MANUSCRIPT TITLE (UP TO 6 INCHES IN WIDTH AND CENTERED, 14 POINT BOLD FONT, MAJUSCULE)

Mohammad Ayoubi[*] and Junette Hsin[†]

A sun avoidance slew maneuver is described in this paper. The algorithm finds the angular velocity, angular acceleration, and quaternion profiles needed to avoid the sun vector that lies near the plane of a sensor's FOV onboard a spacecraft.

INTRODUCTION

Problem Justification

Given: ${}_N\hat{P}_i$, ${}_N\hat{P}_f$, ${}_N\hat{S}$, ${}_G\hat{P}$, ϵ_p, ${}^Nq^G$, ${}^N_G\omega^G(t_i)$, and ${}^N_G\omega^G(t_f)$.

Find:

1. A sequence of slew maneuvers to avoid sun vector.
2. the commanded angular velocity, angular acceleration, and quaternion profiles.

Nomenclature:

- G frame: Unit sphere attached to the gyrostat.
- N: frame: The Newtonian frame fixed in the inertial space.
- ${}_G\hat{P}$: Unit vector along the bore sight of payload in the G frame.
- ${}_N\hat{P}_i$: Unit vector of the initial point in the G frame.
- ${}_N\hat{P}_f$: Unit vector of the final point in the G frame.
- ${}_N\hat{S}$: Unit vector of the sun vector in the N frame.
- ϵ_p: Payload half-cone angle.

[*] Title, department, affiliation, postal address.
[†] Title, department, affiliation, postal address.

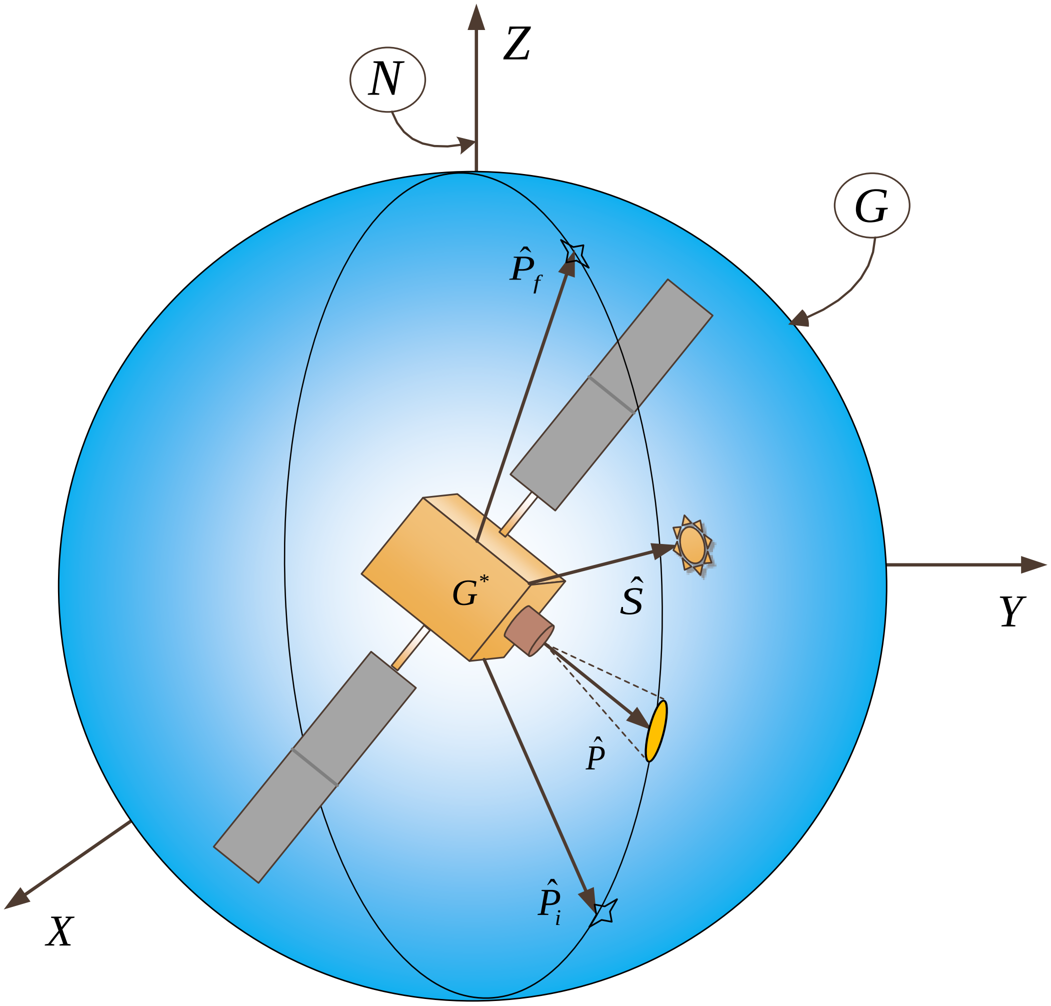


Figure 1. The spacecraft is not drawn to scale.

Literature surveyed

This is the literature surveyed.

Contribution of work

This is the contribution of work.

ALGORITHM DESCRIPTION

Slew Maneuver

Check the Sun Vector Intrusion

1. Check the angular separation between the sun vector, $\hat{S}$, and the $\hat{P}_i - \hat{P}_f$ plane.

$$\alpha = \frac{\pi}{2} - \cos^{-1}(\hat{S}.\hat{e}) \tag{1}$$

   where the eigenaxis is determined by

$$\hat{e} = \frac{\hat{P}_i \times \hat{P}_f}{|\hat{P}_i \times \hat{P}_f|} \tag{2}$$

2. IF $|\alpha| < \epsilon_p$,THEN determine the projection of the sun vector into the $\hat{P}_i - \hat{P}_f$ plane.

$$\vec{S}_{||} = \hat{S}\cos\alpha \tag{3}$$

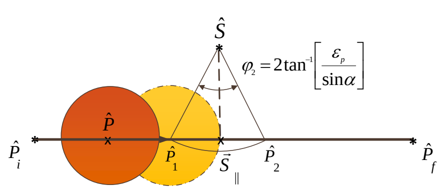
Slew Maneuvers

1. The 1^{st} slew around the eigenaxis,$\hat{e}$, through angle:

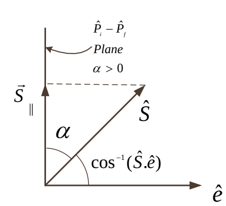
$$\phi_1 = \begin{cases} \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p & when\ \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p \leq \pi \\ \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p - 2\pi & when\ \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p > \pi \end{cases} \tag{4}$$

2. The 2^{nd} slew around the unit sun vector, $\hat{S}$, via ϕ_2.

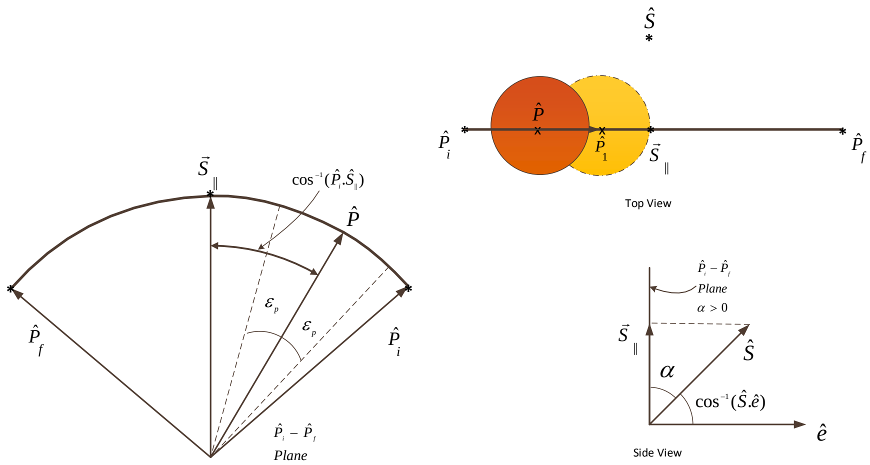
   (a) when $\alpha \neq 0$



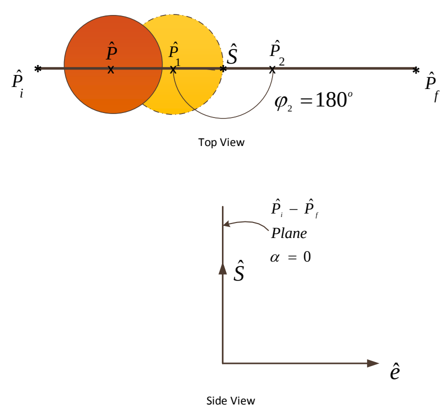
Top View



Side View

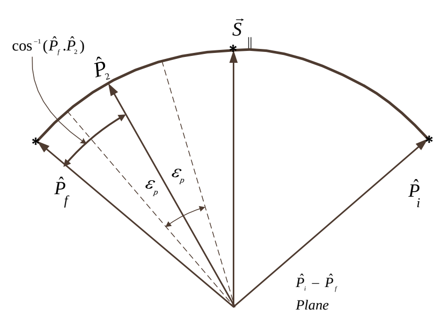


(b) when $\alpha = 0$



3. The 3^{rd} slew about the $\hat{e}$ through angle:

$$\phi_3 = \begin{cases} \cos^{-1}({}_G\hat{P}_f.\hat{P}_2) & when\ {}_G\hat{P}_f.\hat{P}_2 \geq 0 \\ \cos^{-1}({}_G\hat{P}_f.\hat{P}_2) - 2\pi & when\ {}_G\hat{P}_f.\hat{P}_2 < 0 \end{cases} \tag{5}$$



4. The final slew is about the instrument boresight axis to go to the final attitude.

Summary of Algorithm

1. Slew around the eigenaxis,$\hat{e}$, through angle:

$$\phi_1 = \begin{cases} \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p & when \ \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p \leq \pi \\ \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p - 2\pi & when \ \cos^{-1}(\hat{P}._G\hat{S}_{||}) - \epsilon_p > \pi \end{cases} \tag{6}$$

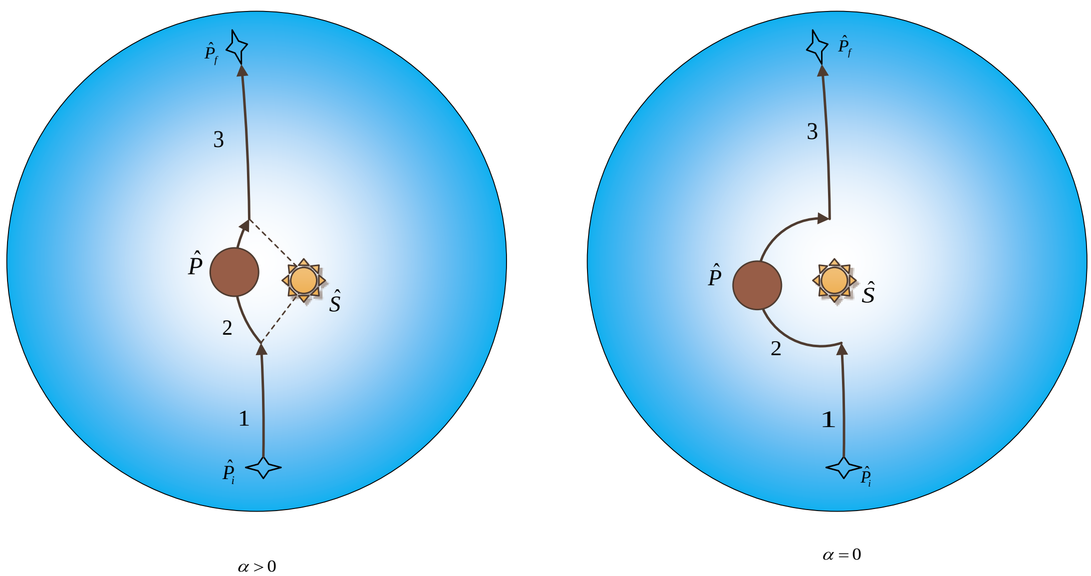
2. Slew around the $\hat{S}$ via:

$$\phi_2 = \begin{cases} 2\tan^{-1}(\frac{\epsilon_p}{\sin\alpha}) & when \ \alpha \neq 0 \\ \pi & when \ \alpha = 0 \end{cases} \tag{7}$$

3. Slew about the $\hat{e}$ through angle:

$$\phi_3 = \begin{cases} \cos^{-1}({}_G\hat{P}_f.\hat{P}_2) & when \ {}_G\hat{P}_f.\hat{P}_2 \geq 0 \\ \cos^{-1}({}_G\hat{P}_f.\hat{P}_2) - 2\pi & when \ {}_G\hat{P}_f.\hat{P}_2 < 0 \end{cases} \tag{8}$$

4. Perform the final rotation, ϕ_4, about the instrument boresight axis to adjust the attitude.



STEERING LAWS

Case 1: Single-Axis, Agile Slew Maneuver with Velocity and Acceleration Constraints.

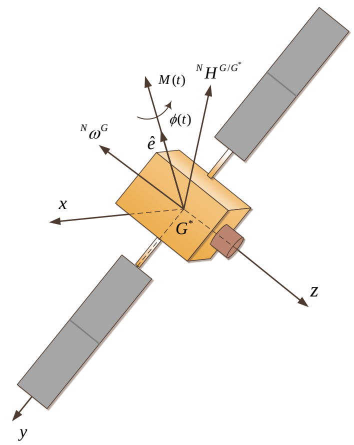
Problem Statement Consider the motion of a rigid spacecraft around a given inertially-fixed axis, ${}_G\hat{e} = [e_x, e_y, e_z]^T$. The problem of minimum-time slew maneuver around the $\hat{e}$ axis can be formulated as

$$\underset{u}{Minimze}\ J[x(.), u(.), t_f] = \int_{t0}^{t_f} dt, \tag{9}$$

subject to the following dynamic constraint

$$\Sigma : \begin{cases} \dot{x}_1 = x_2, \\ \dot{x}_2 = M/I_{\hat{e}}^{G/G*} = u, \end{cases} \tag{10}$$

where $x_1 \triangleq \phi$ and $x_2 = \dot{\phi}$.



Steering Profiles

- Angular acceleration profile (bang-off-bang):

$$\ddot{\phi}(t) = u = \begin{cases} \ddot{\phi}_{max} & when\ t_0 \leq t \leq t_1, \\ 0 & when\ t_1 \leq t \leq t_2, \\ -\ddot{\phi}_{max} & when\ t_2 \leq t \leq t_f. \end{cases} \tag{11}$$

- Angular velocity profile:

$$\dot{\phi}(t) = \begin{cases} \dot{\phi}_0 + \ddot{\phi}_{max}(t - t_0) & when\ t_0 \leq t \leq t_1, \\ \dot{\phi}_{max} & when\ t_1 \leq t \leq t_2, \\ \dot{\phi}_{max} - \ddot{\phi}_{max}(t - t_2) & when\ t_2 \leq t \leq t_f. \end{cases} \tag{12}$$

- Angular position profile:

$$\phi(t) = \begin{cases} \dot{\phi}_0(t - t_0) + \frac{1}{2}\ddot{\phi}_{max}(t - t_0)^2 & when\ t_0 \leq t \leq t_1, \\ \phi(t_1) + \dot{\phi}_{max}(t - t_1) & when\ t_1 \leq t \leq t_2, \\ \phi(t_2) + \dot{\phi}_{max}(t - t_2) - \frac{1}{2}\ddot{\phi}_{max}(t - t_2)^2 & when\ t_2 \leq t \leq t_f. \end{cases} \tag{13}$$

- Using the conditions, $\dot{\phi}(t_1) = \dot{\phi}_{max}$, $\dot{\phi}(t_f) = \dot{\phi}_f$, $\phi(t_f) = \phi_f$, we can determine switching times t_1, t_2, and final time t_f as:

$$t_1 = t_0 + \frac{\dot{\phi}_{max} - \dot{\phi}_0}{\ddot{\phi}_{max}}, \tag{14}$$

$$\begin{aligned} t_2 =& t_1 + \frac{1}{\dot{\phi}_{max}}\Big[\phi_f - \dot{\phi}_0(t_1 - t_0) - \frac{1}{2}\ddot{\phi}_{max}(t_1 - t_0)^2 \\ &- \frac{\dot{\phi}_{max}(\dot{\phi}_{max} - \dot{\phi}_f)}{\ddot{\phi}_{max}} + \frac{(\dot{\phi}_{max} - \dot{\phi}_f)^2}{2\ddot{\phi}_{max}}\Big], \end{aligned} \tag{15}$$

and

$$t_f = t_1 + \frac{1}{\dot{\phi}_{max}}\Big[\phi_f - \dot{\phi}_0(t_1 - t_0) - \frac{1}{2}\ddot{\phi}_{max}(t_1 - t_0)^2 + \frac{(\dot{\phi}_{max} - \dot{\phi}_f)^2}{2\ddot{\phi}_{max}}\Big]. \tag{16}$$

- Steering profiles:

$${}^{N}q^{D}(t) = [e_x \sin\frac{\phi(t)}{2}, e_y \sin\frac{\phi(t)}{2}, e_z \sin\frac{\phi(t)}{2}, \cos\frac{\phi(t)}{2}]^T \tag{17}$$

$${}^{N}_{G}\omega^{D}(t) = \dot{\phi}(t)_G\hat{e} \tag{18}$$

$${}^{N}_{G}\alpha^{D}(t) = \ddot{\phi}(t)_G\hat{e} \tag{19}$$

NUMERICAL SIMULATION

CONCLUSION

ACKNOWLEDGMENT

APPENDIX: TITLE HERE

Miscellaneous Physical Dimensions

REFERENCES