Spacecraft Reorientation planning with attitude constraints based on B-spline quaternion curves

There are many cases where a spacecraft needs to perform reorientation maneuvers during its mission. Reorientation maneuvers of a spacecraft are usually constrained. One example is that the antenna of the spacecraft is required to keep pointing towards one specific direction, such as the direction of the ground station on Earth, for the purpose of communication. Another example would be that the telescope on board the spacecraft is not allowed to point to the bright objects in the space otherwise the sensitive instrument will be damaged.

The topic of this thesis is to investigate the rotation planning for spacecraft with attitude constraints. In this work, quaternion is chosen to represent the attitude of spacecraft. The basic idea is to use B-spline quaternion curves to plan the constrained reorientation motion of spacecraft.

In detail the following tasks have to be performed:

1. To do Literature review of spacecraft reorientation control or planning with attitude constraints
2. To develop the algorithm for planning rotation trajectory based on B-spline quaternion curves
3. To simulate and verify the algorithm with Matlab
4. To write the thesis

Recommended References

[1] Markley, F. Landis, and John L. Crassidis. Fundamentals of spacecraft attitude determination and control. Vol. 33. New York: Springer, 2014.

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[3] Boyarko, George A., Marcello Romano, and Oleg A. Yakimenko. "Time-optimal reorientation of a spacecraft using an inverse dynamics optimization method." Journal of Guidance Control and Dynamics 34.4 (2011): 1197.

[4] Pan, Jia, Liangjun Zhang, and Dinesh Manocha. "Fast smoothing of motion planning trajectories using b-splines." In *Robotics: Science and Systems*. 2011.

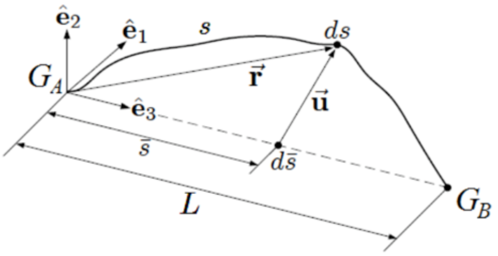
Development of PDE solver for space tether active debris removal missions simulations

The necessity of the removal of inactive spacecraft has been proven for more than 20 years. In several studies many different concepts have been developed. A flexible link/tether is a promising solution for an active debris removal (ADR) mission. Nevertheless, the control and stabilization of the captured target via the flexible connected tether is ambitious. So the development of efficient control algorithms is essential. Therefore, the simulation of the control signal transmitting tether is required.

At the Institute of Space Systems of the university in Brunswick (IRAS) is currently a software tool (Tether Dynamics Toolbox - TDT) under development. The Toolbox provides the capability to analyse a tethered ADR mission starting from the initial capture until the re-entry of the ADR system. In the toolbox the flexible tether can be represented by different modelling approaches:

- as a flexible bar
- lumped mass system
- continuous rope

One way of the tether modelling as continuous rope is to solve a partial differential equation (PDE). The task of the student is the development of an efficient solver for the given tether PDE and the evaluation of the simulation results in comparison to the other simulation models.



$$\vec{r}(\bar{s}, t) = \bar{s}\, \vec{e}_{3,e} + \vec{u}(\bar{s}, t)$$

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To Do List	Depending on the students interest, two topics are possible: **Topic 1: 3D printing with a robotic arm** • Get familiar with the UR3 robotic arm, ROS Kinetic Kame and Fused Deposition Modeling • Research about additive layer manufacturing with robotic arms • Program algorithms required for 3D printing with a robotic arm • Test the algorithms and their influence on the 3D-printed object • Document the results **Topic 2: Tele-operation of a lunar rover** • Get familiar with the levels of autonomy of machines and ROS Kinetic Kame • Research about current plans for lunar space stations and for typical time delays and data loses between a spacecraft and the tele-operator • Create a simulation of the communication between a rover on the Moon and a tele-operator considering time delay and communication losses • Use your simulation to compare teleoperation of a lunar rover from Earth with teleoperation from the planed lunar space station • Document the results
Recommended References	For topic 1: • User Manual of the UR 3 robotic arm, available at https://www.vajdamuvek.hu/files/UR3_User_Manual_en_Global.pdf • Development of algorithms for the robotic arm of the rover-arm-prototype MIRA3D, Yin Ke, Graduation thesis, Institute of Space Systems from TU Braunschweig and NPU, T1807B. • Design and Realization of a 6 Degree of Freedom Robotic Extrusion Platform, Joseph R. Kubalak et al., Proceedings of the 27th Annual International Solid Feeform Fabrication Symposium, 2016. For topic 2: • Contemporary planetary robotics: An approach toward autonomous systems, Yang Gao, Wiley-VCH, Weinheim, 1st edition, 2016. • NASA and Roscosmos to study Deep Space Gateway, Jeff Foust, In: Spacenews.com. 28. September 2017, available at: https://spacenews.com/nasa-and-roscosmos-to-study-deep-space-gateway/.
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