

P07

スペースデブリ除去デバイス取り付けのための機構・制御の検討

A Study of Gripper System for Attaching Debris De-orbit Devices

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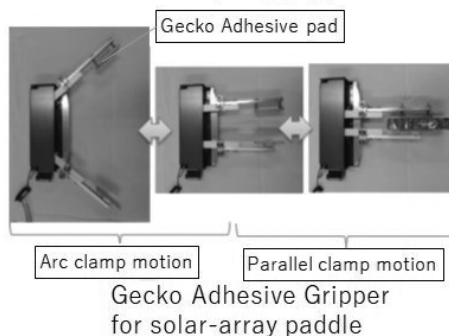
Hiroki Nakanishi, Yuto Masuda and Keisuke Taga (Tokyo Institute of Technology)

能動的スペースデブリ除去 (ADR) 作業において, スラスタや EDT, デオービット膜といったデオービットデバイスの取付は必須の作業であるが, 未だ実現していない. 既存の宇宙用ロボットハンドは, 把持対象に専用の被把持機構を要求するため, そのまま流用することができない. これらの被把持機構を持たない非協力的なターゲットをできるだけ簡易な機構・制御で確実に捕獲し, 上記のデオービットデバイスを固定することが必要である. 筆者らは, 衛星やロケット上段の構造を利用する・または全体を包み込むことにより把持をした後, 直ちにサービス衛星から切り離されることによりデオービットデバイス固定機構としても機能するデブリ把持機構について検討を進めている. 本発表では, これまでの取り組みおよび最新の成果について報告する.

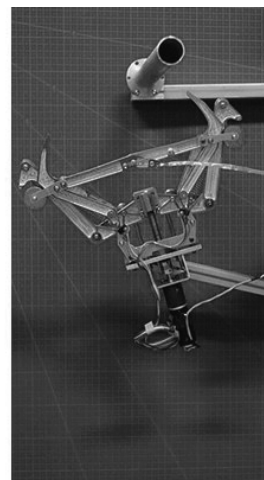
In order to realize the active debris removal (ADR), attaching debris removal device (ex. micro thruster, EDT, and De-orbit membrane, etc.) to debris is a key technology. However, it has never been demonstrated. Any space robot hands in existence cannot be used for capturing debris because they require their dedicated fixtures on the capture target. It is important to establish simple grasping system for uncooperative target without such fixtures. The authors are studying about such grasping system which can grasp original structure of debris or can grasp whole debris. The system can be also used as a fixing mechanism for debris de-orbit devices after separating from service satellite (robot). In this presentation, the overview of our grasping systems and the latest issues are introduced.



Convex spring gripper



Gecko Adhesive Gripper for solar-array paddle



Spring-driven truss gripper

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A Study of Gripper System for Attaching Debris De-orbit Devices

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ABSTRACT In order to realize the active debris removal (ADR), attaching debris removal device (ex. micro thruster, EDT, and De-orbit membrane, etc.) to debris is a key technology. However, it has never been demonstrated. Any space robot hands in existence cannot be used for capturing debris because they require their dedicated fixtures on the capture target. It is important to establish simple grasping system for uncooperative target without such fixtures. The authors are studying about such grasping system which can grasp original structure of debris or can grasp whole debris. The system can be also used as a fixing mechanism for debris de-orbit devices after separating from service satellite (robot). In this presentation, the overview of our grasping systems and the latest issues are introduced.

Background and purpose

Grasping space-debris

Capture of space debris (non-cooperative satellite)

Debris have no dedicated grapple-fixture. (non-cooperative)
=> "Where" and "How" do we capture on debris?

- Easy to access.
- High stiffness enough to be applied force.
- Easy to grasp.
- Easy to recognition. (Shape and color)

Candidate of alternative grapple-fixture

- Antenna (Low stiffness) **Grip · Pinch**
- SAP (Low stiffness) **Pinch**
- Yoke of SAP (Low stiffness) **Grip**
- PAF (Low stiffness) **Grip · Pinch · Hold form inside**
- Large nozzle (Rocket, GEO Satellite) **Pinch, Hold from inside**
- Main Body => **Pinch, Sting, Wrap around**

Purpose
To develop grasping mechanisms for non-cooperative target

Gecko adhesive gripper for solar-array-paddle capture

Low pressure & high friction pinching

Joint research with JAXA

Electro-dynamic tether ©JAXA

Capture Sequence

Motor Driver, Ball Screw, Left-handed Ball Screw, Motor, Coupling, Joint, Guide Rail & Rollers, Spring, Contact Surface

Structure of gecko's foot, CNT gecko-mimetic structure, Gecko Tape ©Nitto Denko Corp.

Arc clamp motion, Parallel clamp motion

Maintaining contact with free-flying nozzle

(a) Conventional impedance control

(b) Impedance control with respect to the inertial coordinate (proposed method)

Impedance control for free-flying robot

Capture probe insertion experiment (HILS simulation)

Contact force

Using an impedance control, a probe keeps the contact and traces the inner wall

Multi joint capture arm for winding around Rocket body

Motion of spring actuated gripper

Rocket capture simulation

Wire-driven retractable multi joint gripper

Retraction Expansion Grasping

Convex Spring gripper with membrane

To wrap debris, web or membrane are useful because they can wrap without shape and attitude requirement for debris.

However... Maintaining and control its shape before capture

RemoveDebris (SSTL)

Backbone of convex spring maintain and control a membrane and web for debris capture

Convex spring gripper (contact force makes start of motion)

Dynamics analysis of convex spring

Designing the shape of convex, the wrapping motion can be controlled.

This work was supported by JSPS KAKENHI Grant Number JP16K21033.

Automatic truss gripper based on a link singularity

Joint research with JAXA

- Contact force makes start the grip motion
- Wide capture range
- Thin required depth clearance behind truss
- Separation after grasp with a de-orbit device
- Reset configuration when grasping is failed

Behind of truss is often filled with equipment

Debris' structure (truss)

Singularity of the link maintains the gripper state. When the debris contact with this point, the singularity is broken and the capture motion is started by spring.

Spring for capture motion

Initial State

Grasping and separation motion

Reset motion (counter rotation of separation ball screw makes reset motion)

Root of gripper can be separated from end-tip of the manipulator by rotating ball screw with motor

Capture State