# Development Process of an Isoperimetric Robot


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## I. Introduction

This extended abstract discusses the the development process of an isoperimetric truss robot, first presented in [1]. The robot and its general principle of operation is shown in Fig. 1. This robot builds on past work done in both the design of truss robots, soft robotics, and modular robotics, while overcoming some of the limitations of these respective approaches. This architecture has led to the creation of a human-scale untethered robot capable of shape change, locomotion, and manipulation tasks. The robot is capable of compliant interaction like soft robots but without an air supply, shape change like truss robots but without brittle rigid components, and can be manually reconfigured like other reconfigurable robots, but where each subcomponent is relatively simple (capable of motion in only one degree of freedom).

The robot consists of a set of robotic roller modules and a set of inflated fabric tubes. The roller modules pinch the tubes between cylindrical rollers, inducing a region of low bending stiffness that acts as an effective joint, but still allowing airflow between adjacent segments of the tube. The tubes are routed such that each tube makes up several of the edges in the final robotic truss structure. The robot changes shape when the roller modules are driven along the inflated beam, lengthening one edge of the robot and shortening another, while conserving the total length of the tube. The fact that the total edge length of the robot is conserved leads us to call this robot an "isoperimetric" robot, meaning that the perimeter of the robot remains constant. The constant perimeter means the total volume within the tubes of the robot remains constant, removing the need for an active source of compressed air.

In this abstract we first describe the work that inspired us to begin development on an truss robot composed of soft pneumatic actuators. After several prototypes, we recognized some of the limitations created by using an onboard pressure source, and discovered a new constant-volume configuration that removed the need for a pressure source but created new mechanical design challenges. The prototype development process is then illustrated and discussed.

## II. Inspiration

Robotic trusses, or networks of linear actuators connected by universal joint capable undergoing shape change, have been proposed by many researchers. These robots could use their high number of degrees of freedom to adapt to many tasks or to locomote over varied terrain. Work on this concept has been done as part of development of variable geometry trusses [2], tetrahedral robots [3],the NASA Ants project [4], and many others. More recent work has focused on tensegrity robots [5], [6] and variable topology truss robots [7]. In many of the past implementations, a significant challenge has been building a device where each edge of the structure has a large extension ratio, the structure can support sufficient load, and be compliant and resilient to impacts. Our initial inspiration was to create a truss robot where the edges consisted of pneumatic actuators. These pneumatic actuators could be lightweight, inherently compliant and designed to have an extremely large extension ratio.

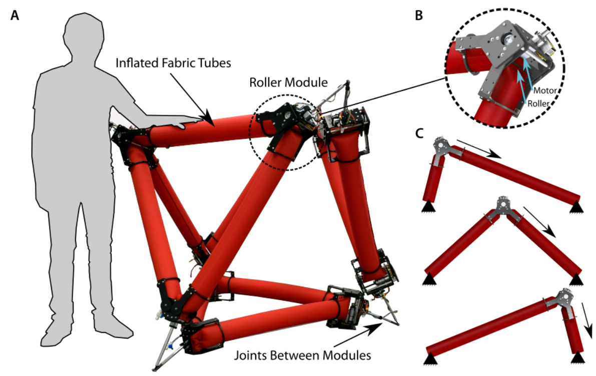


Fig. 1. Overview of the isoperimetric robot.

## III. Early Development and Key Realization

Initially, we developed new types of soft actuators, including the pneumatic reel actuator [8], and antagonistic pneumatic artificial muscle [9], and sought to integrate them into truss robots. These actuators showed some promise when tethered to an external pressure source and valves. However, moving the control valves and pneumatic source onto the robot itself proved challenging in that the added mass of these components frequently caused the robot to collapse, or the limited flow rate of lightweight pumps made actuation extremely slow. With these limitations in mind, we began looking for ways to remove the dependence on slow and inefficient microcompressors. Our key realization was to to switch from using using a pneumatic source to pump air into and out of the system, and instead use a fixed volume of air within inflated tubes that acted as a structural element. From other work with inflated actuators, we were aware that when a high bending moment