Attitude Control using three Control Moment Gyros

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In this paper, the attitude control of spacecraft using three single-gimbal Control Moment Gyros (CMG) is investigated.

There has been much research for attitude control of spacecraft using single-gimbal CMGs. However, in most of this research, four or more CMGs are used. Because the attitude control requires only three degrees of freedom, the spacecraft has redundant degrees of freedom. There are various studies that use the redundancy to pass through the singularities. On the other hand, in the case of three CMGs without redundancy, it takes a long time to pass the singularities by using the conventional steering law. In this paper, the attitude control for configurations of three CMGs by using a steering law with Inverse Kinematics (IK) is proposed. A triangular pyramid configuration (Fig.1) and a square pyramid configuration with a failure (Fig.2) are examples of three CMGs configurations, and their angular momentum envelopes are also shown in the figures.

IK is a method that is usually used in computing angles of links of a robotic arm from its tip position and/or orientation. In this paper, the gimbal angles of the three CMGs are directly computed from the angular momentum of the CMGs by IK, where three gimbal angles are obtained by solving three algebraic equations about the angles. Unlike conventional methods, there is no special problem in the singularities because this method doesn't compute an inverse matrix, and therefore, it is easier to pass the singularities than the conventional methods. A feedback attitude control law by using the steering law is also proposed to decrease the attitude error. Numerical simulation results are shown in Figs. 3 and 4, where a conventional steering law and the IK steering law are applied to a square pyramid configuration with a failure, respectively. As shown in these figures, the gimbal angles in the conventional steering law jump at the singular state, whereas those in the IK steering law change rather smoothly than the conventional law.

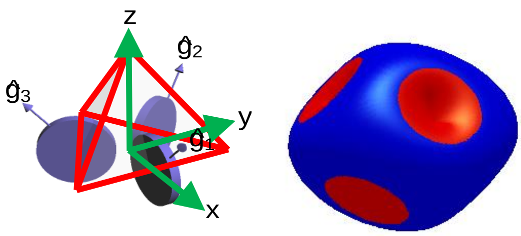

Fig. 1. Triangular Pyramid and its momentum envelope.

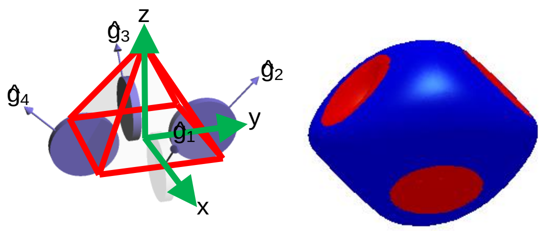

Fig. 2. Square Pyramid with a failure and its momentum envelope.

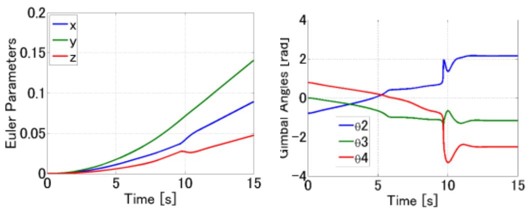

Fig. 3. Simulation results with a conventional steering law
(left: attitude, right: gimbal angles)

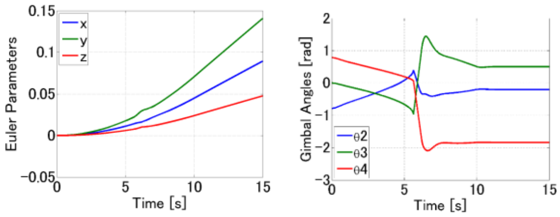

Fig. 4. Simulation results with IK steering law
(left: attitude, right: gimbal angles)