Time-minimal Control of Rigid-body Orientation with a Single Torque

Context and motivation

Miniaturization of space systems resulted in the development of so-called nanosatellites in the last two decades, *i.e.*, fully-featured satellites with a mass smaller than 10 kilograms. Attitude (orientation) control of these satellites is realized by means of reaction wheels and magnetotorquers. However, severe constraints of cost and mass budget often result in the use of a minimal set of actuators, which may constrain the set of possible control torques. The aim of this internship is to study the attitude control problem of a (rigid) satellite using a single torque.

Scientific description

The attitude control problem of a rigid spacecraft is modeled by Euler-Poinsot equations [1], which is a six-dimensional nonlinear system. The aim of the internship is twofold: First, studying the attitude control problem with a single torque in the framework of optimal control, where the cost is the maneuvering time. Starting from the recent analysis of the geodesic flow of this problem in [2] and exploiting the periodicity of abnormal extremals, the objective of the internship is to develop a gate, consisting of a concatenation of abnormal extremals and coasting arcs, capable of steering the system from a resting initial state to a prescribed final one (both the final rotation matrix and angular velocity are imposed) in minimum time. Second, validating the resulting methodology by means of the attitude simulator developed in the framework of the NiceCube mission, the first nanosatellite developed by the *Centre Spatial Universitaire* (CSU) of Université Côte d'Azur.

Practical informations

Supervisors: L. Dell'Elce (Inria, McTAO team) and B. Bonnard (Uni. Bourgogne).

Location: The internship will take place at the Inria center of Université Côte d'Azur (UniCA) (Sophia Antipolis). The student will also interact with members of the CSU for the validation of the methodology.

Student's background: Master 2 in applied mathematics with background on optimal control.

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References

[1] V. I. Arnold, *Mathematical Methods of Classical Mechanics*. Springer New York, 1989.

[2] B. Bonnard and J. Rouot, "Feedback equivalence and time minimal geodesics for controlled euler equations with a single actuator motivated by attitude control," *Preprint*, 2025.

[3] E. Trélat, *Contrôle optimal: théorie et applications*. Vuibert, Collection" Mathématiques Concrètes, 2005.

[4] V. Jurdjevic, *Geometric Control Theory*. Cambridge University Press, 1996.

[5] P. Crouch, "Spacecraft attitude control and stabilization: Applications of geometric control theory to rigid body models," *IEEE Transactions on Automatic Control*, vol. 29, p. 321–331, Apr. 1984.