RENDEZVOUS PROXIMITY OPERATIONS USING MODEL PREDICTIVE CONTROL WITH DYNAMIC EQUATIONS DERIVED USING SINDY AND DUAL QUATERNIONS

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The abstract should briefly state the purpose of the manuscript, the problem to be addressed, the approach taken, and the nature of results or conclusions that can be expected. It should stand independently and tell enough about the manuscript to permit the reader to decide whether the subject is of specific interest. The abstract shall be typed single space, justified, centered, and with a column width of 4.5 inches. The abstract is not preceded by a heading of "Abstract" and its length may not extend beyond the first page.

INTRODUCTION

Space rendezvous missions have been extensively analyzed using various forms of constrained path planning and optimization techniques. The combination of improvements in space-certified hardware and modern control techniques have expanded the capability of spacecraft control and the scope of on-orbit services. Interest in spacecraft refueling and repair has been increasing, and it has inspired research in methods to lower costs, increase fuel savings, and find solutions to rendezvous problems with unique constraints.

One of those methods is model-predictive control (MPC), which has been shown to use less fuel due to minimum-fuel trajectory optimization while finding the best approach path within constraints of sensor visibility and safety. Richards and How developed and evaluated an MPC application against a traditional glideslope approach for a rendezvous mission.[1] Singh and Bortolami presented an MPC approach for a docking vehicle during its approach phases. They analyzed seven real-world cases of the space shuttle's standard orbit raising maneuver on its way to the ISS.[2] Filipe and Tsiotras proposed an adaptive position and attitude controller for satellite proximity operations, which did not require information about the mass and inertia for the chaser satellite.[3]

Filipe and Tsiotras also used a particular set of numbers called dual quaternions, which describe the position and orientation (pose) of a body, and will be explored in this paper. Dual quaternions have been demonstrated to be more computationally efficient, which is especially useful for a processor burdened by the calculations required for MPC.

MPC requires knowledge of the system dynamics, which is not always available to the spacecraft controller. Data-driven system identification can be used to derive the equations of motion for

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nonlinear dynamic systems. Brunton, Proctor, and Kutz used data to derive the nonlinear governing equations for a predator-prey model using Sparse Identification of Nonlinear Dynamics (SINDY), including forcing and input functions, which were then implemented in a controller.[5] The same authors also used SINDY to derive the dynamics of oscillators, chaotic Lorenz systems, and fluid vortex shedding behind an obstacle.[6]

This paper will use SINDY for system identification within a model predictive controller for space rendezvous proximity operations (RPO). The improved efficiency from using dual quaternions over regular quaternions will be explored.

THIS IS A SAMPLE OF A GENERAL SECTION HEADING

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Equations.

Abbreviations.

Figures.

Graphic Formats.

References and Citations.

MANUSCRIPT SUBMISSION

Journal Submission

CONCLUSION

ACKNOWLEDGMENT

NOTATION

APPENDIX: TITLE HERE

Miscellaneous Physical Dimensions

REFERENCES

[1] A. Richards and J. How, "Performance Evaluation of Rendezvous Using Model Predictive Control," *AIAA Guidance, Navigation, and Control Conference and Exhibit*, No. AIAA 2003-5507, 2003.

[2] S. B. Leena Singh and L. A. Page, "Optimal Guidance and Thruster Control in Orbital Approach and Rendezvous for Docking Using Model Predictive Control," *AIAA Guidance, Navigation, and Control Conference*, No. AIAA 2010-7754, 2010.

[3] N. Filipe and P. Tsiotras, "Adaptive Position and Attitude-Tracking Controller for Satellite Proximity Operations Using Dual Quaternions," *Journal of Guidance, Control, and Dynamics*, Vol. 38, No. 4, 2015, pp. 566–577.

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[5] J. L. P. Steven L. Brunton and J. N. Kutz, "Sparse Identification of Nonlinear Dynamics with Control (SINDYc)," *IFAC NOLCOS*, Vol. 49, No. 18, 2016, pp. 710–715.

[6] D. R. W. Mathieu Le Provost and S. L. Brunton, "SINDy analysis of disturbance and plant model superposition on a rolling delta wing," 2018, 10.2514/6.2018-3068.