Methods of actuation planning of active tensegrity structures

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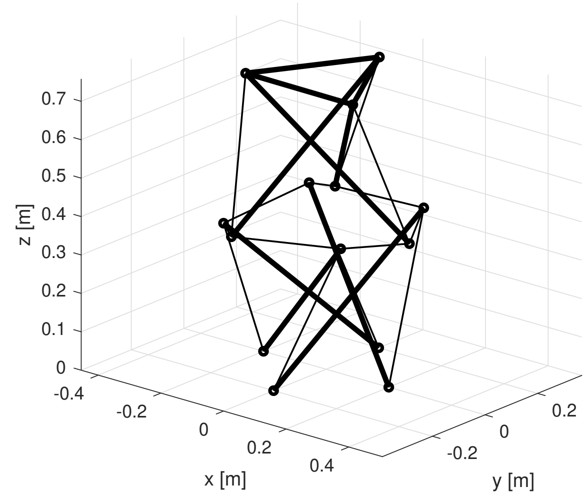
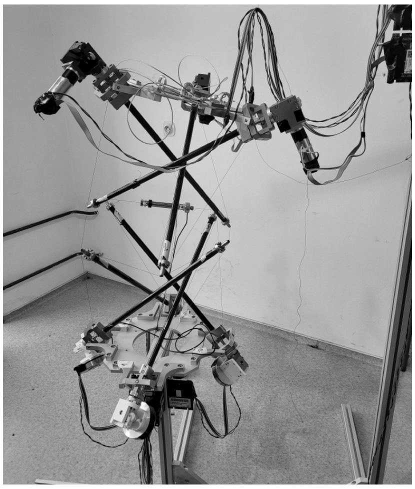
EXTENDED ABSTRACT

1 Introduction

Tensegrity is a general structural concept that contains a discontinuous set of components in compression (e.g. struts) inside a network of components in tension (e.g. cables), and which integrity relies on pre-stress forces [3]. The resulting structures can be easily dismantled, they often reach a very good strength-to-weight ratio and they can perform a wide range of motions. Hence, they can be advantageously utilized in many applications including robotics. An example of such structure is depicted in Figure 1, where both visualization and a real construction are shown. This paper focuses on creating a methodology for identifying cables suitable for actuation based on analyzing structure sensitivity to different forms of actuation.



(a) A visualization.



(b) A real construction.

Figure 1: Tensegrity structure subjected to proposed analysis.

2 Tensegrity computational modelling

During the design and analysis of both passive and active tensegrity structures, it is inevitable to solve the form-finding problem representing a task of searching for a static equilibrium with specified dimensions of compressive and tensile members. A very efficient tool providing the solution for form-finding is the dynamic relaxation method (DRM). The basic idea of the method is to trace step-by-step the motion of the structure until the structure reaches a static equilibrium due to introduced damping [2]. Because a static solution rather than the real dynamic behaviour is searched for, both artificial damping and fictitious mass are added to the system to assure rapid convergence [1, 2].

Simscape software is used for modelling the dynamics of tensegrity structures. Moreover, generation of dynamic models of tensegrities is made fast and smooth thanks to developed software programmed in MATLAB automatically creating Simscape tensegrity models.

3 Actuation strategy and sensitivity analysis

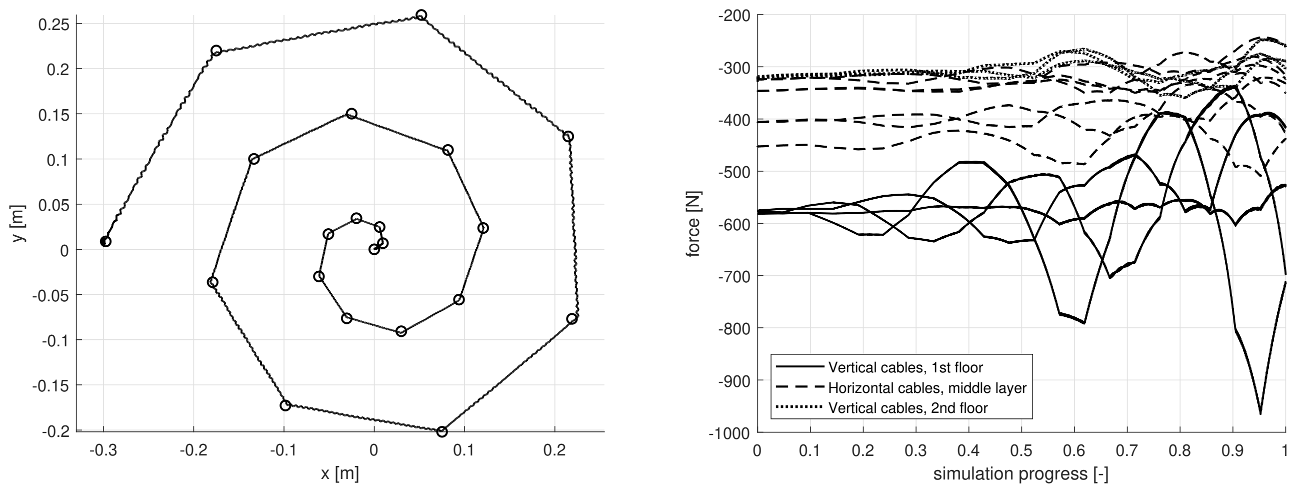
There are several ways how to actuate tensegrities. In this work, the structure can change its shape by adjustments of cables' rest lengths driven by servomotors mounted to struts. In reality, there is limited space where to place motors due to their dimensions, weight, wiring, etc. (see Figure 1b). Therefore, reasonable assumption can be that only one motor at maximum can be placed on one strut. Thus, the number of active cables is equal to the number of all struts at the best. A standard tensegrity contains more cables than struts so there are some cables that are passive (i.e. their rest length is constant). This results in necessity of development of a methodology how to find cables which are suitable candidates to be active.

Possible approach how to discover cables suitable for actuation is to perform an analysis of structure sensitivity to actuation of a particular cable. This is done via changing (in both positive and negative direction) the rest length of the cable in several steps. Advantage of this simple method lies in the possibility of usage of a general form-finding algorithm that discovers the static response to the actuation of a particular cable. This work utilizes the DRM for this purpose.

Another approach is to actuate one point of the structure kinematically (prescribe a specific trajectory) and monitor deviations in force densities in cables (force density is defined as an internal force acting in the member divided by its instantaneous length). Significant changes in some cables' force densities compared to other cables suggest that these cables are the most sensitive to a particular movement. Unfortunately, the form-finding algorithm is impossible to be used concerning the proposed method. Therefore, the dynamic simulation of the process is performed. On the other hand, this approach enables to study sensitivity respecting particular motion of the structure, which is very convenient.

4 Application and conclusions

Both approaches are applied to the two-floor tensegrity structure made of 7 struts and 14 cables shown in Figure 1. Tensegrity is attached to the frame by 3 spherical joints in bottom nodes and the top of the structure is formed by a horizontal platform. From the limitation mentioned in the previous paragraph, 7 servomotors are available to actuate 7 cables. Thus, the task is to choose 7 cables out of 14, which can efficiently move the whole structure in a required manner.



(a) Discretized required motion and an achieved trajectory.

(b) Achieved internal forces in cables.

Figure 2: Results of a dynamic simulation.

The structure is subjected to the proposed analysis. The target motion, a spiral lying on the surface of a hemisphere discretized into several points, is examined in the middle point of the top platform. Discretization points are depicted in circles from the top view in Figure 2a. The analysis of sensitivity shows that if vertical cables are active and horizontal cables are passive, the structure is able to follow the required trajectory effectively. Figure 2a contains achieved trajectory of the examined point and internal forces in particular cables are depicted in Figure 2b. Both sets of quantities are results of a dynamic simulation.

A proper identification of cables suitable for actuation is a crucial step in active tensegrity design – structure has then the opportunity to reach very wide spectrum of motions and can be pretty efficient from the energetic point of view. On the other hand, inconvenient choice of active cables can lead to problems with controlling the structure shape or even control inability.

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