Autonomous Vehicle Simulation (AVS) Laboratory

AVS-Sim Technical Memorandum

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GUIDANCE MODULE FOR GROUND LOCATION POINTING

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Status: Initial Version	
Scope/Contents	
Generate the attitude reference to perform a constant pointing towards a static ground location	

Rev:	**Change Description**	**By**
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Contents

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1 Module Input and Output

Table 2 shows the Spacecraft State input message.

Table 2: Input Spacecraft States Message

Name	Type	Length	Description
$\boldsymbol{r}_{B/N}$	double []	3	Position vector of the spacecraft body-point with respect to the inertial frame in inertial frame components (${}^{\mathcal{N}}\boldsymbol{r}_{B/N}$) .
$\boldsymbol{\omega}_{B/N}$	double []	3	Angular velocity vector of the spacecraft point with respect to the inertial frame in body frame components (${}^{\mathcal{B}}\boldsymbol{\omega}_{B/N}$).

Table 4 shows the Ground State input message.

Table 3: Input Ground State Message

Name	Type	Length	Description
$\boldsymbol{r}_{L/N}$	double []	3	Position vector of the ground location with respect to the inertial origin in the inertial frame (${}^{\mathcal{N}}\boldsymbol{r}_{L/N}$).

Table 4 shows the user specified inputs required.

Table 4: User Specified Input

Name	Type	Length	Description
$\hat{\boldsymbol{p}}$	double []	3	Satellite vector that will be aligned to point at the ground location.

Table 5 shows the Attitude Guidance output message of the module locationPointing.

Table 5: Output Attitude Guidance Message

Name	Type	Length	Description
$\sigma_{B/R}$	double []	3	Current attitude error estimate of B relative to R.
$\omega_{B/R}$	double []	3	Current body error estimate of B relative to R in B frame components (${}^{\mathcal{B}}\omega_{B/R}$).
$\omega_{R/N}$	double []	3	Reference frame rate vector of R relative to N in B frame components (${}^{\mathcal{B}}\omega_{R/N}$).
$\dot{\omega}_{R/N}$	double []	3	Reference frame inertial body acceleration of R relative to N in B frame components (${}^{\mathcal{B}}\dot{\omega}_{R/N}$).

2 Introduction

In this module, the output attitude guidance message acts to point a prescribed satellite vector toward a static ground location. An example formulation of this problem is shown below.

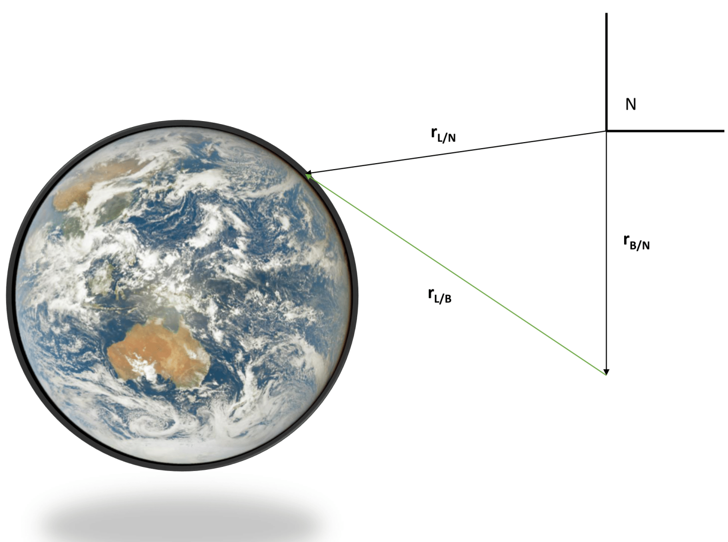

Fig. 1: Problem formulation

The position of the spacecraft relative to the ground location is calculated by the following simple subtraction:

$$\bar{\boldsymbol{r}}_{\boldsymbol{L/B}} = \bar{\boldsymbol{r}}_{\boldsymbol{L/N}} - \bar{\boldsymbol{r}}_{\boldsymbol{B/N}} \tag{1}$$

From this, the eigen axis is computed using the value calculated above and the user given satellite pointing vector.

$$\hat{e} = \frac{\hat{\boldsymbol{p}} \times \bar{\boldsymbol{r}}_{\boldsymbol{L/B}}}{|\hat{\boldsymbol{p}} \times \bar{\boldsymbol{r}}_{\boldsymbol{L/B}}|} \tag{2}$$

Next, ϕ was calculated again using the pointing vector and the relative position of the ground location w.r.t the spacecraft:

$$\phi = \arccos \frac{\hat{\boldsymbol{p}} \cdot \bar{\boldsymbol{r}}_{\boldsymbol{L/B}}}{|\bar{\boldsymbol{r}}_{\boldsymbol{L/B}}|} \tag{3}$$

The current attitude error estimate of B relative to R (an output of the module) is computed using the above intermediate value:

$$\boldsymbol{\sigma_{R/B}} = \tan\frac{\phi}{4}\hat{\boldsymbol{e}} \tag{4}$$

$\sigma_{B/R}$ is the negative of $\sigma_{R/B}$, as shown below:

$$\boldsymbol{\sigma_{B/R}} = -\boldsymbol{\sigma_{R/B}} \tag{5}$$

A basic finite difference was used to calculate the time derivative of σ. Only two consecutive data points were used for the computation over the uniform time-step between them:

$$\dot{\boldsymbol{\sigma}}_{\boldsymbol{R/B}} = \frac{\Delta\boldsymbol{\sigma_{R/B}}}{\Delta t} \tag{6}$$

At which point we can calculate the angular velocity required in the output message:

$$\boldsymbol{\omega_{R/B}} = 4\dot{\boldsymbol{\sigma}}_{\boldsymbol{R/B}} B(\boldsymbol{\sigma_{R/B}})^{-1} \tag{7}$$

Where B inverse is computed using the following:

$$B^{-1} = \frac{1}{|\boldsymbol{\sigma_{R/B}}|^2}\begin{bmatrix} 1-|\boldsymbol{\sigma}|+2\boldsymbol{\sigma}_0^2 & 2(\boldsymbol{\sigma}_0\boldsymbol{\sigma}_1+\boldsymbol{\sigma}_2) & 2(\boldsymbol{\sigma}_0\boldsymbol{\sigma}_2-\boldsymbol{\sigma}_1) \\ 2(\boldsymbol{\sigma}_1\boldsymbol{\sigma}_0-\boldsymbol{\sigma}_2) & 1-|\boldsymbol{\sigma}|+2\boldsymbol{\sigma}_1\boldsymbol{\sigma}_1 & 2(\boldsymbol{\sigma}_1\boldsymbol{\sigma}_2+\boldsymbol{\sigma}_0) \\ 2(\boldsymbol{\sigma}_2\boldsymbol{\sigma}_0+\boldsymbol{\sigma}_1) & 2(\boldsymbol{\sigma}_2\boldsymbol{\sigma}_1-\boldsymbol{\sigma}_0) & 1-|\boldsymbol{\sigma}|+2\boldsymbol{\sigma}_2\boldsymbol{\sigma}_2 \end{bmatrix} \tag{8}$$

The angular velocity of the reference frame vector relative to the inertial frame in B frame components is then computed using the values calculated above.

$$\boldsymbol{\omega_{R/N}} = \boldsymbol{\omega_{R/B}} + \boldsymbol{\omega_{B/N}} \tag{9}$$

Finally, the angular acceleration of R relative to N is computed using a finite difference of the angular velocity values over 1 time-step.

$$\dot{\boldsymbol{\omega}}_{\boldsymbol{R/N}} = \frac{\Delta\boldsymbol{\omega_{R/N}}}{\Delta t} \tag{10}$$