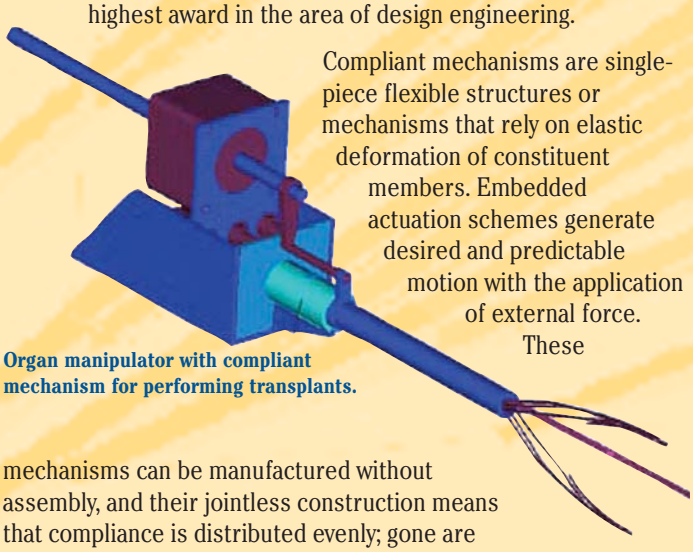
Taking Cues from Nature

Professor Sridhar Kota's work in the area of compliant mechanisms and biomimetics, where principles from nature are applied to engineering problems, has led him to novel and practical developments across myriad materials, industries, disciplines and domains in micro, meso and macro scales. For his innovative work, Kota has earned the prestigious 2004 American Society of Mechanical Engineers Machine Design Award, ASME's highest award in the area of design engineering.



Organ manipulator with compliant mechanism for performing transplants.

Compliant mechanisms are single-piece flexible structures or mechanisms that rely on elastic deformation of constituent members. Embedded actuation schemes generate desired and predictable motion with the application of external force. These mechanisms can be manufactured without assembly, and their jointless construction means that compliance is distributed evenly; gone are problems due to wear, friction, backlash or lubrication. In military applications, it means a reduction in radar cross section. Mechanisms can be designed for desired stiffness and in a variety of materials, including titanium, aluminum, steel, nitinol and composites.

Much of Kota's work has been focused on developing design algorithms for systematically generating these optimal compliant structures for a desired shape change that meets such conflicting requirements. Six of his PhD students who worked in this area have assumed faculty positions at U.S. research institutions.

Kota has developed a novel approach to varying airfoil geometry by combining advances in topological optimization methods and kinematics. The simplicity and scalability of his approach enable the aerodynamic benefits of airfoil shaping to be realized without the high cost, weight, and supportability penalties of past concepts.

Some of the practical applied research and development efforts are being carried out at FlexSys, Inc., a company Kota founded a few years ago. Dr. Joel Hetrick, a former student, continues to turn these new concepts into practical realities as FlexSys vice president. Commenting on this applied research, Dr. Donald Paul, Chief Scientist-Air Vehicles Directorate, Wright Patterson Air Force Base, Ohio, said, "His approach is enabling for future morphing aircraft concepts and could revolutionize aircraft design. Professor Kota's compliant wing technology has matured through several successful wind tunnel demonstrations and is ready for flight demonstration — the final step toward transition to future aircraft."

Another aircraft application involves active flow control to prevent boundary layer separation in order to improve aircraft performance. Kota and Hetrick have developed an electromechanical flow control device that couples a high frequency piezostack actuator with a 65X compliant displacement amplification mechanism to oscillate 16 vortex generating blades at rates up to 250 hundred hertz. The device is scalable over a range of operating frequencies, compact and requires little power, about one watt per device. Wind tunnel testing has shown a lift increment of nine percent with oscillating versus static blades.

In collaboration with transplant surgeon Juan Renas, M.D., assistant professor of surgery at the U-M Medical School, Kota's students have designed an organ manipulator that uses a compliant mechanism for performing organ transplants and other surgical tools. The device will soon be prototyped using titanium and tested.

Kota's innovative compliant mechanisms are uniquely suited for MEM's unusual constraints. His work has enabled many successful three-dimensional MEMS devices in the past five years. According to MEMS pioneer Steven Rodgers of MEMX, Albuquerque, New Mexico, Kota's designs "enabled the creation of industry leading optical components with sub-milliradian angular repeatability with simple open-loop control. More amazingly, we have not detected hysteresis with Professor Kota's mechanical amplifiers even though we are sensitive to just a few angstroms of input displacement."

Piezo-compliant actuators embedded in an aircraft wing.

Because compliant design eliminates the issue of mechanical wear, during lifetime testing of the optical components, "MEMX recently passed one-half trillion total accumulated cycles without a single failure. Such levels of performance and endurance would have been unimaginable without Professor Kota's innovations."

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