Kinematic Analysis and Design of a Compliant Microplatform

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INTRODUCTION

Mechanisms formed by rigid links and rigid joints are well suited to work at the macro-scaled world. However when the dimensions of the systems are on the order of microns, limitations due to manufacturing processes impose severe limitations, and the generation of motion requires alternative approaches.

Most devices for micro-electro-mechanical systems (MEMS) are basically planar devices. This is due the current manufacturing techniques that are derived from the IC industry. Thus, creating 3D structures at the micro level is a difficult task. This paper presents a new approach for a spatial microplatform that incorporates compliant elements in order to allow for a desired range of spatial motion without the need for complicated mechanical or stress concentrated joints. It has application to micro-assembly tasks where the platform can be used as a 'finger tip' to manipulate micro-scaled components.

BACKGROUND

Out of plane actuators can convert input signals into displacements normal to the surface of a substrate. Three-dimensional microdevices are useful for different tasks as for example, object positioning, micromanipulators, optical scanners, tomographic imaging, optical switches, microrelays, adjustable lenses and bio-MEMS applications. References [1]-[8] provide an overview of some of recent advancements.

The approach utilized here to achieve a spatial device incorporates the principles of tensegrity. The word tensegrity is a contraction of tension and integrity and refers to structures formed by rigid and elastic elements that maintain their shape due only to their configuration. Rigid elements do not touch one another and they do not require external forces to maintain their unloaded position. Figure 1 shows a prismatic tensegrity structure where the elastic elements are represented by springs.

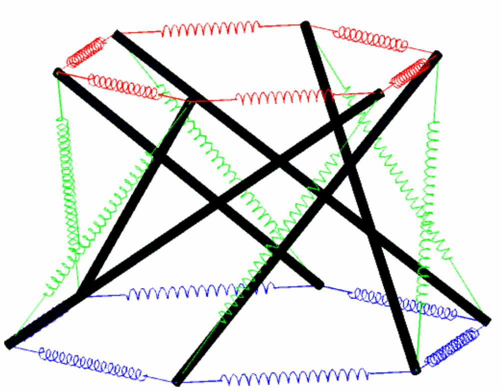

Fig. 1. Tensegrity Structure

Tensegrity structures were discovered by architects in the middle of the last century. Research began with Fuller [9]. First contributions were made by [10] and [11]. Static and dynamic analysis studies have been made [12] and [13]. Proposed applications include antennas [14], flight simulators [15], deployable structures [16], and force and torque sensors [17]. Tensegrity has been also proposed to explain the deformability of cells [18].

Due to the presence of elastic ties, tensegrity structures are foldable. If in the folded position external constraints are released, they can recover suddenly their original shape by themselves. The deployment can be also achieved in a controlled way using telescopic struts or controlling the elastic ties.

DESCRIPTION OF DEVICE

Figure 2 depicts the device that is addressed in this research. It can be considered as a simplification of the tensegrity system presented in Figure 1. The system maintains its shape due to the upward deflections of the beams. It is formed by three sets of bimorph actuators which transmit their motion to the central platform through compliant joints. The position of the device is influenced by the stiffness and free lengths of the ties, the location and nature of the joints, and the length and the current curvature of the beams.

KINEMATIC ANALYSIS

Two analyses have been completed for this design. In both analyses it is assumed that the three spring constants and spring free lengths are known together with the dimensions of the moving platform and the location of the base points of the actuator beams. It is also assumed

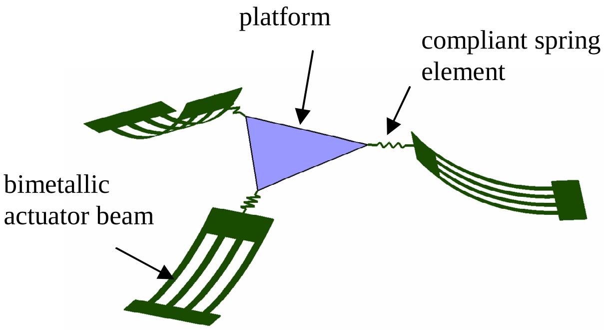

Fig 2. Compliant Microplatform

that the platform is massless and that the deflections of the actuator beams due to the forces of the spring element are negligible. This last assumption has been verified via strength of materials calculations.

The first analysis is a forward analysis whereby the end points of the beam actuators are known and the position and orientation of the platform is determined. The second analysis is a reverse analysis whereby the direction of the vector normal to the platform is specified and the required positions of the end points of the beam actuators are determined. These analyses have been completed and verified via an equilibrium check. The complete approach is not presented here.

CONCLUSION

In summary, a spatial microplatform has been designed which incorporates compliance. The advantage of this approach is that standard MEMS fabrication techniques can be incorporated to build the device in the plane, yet gross spatial motion can be achieved without any complicated mechanical joints. Control approaches have been developed which will allow for orientation of the platform or the positioning of a point in the platform as desired. The device can be applied to a variety of problems such as object positioning, micromanipulators, optical scanners, tomographic imaging, optical switches, microrelays, adjustable lenses and bio-MEMS applications.

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