# Topology Optimization of Soft Actuators: Designing Stretchable Inflatable Membranes

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## ABSTRACT

To increase the capabilities of devices such as actuators, the use of soft materials is emerging in the field of engineering to replace rigid materials. The stiffness of these soft materials make the devices ideally suited for delicate and diverse tasks. Although these new soft devices can be very valuable in a broad range of applications, their behavior is most often characterized by a highly non-linear response. This makes the design of soft devices more difficult, since the non-linear behavior is often unpredictable. Mostly, the design of devices is based on trial and error, which can be a satisfactory methodology when dealing with rigid structures showing linear response. However, the often unpredictable non-linear response of soft structures makes the design process more time consuming and costly and has a negative influence on the quality of the final design.

Luckily, computational modeling tools such as Finite-Element Analysis (FEA) provide a way of predicting the behavior of soft structures prior to fabrication. FEA proves an invaluable method that reduces costs in the design phase. However, to effectively design soft devices, it is of key importance to develop a highly sophisticated and vigorous approach. Mathematical topology optimization (TopOpt) and FEA can function as a powerful combination that not only automates design processes, but also finds truly optimal solutions. This new approach has been successfully applied to linear design challenges. However, the use of TopOpt for the design of soft structures is still in its infancy. Especially non-linear TopOpt is very promising as it will allow the design of structures that show highly complex and versatile behavior.

To explore the possibilities and difficulties of such an approach, we have employed TopOpt and FEA to design stretchable inflatable membranes. By locally varying the membrane thickness, we can design structures that inflate to a large variety of shapes, or optimize behavior for a specific pressure-volume relation. This research paves the way for the design and development of a large variety of optimized soft devices.These soft and adaptable structures are extremely suitable for application in a large range of devices, as they resemble the complex characteristics and movements of living organisms. In this sense, TopOpt imitates evolutionary processes in nature.