v2640 offered by High Speed Vision GmbH delivers the required ultrahigh-speed imaging capabilities required for accurate motion analysis.

PRECISE ANALYSIS

The variable electrical voltage applied to the actuator/joint can be regulated in all its range of square, triangular, sinusoidal and linear voltages. Deformation of the bags as a function of time can thus be controlled very precisely. These bionics replicate the movements of insect legs (e.g. spiders) in terms of speed, power, and bi-directional movement. Of even greater importance is the replication of human extremities (fingers, hands, arms, legs). For over a year, the MPI-IS in Stuttgart has been researching the basics of understanding these complex multi-layered bionic processes. This research work has also become known under the title of spider-inspired electrohydraulic soft-actuated (SES) joints.

Equipped with the latest CMOS sensor technology, the Phantom v2640 camera offered by High Speed Vision GmbH provides the necessary ultrahigh-speed image sequences for precise motion analysis. This allows the quantitative and qualitative acceleration, speed, and movement behaviour of an articulated arm to be followed very precisely — through slow-motion, high-resolution imaging.

Together with simultaneous tracking of the geometric deformation of these actuators, including the fluid flow occurring within them (flow behaviour), researchers are able to analyze many other important aspects and functional factors. The high-speed (HS) video sequences enable detailed frame-to-frame analysis at strain rates of up to 7,000%/sec. Working ranges of over 100,000 frames per second (fps) correspond to an increment of 0.01 milliseconds. These are recorded synchronously with other measurement data.

Logical processes in the range of milliseconds are recorded in their entirety, enabling precise information to be extracted. An example benchmark is a 1-cm long bag recorded at 0.1 ms with real FULL HD resolution and 10,000 fps. This enables movement differences in the range of 0.001 mm to be captured.

ULTRAHIGH-SPEED VIDEO PROVIDES VERSATILE PRECISION

During the course of the experiments, further questions continually arise. As a result, new requirements in the fundamental research on the SES joints must be examined in detail. The use of lasers only allows discontinuous measurements, whereas ultrahigh-speed video recordings enable the entire actuator geometry to be tracked, thus providing a wide range of precise information, both quantitative and qualitative. Small air bubbles in the liquid, for example, can be tracked simultaneously with the bag deformation and joint movement. This provides valuable information about the flow behaviour of the liquid in the bag according to the voltage applied.

A major benefit here is the high image resolution of the Phantom v2640 with simultaneous and extremely fast frame rates. In accordance with its stringent requirements and in anticipation of further beneficial functions being added, the MPI-IS decided to purchase the Phantom v2640. High Speed Vision's extensive knowledge and expertise being available in an advisory capacity were also an important part of this decision.

The Phantom v2640 is the world's fastest 4-megapixel camera with a maximum resolution of 2048 x 1952 pixels at a frame rate of 6,600 fps and 12-bit image resolution. With a reduced resolution of 300,000 fps and a minimum exposure time of 142 ns. In binned mode (2 x 2 pixels), photosensitivity is increased from mono 16,000 ISO up to 25,000 ISO.

This high photosensitivity enables recordings to be made in daylight, making handling easier and considerably simplifying the experiment setup. No complex additional lighting is necessary, thus avoiding possible external influences (heat input) which could impair the experiment. High photosensitivity also has the major benefit of being able to close the lens aperture to a large extent to improve the depth of field.

The Phantom v2640 also has far more superlative performance data. An extremely fast internal sampling rate of 26 Gpx/Sec and a ring memory upgradable to 288 GB. Fast download speeds for data backup are available with the 10 GB Ethernet interface. Alternatively, there is the optional CineMag V storage with up to 8TB volume, enabling 288 GB of data to be downloaded in less than 5 minutes. The menu-guided user interface enables easy camera operation.

SMALL DETAILS, BIG IMPACT

The goal is to precisely measure all aspects of the ongoing dynamics with very high resolution. Combining and synchronizing different electronical measurement techniques with high speed imaging data allows to qualify and quantify those dynamics.

The electro-hydraulic "muscles" have a considerable advantage over the behaviour and necessary design of electric motor solutions with the same tasks/results. This gives SES joints a high level of protection against overloading.

By connecting several joints and several fingers in series, extremely sensitive and versatile control is possible. The first joint is powerful and the last joint is very gentle. This not only relates to the respective forces exerted, but also to the acceleration of the components of each joint. A future step is planned with an additional camera to open the 3D space using ultrahigh-speed video, with high time and image resolution for analytical precision.

The easy-to-control actuators also operate under water. Because the liquid in the bags is scarcely compressible, the surrounding water pressure does not negatively affect how strong or soft the grip is compared to operation on land. The joints can also be easily dipped in alcohol for disinfection.

GRAND FUTURE

Bionic electrohydraulic actuators have enormous potential in terms of their design, application and cost-effectiveness in future soft robotics and other interacting areas. The following attributes are not exaggerated statements, but instead, show just some of the emerging properties and possibilities of new applications.

The soft-working joints are ingeniously simple, light, extremely agile, space-saving, easy and very cheap to produce. They are versatile in design from delicate to robust, with synergy of multi-part joints, minimal mechanical effort, low energy consumption, normal plastic foil, and are hygienically easy to care for. Also, they are waterproof, highly efficient with sensitive or strong power transmission, have easily scalable production, and are particularly easy to control digitally.

The outstanding strengths and international success of the many MPI disciplines and departments are the result of its entirely independent fundamental research. Because there are no sponsors to influence its work, MPI enjoys maximum freedom for successful research.

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