講演会

日時： 2018 年 3 月 15 日 (木) 10:30〜12:30

講演１： 10:30〜11:30
Sliding Mode Control Strategies for Spacecraft Rendezvous Maneuvers
Elisabetta Punta 博士 (イタリア CNR-IEIIT)

講演２： 11:30〜12:30
"Flyable" guidance and control algorithms for Rendezvous Maneuver: APF and Obstacle Avoidance
Elisa Capello 博士 (イタリア トリノ工科大学 / CNR-IEIIT)

場所： 大阪大学 吹田キャンパス 情報科学研究科 C 棟 1 階 C101 室 (住所：吹田市山田丘 1–5)

講演１： 10:30〜11:30

題目： Sliding Mode Control Strategies for Spacecraft Rendezvous Maneuvers
講師： Elisabetta Punta 博士 (イタリア CNR-IEIIT)
概要： The rendezvous and docking maneuvers are a key operational technology that is required for many missions, and it consists of a series of orbital maneuvers and controlled trajectories, where an active spacecraft (Chaser) tries to capture a passive Target vehicle or to reach and remove large space debris object. In this presentation, the goal of the considered mission is that a Chaser vehicle has to safely and efficiently approach the Target vehicle (that is in a fixed position) to within a few centimeters (surface-to-surface) and remain stationary there until the hold mechanism captures and docks the target vehicle. The focus of the presentation will be on the implementation of sliding mode strategies for the Chaser position tracking during the final approaching phase (starting 500 m far from the target point). In the final phase, the Chaser approaches the Target along a straight line as close as possible to satisfy the strict requirements of docking in terms of relative positions and speeds. For this reason, the desired positions are assigned by a guidance algorithm to obtain a forced motion inside a defined path cone with an assigned desired speed profile.

In the first part of the presentation, it will be detailed the design of a combined first order and super-twisting (second order) sliding mode controller (SMC) for a 6 degree-of-freedom (6-DOF) spacecraft system. The proposed control strategy considers different phases of the approaching maneuver, which are identified mainly based on the Chaser distance from the Target. The various stages correspond to different choices of the designed sliding mode control switching parameters (different frequencies, gains and desired velocity). In order to guarantee the physical feasibility of the proposed control, the sliding surface is modified according to the phase of the maneuver. The obtained results are analyzed in order to evaluate the impact of the different choices on the overall performances (fuel consumption, precision of the docking and time required to complete the maneuver).

Space systems often need to be controlled by actuators with limited output level, guaranteeing strict requirements in terms of relative position and attitude. In the last years, autonomous spacecraft rendezvous and docking (RVD) maneuvers have been extensively studied, in order to obtain controlled trajectories during which the Chaser (active) tries to dock a Target spacecraft. In the second part of the presentation, it will be detailed the design of a combined simplex and super-twisting SMC for a 6-DOF spacecraft system. The proposed simplex SMC is able to minimize the required on-board number of thrusters. This controller permits to reduce the fuel consumption and to modulate the thrust assigned along the system axes, due to the position of the thrusters themselves. The capability of low-power spacecraft processors to handle real-time computational load is fully established. Therefore, the proposed control strategy is simple to implement and be easily converted in an on-board algorithm, guaranteeing a minimum computational effort and reduced fuel consumption.

略歴： Elisabetta Punta (MSc, Electronic Engineering, 1993, and PhD, Electronic Engineering and Computer Science, 1998, Genoa University, Italy) is a researcher of the National Research Council of Italy (CNR) at the Institute CNR-IEIIT. From 1994 to 2003, she was research fellow at Genoa University. She participated and directed several research projects. She is a member of the Italian Research Unit of the Joint International Lab COOPS, CNR Italy and JST Japan, 2015-2017. Dr. Punta is Senior Member IEEE, member of the IEEE-CSS Technical Committee on Variable Structure and Sliding Mode Control, member of the IPC of the IEEE International VSS Workshop, member of the CEB of the IEEE-CSS, Subject Editor for International Journal of Adaptive Control and Signal Processing and Associate Editor for IMA Journal of Mathematical Control and Information. She is author of more than 90 works published in international journals, books, and proceedings of international conferences. Her research interests include Variable Structure Systems, Sliding Mode Control Theory, Higher Order Sliding Mode Control, Sliding Mode Observers, Nonlinear Control, Nonlinear Observers, Mechanical Systems, Time Delay Systems, Energy Production Systems, Telecommunication Systems, Control and Optimization Methods for Freeways, and Complex Systems.

講演2： 11:30〜12:30

題目： “Flyable” guidance and control algorithms for Rendezvous Maneuver: APF and Obstacle Avoidance

講師： Elisa Capello 博士 (イタリア トリノ工科大学 / CNR-IEIIT)

概要： Rendezvous orbital maneuvers are planned operations, which intend to make two spacecraft meet, while avoiding collisions. Aspects such as trajectory safety and robustness, as well as obstacle avoidance are fundamental for the mission success. The aim of this talk is to provide an overview of some recent algorithms for guidance and control systems, and also their combined exploitation, which can result to be really powerful.

Recent studies concern the use of unmanned spacecraft in orbital servicing mission and, in particular, the development of a robust flight software. This on-board software has to manage unexpected events, such as environment disturbances and noise, and/or crossing of small objects. This overview focuses the attention on those algorithms that are characterized by key features, with low computational effort, low fuel consumption, and high safety and robustness. The proposed approaches are designed as close as possible to “flyable” format, as required by EASA standards.

For guidance algorithms, focusing on low computational effort and low fuel consumption, feedback-based algorithms are selected. In detail, in this class of guidance laws, algorithms based on the theory of artificial potential fields are included, for avoiding undesired collisions. Since one of the essential requirement for automated rendezvous maneuver is the ability to reach the Target and to maneuver in proximity of obstacles, the motivation of using Artificial Potential Fields (APFs) is to provide an analytical method to reach the Target in a safe way. The main idea of the artificial potential field theory is to construct a potential field with a gradient acting attractive toward the goal and repellent from obstacles. The desired velocity and the desired attitude are defined by the APF algorithm, to track the desired trajectory and avoiding obstacles. In this talk, a simple shape APF algorithm is proposed to have a reliable method (the same field for all the maneuver) and to avoid obstacles, even for the experimental testbed with multiple obstacle scenario. Moreover, external disturbances are also considered, to demonstrate the robustness of the proposed controller.

The developed algorithms are experimentally tested and evaluated on the NPS-POSEIDYN test bed at the Spacecraft Robotics Laboratory, Monterey, California. The experimental setup includes floating spacecraft simulators (FSS), a polished granite table, a ground station computer, and a Vicon motion capture system. Wi-Fi module provides the FSS with wireless communication capabilities with other FSS and the ground station. Furthermore, once the location of the FSS is determined by the Vicon system, an external computer streams the telemetry data to the FSS using the Wi-Fi link. Both a baseline scenario and multiple obstacles are analyzed.

略歴： Elisa Capello received her PhD (March 2011) from Politecnico di Torino and now she is in the Flight Mechanics group of the Mechanical and Aerospace Engineering Department of Politecnico di Torino as Assistant Professor. She is a research associate of the National Research Council of Italy (CNR) at the Institute of Electronics, Computer and Telecommunication Engineering (CNR-IEIIT) from 2012 and she is currently involved in a Joint Lab Project with the Department of Information and Physical Sciences, Osaka University/JST CREST.

Her domains of expertise are flight mechanics, aircraft (manned and unmanned) control system, Matlab programming. She worked in some Italian projects supported by the Piedmont region and by the Italian Antarctica Research Project. She serves as regular reviewer for scientific journals, published by Springer, Emerald, ASCE, etc.. She worked on the assessment of load control system activation logics to react effectively to sudden or quasi-static external load source, in the JTI Clean Sky project supported by EU research funds and on the development of a 6 dof simulator for rendezvous e docking maneuvers. She is an international FAI judge for helicopter championships.

企画： 大阪大学 大学院情報科学研究科 情報数理学専攻
藤崎泰正

共催： IEEE Control Systems Society Kansai Chapter

担当： 藤崎泰正 (教員室 TEL: 06-6879-7868, Email: fujisaki@ist.osaka-u.ac.jp)