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

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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. 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. 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.

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. The same authors also used SINDY to derive the dynamics of oscillators, chaotic Lorenz systems, and fluid vortex shedding behind an obstacle.

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.

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Equations.

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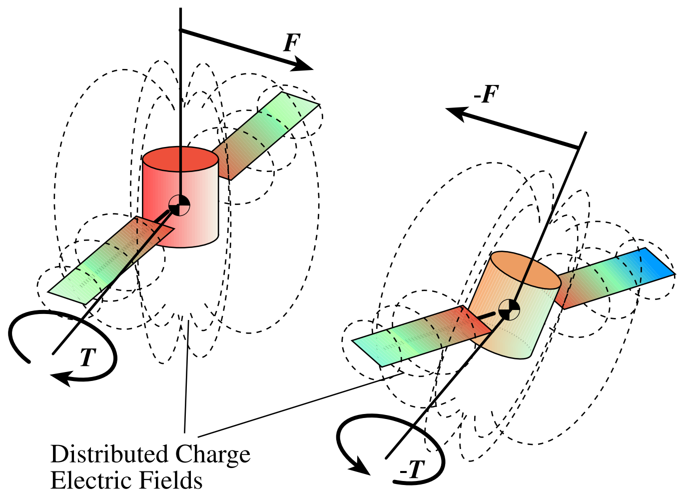

Figure 1. Illustration Caption Goes Here

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Table 1. A Caption Goes Here

Animal	Description	Price ($)
Gnat	per gram	13.65
	each	0.01
Gnu	stuffed	92.50
Emu	stuffed	33.33
Armadillo	frozen	8.99

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[*] `http://www.univelt.com/FAQ.html#SUBMISSION`

[†] Gangster, Maurice (1999), personal correspondence of March 21st. Sr. Consultant, Space Cowboy Associates, Inc., Colorado Springs, CO.

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ACKNOWLEDGMENT

Any acknowledgments by the author may appear here. The acknowledgments section is optional.

NOTATION

a	a real number
b	the square root of a

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REFERENCES

[1] J. L. Doe and J. Q. Public, “The Parameterization of the Rotation Matrix using Redundant Attitude Coordinates,” *Nonlinear Dynamics*, Vol. 32, No. 3, 2005, pp. 71–92.

[2] *Style Manual*. New York 17, New York: American Institute of Physics, 2nd ed., 1959.