Mechatronics get smart

A complete mechatronic system, including all mechanical parts, controls, electronics, sensors and actuators, combined in a single monolithic unit and fabricated in one go by a 3D-printer-like machine. That is the very ambitious goal of Dr. Hassan HosseinNia, assistant professor at the Mechatronic System Design research section of TU Delft's Department Precision and Microsystems Engineering (PME). In trying to revolutionize the field of mechatronics, he is looking at smarter materials, smarter designs and smarter controls. "I am convinced the future of mechatronic systems is beyond our current imagination. Developments in this research area will create magic, and we hope to be at the forefront of it all."

There are many areas in which the field of mechatronics can move forward, according to HosseinNia. "Take for example actuators. Generally, they perform their action at a single point. For certain applications, where action is required on many points, such as in the handling of delicate wafers, this is very impractical. HosseinNia: "In the human body, actuators are distributed over larger areas of the body. It's never just a single component that moves, everything is connected." Learning from nature, HosseinNia and his team are exploring how they can distribute sensors and actuators over the system, preferably integrating the two functionalities. "A smart actuator is a distributed actuator."

Distributed mechatronics

In another development, HosseinNia looks at exploiting smart materials, a term which refers to materials that have an extra functionality that allows them to act upon an external stimulus. For example, piezoelectric, electroactive or ionic polymers change shape when an electrical voltage is applied. Shape-memory alloys return to a pre-defined shape when heated. Smart materials are mostly 2D materials. "The innovative step is that we can cut, etch and fold these two-dimensional building blocks to form three-dimensional structures in a way that is most reminiscent of kerigami, a Japanese art of folding paper." The difference between kerigami and origami is that the former also involves cutting the paper, or, in the analogy with mechatronics, the two-dimensional building blocks. Actuation and sensing units are etched and cut into the two-dimensional material sheet that is further deformed in order to induce controlled buckling, forming a three-dimensional structure with multiple transducer units. The resulting system features distributed sensing and actuation, and offers the advantage of easy scaling. "Current generations of sensors and actuators are often large and bulky, and difficult to miniaturize. Using the kerigami approach, it is no longer necessary to completely rethink all individual components in order to make the system smaller. Irrespective of the scale, the structure composed of two-dimensional building blocks functions in the same way."

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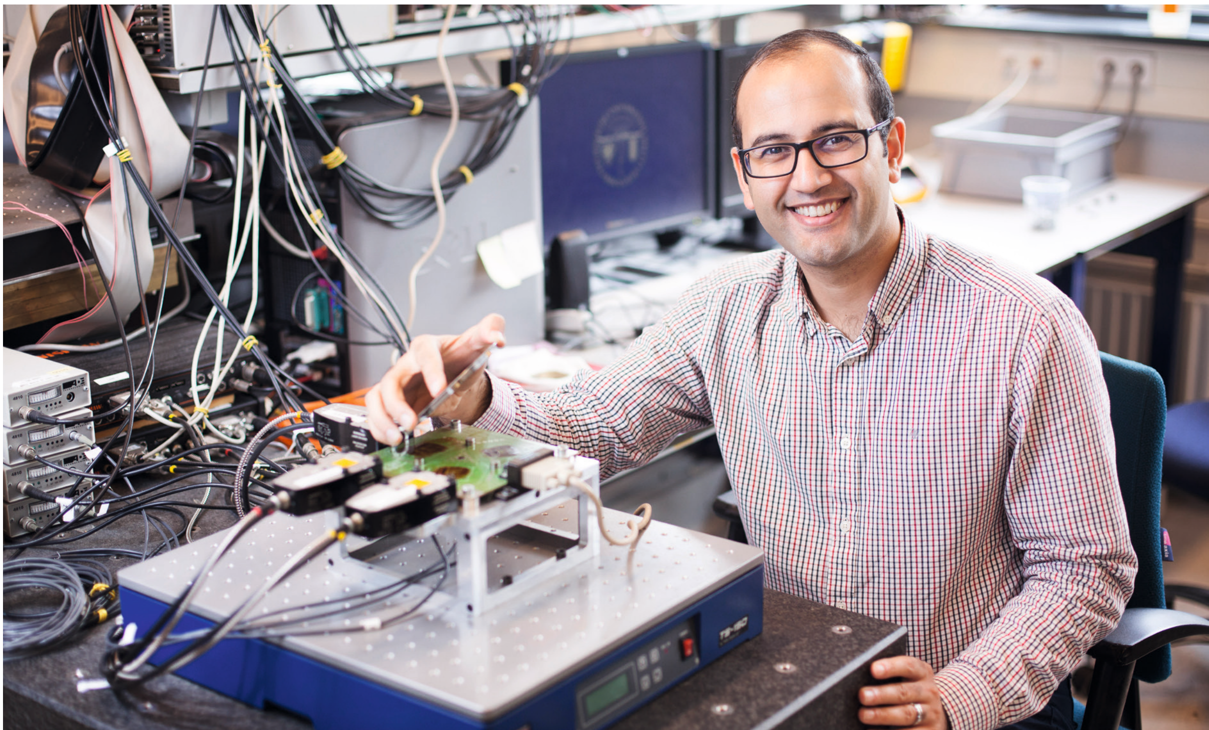


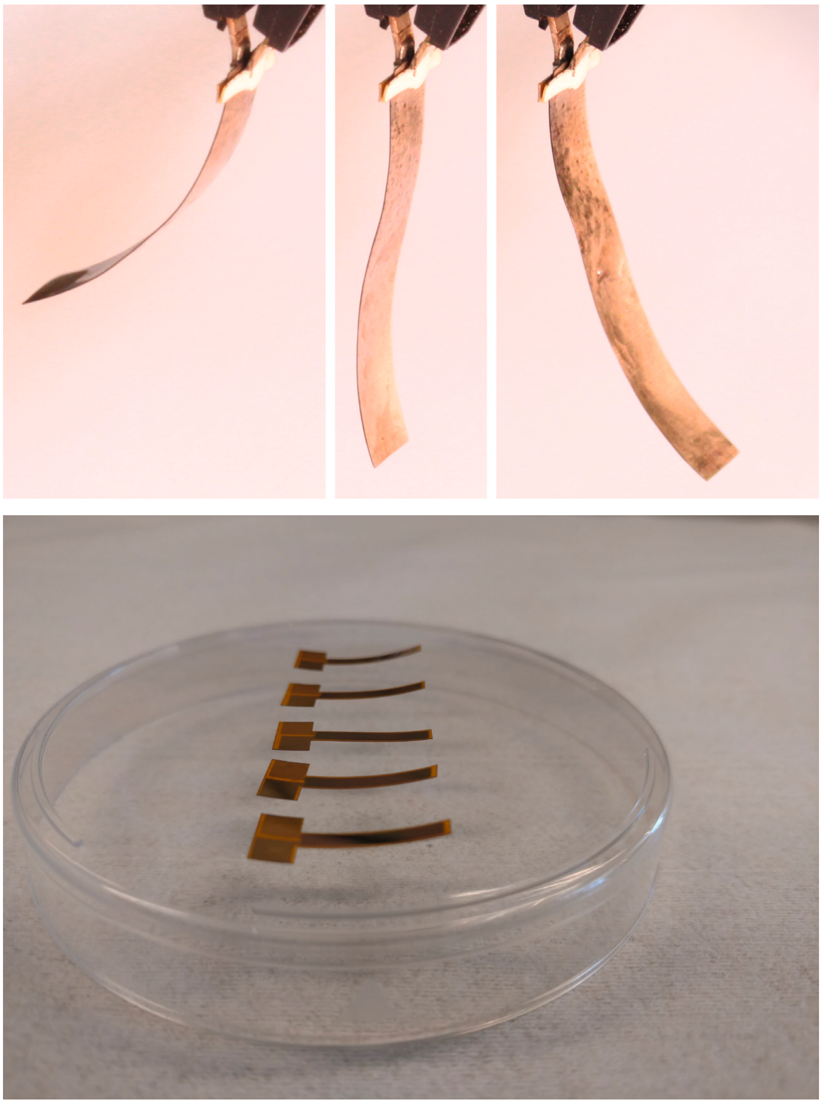
TU Delft

Nonlinear precision control compatible with Industry standard

However, the main development HosseinNia is focusing on, concerns the 'brains' of the mechatronic system: the controls. "When we move from a single-point actuator to a distributed actuation design, new interactions come into play. This requires more advanced control paradigms. Current control approaches are based on linear theory. This theory fundamentally implies a trade-off between precision, stability and speed: a system designed along these lines cannot be extremely fast, stable and very precise at the same time, which limits the achievable performance levels. We are developing a novel nonlinear theory to achieve the ideal performance that was predicted by Bode more than 50 years ago." HosseinNia stresses that he does so with a keen eye on the compatibility of the resulting systems with industry standards.

Microrobots

What about the nanoscale? "We are also looking at systems on the scale of micrometers or even nanometers. The trend towards miniaturization asks for systems with distributed motion as well as distributed actuation and sensing." "For example," HosseinNia explains, "can we exploit smart materials to get tiny systems to move inside a liquid environment?" In one approach, HosseinNia is exploring the possibility to build a tail-like component to propel such a system, mimicking bacteria or sperm cells. Ionic polymer-metal composites are promising smart materials to realize such a component: they display artificial muscle behaviour under an applied voltage or electric field. The dream of a microrobot navigating through veins to locally diagnose or even treat a medical condition from inside our body is still far, far away, but HosseinNia is determined to get there, working on larger-scale prototypes. "Distributed mechatronics are not solely focused on the nanoscale, but it most certainly is a very interesting scale because of the challenges involved." He adds: "It definitely is the future of mechatronics."



The workhorse of mechatronics is a very thin (two-dimensional) transducer that can be made to bend its shape. HosseinNia incorporates smart materials such as polymers. The transducers of the top pictures contain an ionic polymer, those of the bottom picture a piezoelectronic polymer.