Chapter 2
Machine Learning and Optimization Applications for Soft Robotics

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ABSTRACT

Due to their adaptability, flexibility, and deformability, soft robots have been widely studied in many areas. On the other hand, soft robots have some challenges in modeling, design, and control when compared to rigid robots, since the inherent features of soft materials may create complicated behaviors owing to non-linearity and hysteresis. To address these constraints, recent research has utilized different machine learning algorithms and meta-heuristic optimization techniques. First and foremost, the study looked at current breakthroughs and applications in the field of soft robots. Studies in the field are grouped under main headings such as modelling, design, and control. Fundamental issues and developed solutions were analyzed in this manner. Machine learning and meta-heuristic optimization-oriented methods created for various applications are highlighted in particular. At the same time, it is emphasized how the problems in each of the modeling, design, and control areas impact each other.

INTRODUCTION

As the use of robots grows, it may be necessary to redefine flexibility once more. While speed was one of the most essential factors for efficiency expected from robots confined to factories in the early stages of industrialization, flexibility could be considered as a margin of error. This approach may be appropriate for indoor applications. However, in outdoor applications, the opposite of this approach is mostly valid.

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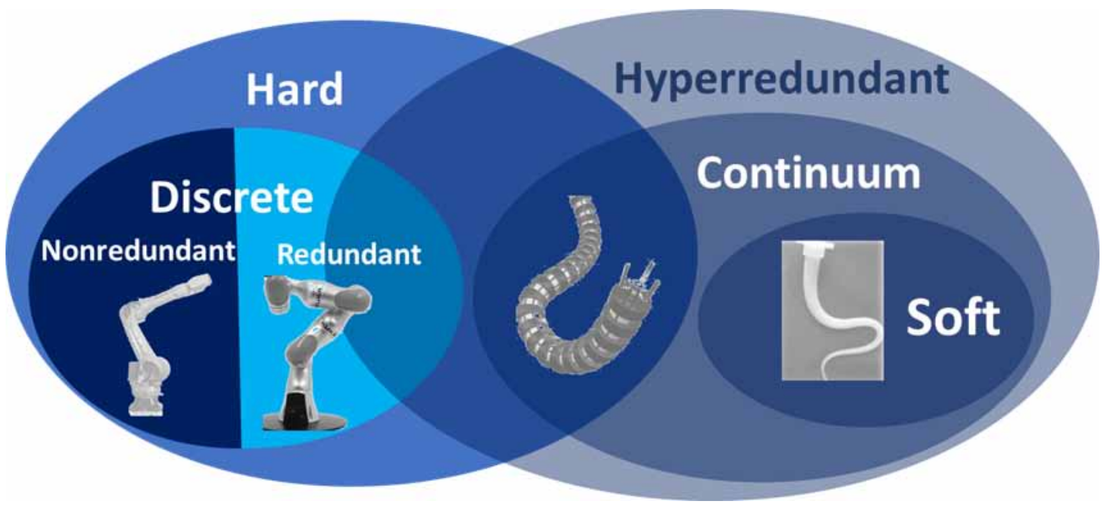
In fact, since the ideal conditions in the external environment disappear, the adaptation of traditional robots becomes very difficult with their cumbersome structure. When we look at the living nature, the reason for this is better understood. Because one of the features that ensures the existence of life even under the most extreme conditions is flexibility. Gerringer et al. (2017), for example, found that a fish species (hadal belt snail fish) can survive in the Mariana Trench at a depth of about 8 km and a pressure of around 800 atm. The adaptability brought about by flexibility enables the living thing to accept even the most difficult conditions (very high pressure, etc.) as new conditions, not as a disturbance effect, and to continue its standard behaviors such as feeding and reproduction. The development of the idea of benefiting from flexibility and deformation, inspired by living things with such examples, has led to the emergence of soft robots.

Figure 1. Classification of robots by materials and degrees of freedom (Trivedi, 2008)



Soft robotic technologies have opened the door to a new era in robot design and development. However, these technological developments face new challenges and limitations due to the hyper-redundancy (Figure 1) and high degree of freedom caused by the flexible nature of the materials used. It also causes complex and unexpected behavior as a result of the nonlinear relationship between the input and output of the system.

The increasing complexity of soft robotic systems, which may be due to shape, material, actuation, and their complicated connection, renders conventional robot design methods inapplicable (Chen & Wang, 2020). The simulation and analytical tools required to effectively predict the complex mechanical behavior of soft robots are insufficient. In addition, there was a lack of effective optimization algorithms to automate the design process in the literature. To bridge this gap, optimization techniques have started to be implemented in the design of the soft robotics field.

On the other hand, the control challenges can be considered the final challenge to overcome before a soft robot can be utilized in the physical world. Although designs that use on-off logic, such as the soft robotic gripper, do not require control, this cannot be said for the other soft robot kinds. High-fidelity soft systems models have been effectively used to control soft systems, but this needs precise system

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