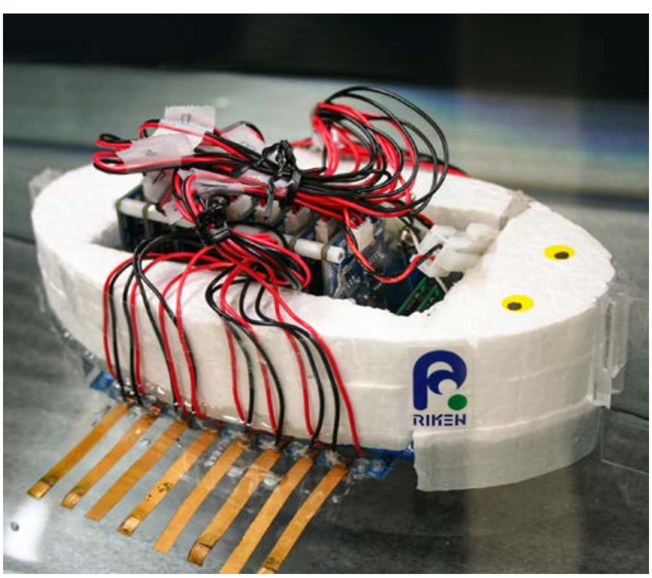
GETTING A GRIP ON MASS-PRODUCED ARTIFICIAL MUSCLES

A team from Toyohashi University of Technology is helping manufacturers understand the physics that can TRANSFORM ORDINARY PLASTICS INTO SHAPE-SHIFTING ROBOTS.

Shortly after pausing a video showing some of his earliest creations — snake- and fish-shaped robots that wriggle and swim underwater using electrically controlled strips of plastic — Kentaro Takagi reflects on the rapid transformation his discipline has undergone in the past 20 years.

"The field of soft robotics hadn't even been born when I started researching artificial muscle technology in 2004," he says. "But now, we have collaborators in Japanese industries looking to develop new products using polymer actuators and sensors. They need design guides for mass production."

A professor in mechanical engineering at Toyohashi University of Technology, Takagi is leading a team of graduate students looking to usher in a new era of soft robotics by implementing the sharp rules of control engineering — an approach that uses mathematical modelling to approximate and optimize the behaviours of complex systems.



Kentaro Takagi/RIKEN

▲ A fish-shaped robot that can swim under water.

SLIPPERY SENSORS

Artificial muscles on Takagi's radar include ionic polymer–metal composites, thin membranes that curl up when a voltage is applied to them. But predicting how quickly and precisely these muscles move is tricky because performance is related to variables that change rapidly in time and space, such as the ion concentration inside the membranes.

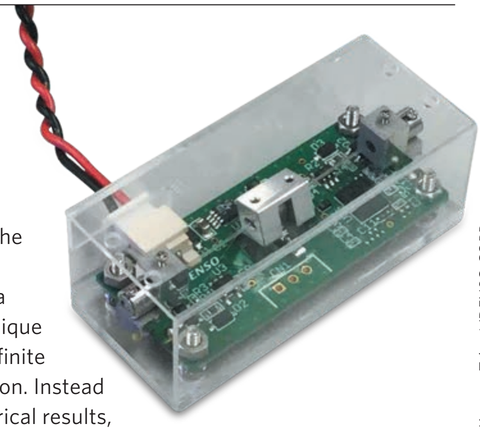
"The equations governing polymer materials are complicated and difficult to solve," says Takagi. "Engineers typically use finite element analysis software, but it has a high cost — financially, computationally, and in terms of human resources."

To approximate the complex equations, the team turned to a mathematical technique known as symbolic finite element discretization. Instead of generating numerical results, symbolic analysis produces equations that relate system performance to various design parameters. By modelling sensors based on ionic polymer–metal composites with these new equations, Takagi's team was able to accurately forecast regions of high ion concentrations at a fraction of typical computational costs.

FISHING FOR A SILENT MOTOR

Takagi was recently approached by DENSO CORP., a Japanese manufacturer of automobile components, to tackle an unexpected side-effect of electric-vehicle adoption: consumers now want all interior motors, such as electric fans, to be as silent as the battery-powered engine.

DENSO CORP. had developed a noiseless motor using twisted polymer fishing lines that twist in response to heat with hundreds of times the mechanical power of human muscles. Takagi helped the company understand how highly twisted geometries can move in ways that appear counter-intuitive at first glance.



Kentaro Takagi/DENSO CORP.

▲ An artificial muscle motor that twists in response to electrical signals.

SMART UPGRADES

"When we twist the fibre, the polymer chains become inclined and that changes the directions of contraction and expansion," explains Takagi. "And if you put in more twists, you can eventually lower the tension in the coil while still having high torque. This is critical for understanding how these coiled fishing-line muscles contract."

Takagi's lab is now seeking to expand upon a field he dubs smart materials robotics. "Being able to model several different polymer actuator materials is our advantage; there are limited places in the world that can do this," says Takagi. "We're seeking to connect materials scientists and robotic researchers using the toolbox of control engineering." ■

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