Morphological Computation towards Complexity Challenge of Soft Robots

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1 Morphological Computation

Every computational process, artificial or natural, has its origin in physically grounded dynamics such as electrons moving on a silicon chip or action potentials in a biological brain. Such dynamics forms the basic substrate, so to speak, for all of the processing from which ultimately complex adaptive behaviors can emerge. Although computational processes determine the relationship between input and output, it is unclear where they occur and how they come about when considering concrete physical systems embedded in the real world (e.g., in animals or robots).

From this perspective we have been exploring the concept of morphological computation [1], because the kinds of computation or information processing that we are interested in seem to be something beyond the Turing or Shannon sense. The computation implemented in the morphological domain tends to have several unique characteristics; for example, it is typically energetically efficient and very fast and has low cost. It can be also scaled up such that much more complex systems comprising many degrees of freedom can be handled by a simple controller. Often, through morphological computation, sophisticated behaviors, such as grasping of unknown objects or legged locomotion in unstructured terrains [2], can be achieved with much simpler computational architectures.

2 Complexity Challenges of Soft Robotics

Morphological computation is particularly a powerful concept for complex systems such as soft robots that have been recently attracting considerable attention of robotics researchers. Compared to the conventional rigidly built robots, soft systems are typically cheaper, smaller, safer, and more adaptive, which open doors for many high-impact applications [2].

One of the most fundamental reasons why soft robots are important and interesting lies in the fact that deformation is the origin of all intelligent adaptive behaviors in biological systems as exemplified by muscles deforming to generate motions, heart and lung fluctuate for circulating fluid necessary for our metabolism. There are a few distinctive reasons why soft robotics became popular in the last few years. First, there have been a number of soft functional materials that can be employed in robotic systems, such as electrically conductive elastomers to be used as sensors and actuators. Second, advanced fabrication techniques of soft robots are accessible such as additive fabrication devices. And third, we have identified practical applications such as wearables and soft manipulators. In short, soft robotics has been a technological driver to make a significant impact toward novel robotic applications.

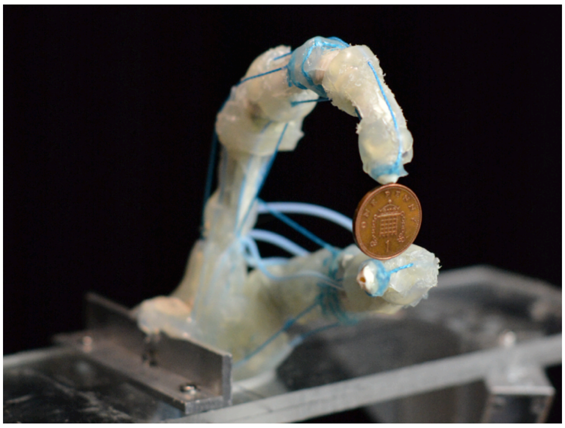

Figure 1 Anthropomorphic soft robotic finger [3].

Despite all these favorable characteristics of soft robotics technologies, there have been a few fundamental challenges to be tackled. In particular, it has been pointed out that soft robots are slow, weak, small, and inprecise, because of the intrinsic problem of deformable structures which don't allow to transfer large forces through. On the other hand, for these challenges, soft structures need to be combined with rigid structures, powered by many actuators [3], and monitored through many sensory receptors [4]. The goal of my presentation is to explain the fundamentals of these problems which we identified in our recent works, and discuss whether autonomous morphological adaptation technologies would be a potential breakthrough [5].

References

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