Motion of Soft Robots with Physically Embodied Intelligence

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Soft robotics deals with interaction with environments that are uncertain and vulnerable to change, by easily adapting to the environment with soft materials. However, softness inherently has large degrees of freedom which greatly complicates the motion generation. There has been no underlying principle for understanding the motion generated of soft robots. A big gap between rigid robots and soft robots has been that the kinematics of rigid robots can be defined using analytical methods, whereas the kinematics of soft robots were hard to be defined. Here, I suggest to use the minimum energy path to explain the kinematics of soft robots. The motion of soft robots follow the path where minimum energy that is required to create deformation. Hence, by plotting an energy map of a soft robot, we can estimate the motion of the soft robot and its reaction to external disturbances. Although it is extremely difficult to plot the energy map of a soft robot, this framework of using energy map to understand the motion of a soft robot can be a basis for unifying the method of explaining the motion generated by soft robots as well as rigid robots. A concept of physically embodied intelligence is a way to simplify the motion generate by soft robots by embodying intelligence into the design. Better performance can be achieved with a simpler actuation by using this concept. In nature, there are few example that exhibit this property. Flytrap, for example, can close its leaves quickly by using bistability of the leaves instead of just relying on the actuation. Inchworm achieves adaptive gripping with its prolegs by using the buckling effect. In this talk, I will give an overview of various soft robotic technologies, and some of the soft robots with physically embodied intelligence that are being developed at SNU Biorobotics Lab and Soft Robotics Research Center. These examples will show that the concept of physically embodied intelligence simplifies the design and enables better performance by exploiting the characteristics of the material and the minimum energy path concept can be a powerful tool to explain the motion generated by these robots.