



# Editorial: Machine Learning Techniques for Soft Robots

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**Keywords:** soft robotics, machine learning, editorial, soft sensing, modeling and control

## Editorial on the Research Topic

### Machine Learning Techniques for Soft Robots

Soft robotic technologies have introduced new paradigms in the design and development of robots. This shift in outlook presents new challenges and opportunities for modeling, control, and design of these robots. Traditional techniques based on analytical models have proven to be insufficient to tackle these new challenges. This is because of their highly nonlinear, time-varying and high-dimensional characteristics coupled with an immense diversity in their design. Machine learning-based approaches provide a promising alternative to traditional analytical approaches. Learning-based approaches have proven to be a valuable tool for control, data-processing, and design optimization of nonlinear systems in traditional robotics and other scientific disciplines. However, their usage has been largely limited and unexplored in soft robotics, in spite of their potential value.

This research topic was initiated to investigate and advance new learning-based approaches for modeling, control, and design of soft robots. The eight articles present novel approaches for modeling, sensing and design optimization. When it comes to modeling soft robotic systems it can be clearly seen that the field is turning toward recurrent neural networks (RNNs) (Tariverdi et al., 2021; Tsompanas et al., 2021) or hybrid approaches (Johnson et al., 2021). In order to capture the temporal nonlinearities in a soft robotic system, it is vital to use learning architectures that have dynamic properties. This was demonstrated for real-time dynamic modeling of a soft continuum manipulator in Tariverdi et al. (2021) and for characterization of a Microbial Fuel Cell in Tsompanas et al. (2021). Hybrid models combining physics-based analytical models and deep learning also promises to be an alternate approach, especially when data is scarce as shown in Johnson et al. (2021).

A significant portion of the submitted works focus on sensing and state estimation for soft robots, a topic which has wider applications in wearables and biomedical fields. De Barrie et al. (2021) presented a learning based framework for contact force prediction and stress distribution in real-time using deep learning and FEA models. Such techniques are powerful tools to reduce computational complexity without compromising on accuracy. Hofer et al. (2021) presented a vision-based sensing approach for state estimation in soft robots using convolutional neural networks. Khin et al. (2021) developed grip-state estimation networks for feedback control of sensorized soft robotic hands. Finally, Raffin et al. (2021) presented ensemble networks to detect and handle sensor failures.

Design optimization is one of the biggest challenge in soft robotics due to the computational complexity of parametrized analytical models. Raeisinezhad et al. (2021) presented a deep reinforcement learning (DRL) algorithm for design optimization of a pneumatic soft robotic

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### Edited and reviewed by:

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Sant'Anna School of Advanced  
Studies, Italy

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### Specialty section:

This article was submitted to  
Soft Robotics,  
a section of the journal  
Frontiers in Robotics and AI

**Received:** 17 June 2021

**Accepted:** 21 June 2021

**Published:** 01 July 2021

### Citation:

George Thuruthel T, Falotico E,  
Beccai L and Iida F (2021) Editorial:  
Machine Learning Techniques for  
Soft Robots.  
Front. Robot. AI 8:726774.  
doi: 10.3389/frobt.2021.726774

actuator on a simulated model. The key idea here being that DRL methods would be more sample efficient than traditional optimization methods with additional capabilities. In conclusion, learning-based techniques hold a strong potential for addressing the major challenges in soft robotics, be it design, modeling, sensing or control. Different learning architectures (recurrent neural networks, deep neural networks, hybrid networks) and approaches (supervised/unsupervised learning, reinforcement learning) have to be adopted based on the problem and application. Finally, machine learning can become a vital tool when used in soft sensing. In particular to obtain repeatable and reliable data in spite of non-linearities of constituting materials and/or sensor failures.

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## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

## FUNDING

This work was supported by the SHERO project, a Future and Emerging Technologies (FET) program of the European Commission (grant agreement ID 828818) and the European Union's Horizon 2020 FET-Open program under grant agreement no. 863212 (PROBOSCIS project).

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling editor declared a shared affiliation with one of the authors EF.

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