Structure Design of Polyhedral Grippers with Deployable Faces for Capturing Non-cooperative Targets

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ABSTRACT

1 Introduction

Recently, with the growth of inactive satellites and debris, the orbit has become increasingly crowded, which creates risk and uncertainty for the conduction of space missions. For the sustainable utilization of orbit resources, various schemes and devices are proposed to capture non-cooperative targets through force interaction or form enclosure [1, 2]. Among relevant devices, polyhedral grippers [3, 4], able to transform between an unfolded diagram and the enclosed polyhedron, can realize target capture by form enclosure during the shape transformation. Due to the reduction of contact, polyhedral grippers have priority in concise control strategy, low damage to the targets, and avoidance of generating extra fragments. However, to capture larger targets, polyhedral grippers are required to form larger enclosed spaces, while the size enlargement brings storage difficulty. Developing polyhedral grippers with deployable functions may solve this contradiction between the large size requirement and limited launching space. In this paper, polyhedral grippers with deployable faces are proposed for enhanced capturing capacity, which have two degrees of freedom for deployment and capturing. The size of the polyhedral grippers can be adjusted through the synchronous fold or deployment of each deployable face. Therefore, the proposed grippers can be folded for storage, then conduct face deployment in orbit, and finally capture non-cooperative targets through the enclosure motion. This extended abstract provides a brief introduction to the proposed polyhedral grippers with deployable faces.

2 Structure design

2.1 Description of the design flow

For the easy conduction of the gripper design, a design flow is proposed to construct different polyhedral grippers with similar basic modules. These modules, containing three deployable polygon faces connected with revolute joints and constraint branch chains, can realize face deployment and shape transformation. By sharing two deployable faces, two basic modules can be expanded to a larger mechanism. Finally, a polyhedral gripper able to conduct size adjustment and enclosure motion can be achieved through module expansion.

2.2 Deployable polygon faces

To enhance the space utilization of the grippers in the launching vehicles, each face of the polyhedral grippers is expected to have the deployment function. Therefore, various deployable polygon faces are proposed for the gripper design. These deployable polygon faces are inspired by the Sarrus linkage. As an example, the mechanism design of a deployable square face is presented in Fig. 1. With the relative translational motion between the center node and the center frame, the face can transform from the folded state to the deployed state.

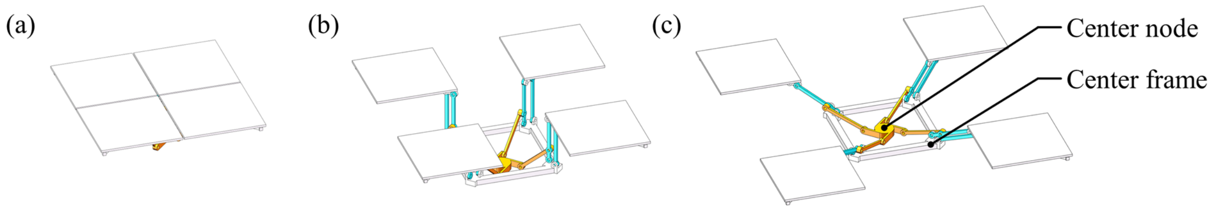

Figure 1: The proposed deployable square faces: (a) the folded state, (b) the intermediate state, and (c) the deployed state.

2.3 Gripper construction through the design flow

The basic module containing three deployable polygon faces is the key component of the proposed polyhedral grippers with deployable faces. To construct the polyhedral gripper, type synthesis of the basic modules is first conducted with the Grassmann line geometry and line graphs. A synthesized basic module containing three deployable square faces is presented in Fig. 2 as an

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example. The three deployable faces of the basic modules can realize deployment and synchronous motion.

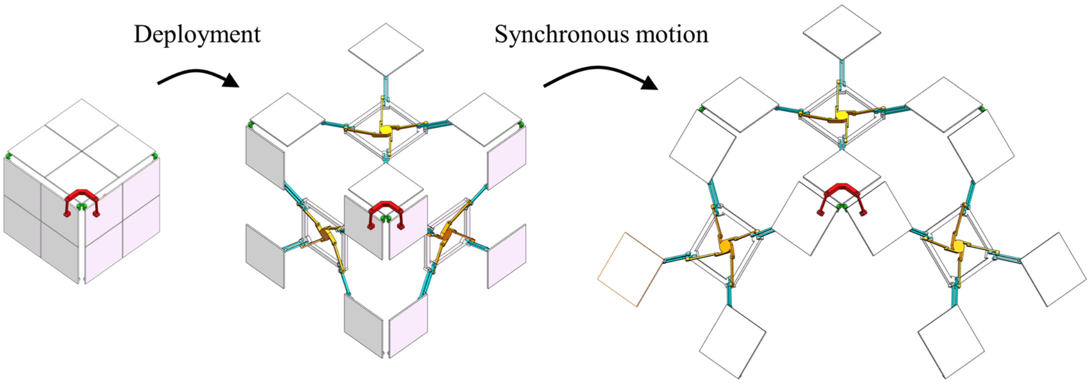

Figure 2: The function schematic of a synthesized basic module containing three deployable square faces.

According to the proposed design flow of the polyhedral gripper, two basic modules can be expanded to a larger mechanism by sharing two deployable faces, and the expected polyhedral gripper can be achieved through module expansion. Based on the basic module containing three deployable square faces in Fig. 2, a cube gripper with deployable faces is designed, which can conduct size adjustment and enclosure motion as presented in Fig. 3.

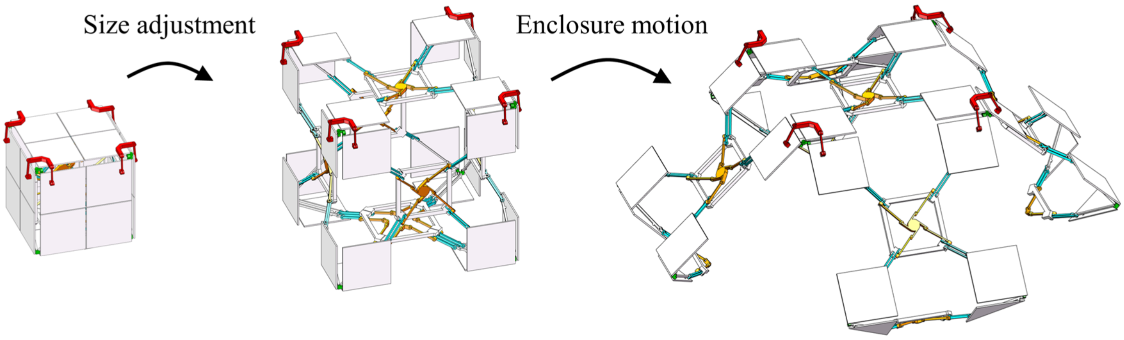

Figure 3: The function schematic of a cube gripper with deployable faces.

3 Conclusion

In this paper, polyhedral grippers with deployable faces are proposed to achieve the enhanced capacity of capturing non-cooperative targets by adopting deployable polygon faces. Through the in-orbit deployment of each deployable face, the proposed polyhedral grippers can be efficiently storage within the launching vehicles, and are competent for capturing larger objects. Based on different polyhedrons, various polyhedral grippers with deployable faces can be constructed by following the proposed design flow, and have the potential for satisfying different capturing requirements. These polyhedral grippers may serve as candidates for diverse spatial capturing missions, and provide references for the structure designs of deployable mechanisms with multiple degrees of freedom.

Acknowledgments

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