VML 3.0 Reactive Sequencing Objects and Matrix Math Operations for Attitude Profiling

Dr. Christopher A. Grasso[1]
Blue Sun Enterprises, Boulder, Colorado, 80302

and

Joseph E. Riedel[2]
Jet Propulsion Laboratory / California Institute of Technology, Pasadena, California, 91109

VML (Virtual Machine Language) has been used as the sequencing flight software on over a dozen JPL deep-space missions, most recently flying on GRAIL and JUNO. In conjunction with the NASA SBIR entitled "Reactive Rendezvous and Docking Sequencer", VML version 3.0 has been enhanced to include object-oriented element organization, built-in queuing operations, and sophisticated matrix / vector operations. These improvements allow VML scripts to easily perform much of the work that formerly would have required a great deal of expensive flight software development to realize. Autonomous turning and tracking makes considerable use of new VML features. Profiles generated by flight software are managed using object-oriented VML data constructs executed in discrete time by the VML flight software. VML vector and matrix operations provide the ability to calculate and supply quaternions to the attitude controller flight software which produces torque requests. Using VML-based attitude planning components eliminates flight software development effort, and reduces corresponding costs. In addition, the direct management of the quaternions allows turning and tracking to be tied in with sophisticated high-level VML state machines. These state machines provide autonomous management of spacecraft operations during critical tasks like a hypothetic Mars sample return rendezvous and docking. State machines created for autonomous science observations can also use this sort of attitude planning system, allowing heightened autonomy levels to reduce operations costs. VML state machines cannot be considered merely sequences - they are reactive logic constructs capable of autonomous decision making within a well-defined domain. The state machine approach enabled by VML 3.0 is progressing toward flight capability with a wide array of applicable mission activities.

I. Introduction

VML (Virtual Machine Language) has been used as the sequencing flight software on thirteen deep-space missions, most recently flying on GRAIL and JUNO, and slated for flight on OSIRIS-Rx. In conjunction with the NASA SBIR entitled Reactive Rendezvous and Docking Sequencer, VML version 3.0 has been enhanced to include object-oriented element organization, built-in queuing operations, and sophisticated matrix and vector operations. These improvements allow VML scripts to perform much of the work that formerly would have required a great deal of expensive flight software development to realize. Attitude profiling in VML is an example of a malleable guidance, navigation, and control (GNC) flight capability which can enhance safety by rejecting illegal attitude changes and lower implementation effort relative compared to equivalent flight software implementations.

Autonomous slewing and tracking makes considerable use of new VML features. Profiles generated by flight software are managed using object-oriented VML data constructs executed in discrete time by the VML flight software. VML vector and matrix operations provide the ability to calculate and supply quaternions to the attitude controller flight software which produces torque requests. Targeting the new spacecraft attitude involves

[1] Principal VML Engineer, Blue Sun Enterprises, 1942 Broadway Suite 314, Boulder, CO, 80302, Senior Member.
[2] Principal Engineer, Optical Navigation, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA, 91109.