Aerobraking Guidance, Navigation and Control

A Comparison of State Variables Performance in Propagation

Delft University of Technology

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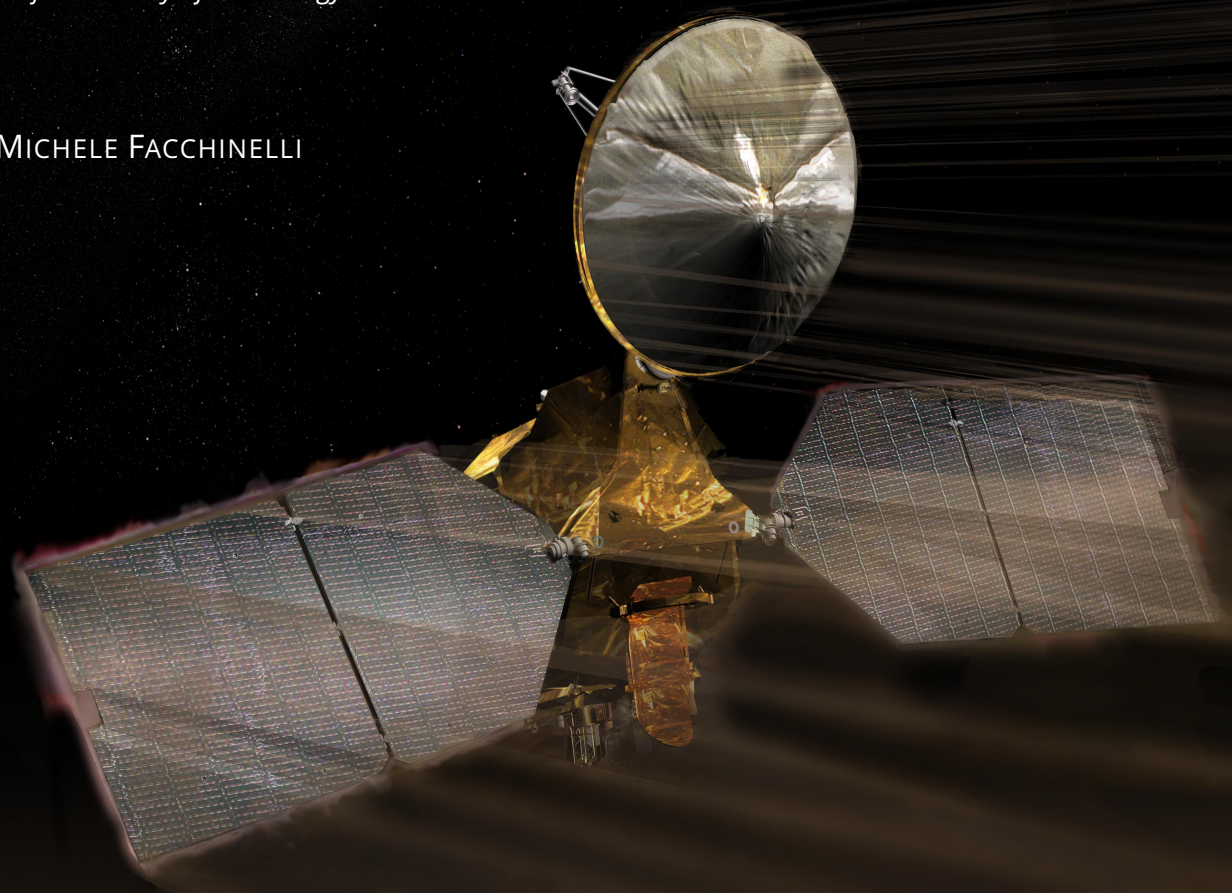

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A Comparison of State Variables Performance in Propagation

by

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Cover picture by Jet Propulsion Laboratory, depicting Mars Reconnaissance Orbiter during Aerobraking. Available at https://goo.gl/tKorKM.

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List of Symbols

Latin Symbols:

c	Speed of light	[m s^{-1}]
g	Gravitational acceleration	[m s^{-2}]
$\mathscr{R}$	Universal gas constant	[J mol^{-1} K^{-1}]
$\mathbf{x}$	State vector	variable
$\mathbf{0}$	Zero matrix	[–]

Greek Symbols:

α	Angle of attack	[rad]
μ	Standard gravitational parameter	[m^3 s^{-2}]
σ	Stefan-Boltzmann constant	[W m^{-2} K^{-4}]
$\boldsymbol{\omega}$ or ω	Angular velocity	[rad s^{-1}]

Sub- and Superscripts:

A	Airspeed
grav	Gravitational
L	Lift

Reference Frames:

$\mathcal{F}_{\mathcal{B}}$	Body-fixed reference frame
$\mathcal{F}_{\mathcal{I}}$	Inertial planetocentric reference frame
$\mathcal{F}_{\mathcal{R}}$	Rotating planetocentric reference frame
$\mathcal{F}_{\mathcal{V}}$	Vertical reference frame

Special Characters:

$\hat{\blacksquare}$	Unit vector
$\blacksquare^{\mathrm{S}}$	Skew-symmetric matrix in terms of vector elements
$\blacksquare^{\mathrm{T}}$	Matrix transpose
$\|\|\blacksquare\|\|$	Magnitude of vector
$\bar{\square}$	Average
$\hat{\square}$	Estimated value
$\square'$	Intermediate value
$\overline{\square}$	Normalized
$\square^{\circledast}$	Optimal value
$\square'$	Post-maneuver value
$\triangleq$	Defined as
$\leftarrow$	Transformation to

Astronomical Symbols:

$\odot$	Sun
♀	Venus
♁	Earth

☾	Moon
♂	Mars
♄	Saturn
☽	Titan
♈	Vernal equinox

Chemical Formulas:

Ar	Argon
$\mathrm{CH_4}$	Methane
CO	Carbon monoxide
$\mathrm{CO_2}$	Carbon dioxide
H	Monoatomic hydrogen
$\mathrm{H_2}$	Diatomic hydrogen
$\mathrm{H_2O}$	Dihydrogen monoxide
He	Helium
$\mathrm{N_2}$	Nitrogen
O	Monoatomic oxygen
$\mathrm{O_2}$	Diatomic oxygen
$\mathrm{O_3}$	Ozone

List of Abbreviations

ESA	European Space Agency
JPL	Jet Propulsion Laboratory
LaRC	Langley Research Center
NASA	National Aeronautics and Space Administration
RK4	Runge-Kutta Fourth-order Integrator
Tudat	TU Delft Astrodynamics Toolbox
TU Delft	Delft University of Technology

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1 This is the Chapter Title

This is how a chapter looks like. Note that in the first *numbered* chapter you write (the introduction, for instance), you have to include the command:

```
\pagenumbering{arabic}\setcounter{page}{1}
```

otherwise, the page numbering will be shown in Roman numerals and the page counter won't be reset.

1.1 | This is the Section Title

This is how a section looks like.

1.1.1 | This is the Subsection Title

This is how a subsection looks like.

This is the Subsubsection Title

This is how a subsubsection looks like.

THIS IS THE PARAGRAH TITLE And finally, this is how a paragraph looks like. Notice how both subsubsections and paragraphs are not numbered, but can be used to give more structure to your document.

Now, we can explore some of the features mentioned in the `README.md` file.

First, let's talk math. You can use the `\v{}` command, to show a vector $\mathbf{x}$, or with a greek symbol $\mathbf{\Gamma}$. When compared to the scalar versions of the same letters (i.e., x and Γ), the vectors will appear as bold and not italic. For the three-dimensional column vector, you can use the `\vthree{}{}{}` command, and `\quaternion` to show the quaternion vector:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \boldsymbol{\varepsilon} \\ \eta \end{pmatrix}$$

Since quaternions have 4 elements, the above expression makes no sense, but gladly this is not my thesis. There are also commands for derivatives, such as:

$$\mathrm{d}x \qquad \frac{\mathrm{d}x}{\mathrm{d}t} \qquad \frac{\mathrm{d}^2x}{\mathrm{d}t^2} \qquad \frac{\partial x}{\partial t} \qquad \frac{\partial^2 x}{\partial t^2} \qquad g^{(2)}\left(x\right)$$

You can also use the `f{}` command to print a function. For instance, you can have $f\left(x\right)$ or $\mathbf{X}\left(y\right)$. Finally, you can use the `\chem{}` command to show chemical formulas, such as $\mathrm{H_2O}$ or $\mathrm{C_6H_{12}O_6}$.

Then, we can talk about the mouse-hover tags. Make sure to be using Adobe Reader to see these effects. The first command is the `\abbr{}` command. When looking at the text, you won't notice anything different about the NASA abbreviation. But when you hover your mouse over this word, you will notice that a small window will appear, saying 'National Aeronautics and Space Administration'. You can do this for any other abbreviation in the `tags.tex` file, such as JPL, Tudat or RK4.

The two other tags that can be used are `\citeframe{}` and `\citefframe{}`. The first one prints the frame as $\mathcal{I}$-frame, whereas the second one as $\mathcal{F}_{\mathcal{I}}$. Once again, the reader will not notice anything different while looking at the output of these commands, unless she/he hovers their mouse over them. In this case, she/he will read 'Inertial Planetocentric Reference Frame'. Notice how the font of the frame letter is different from the usual math font. This is set by the `\framefont{}` command, and its default value is `\mathcal{}`. Thus, I can also write the output of `\citeframe{I}`, as $\mathcal{I}$-frame (`\framefont{I}-frame`), but in this case no pop-up appears.

Table 1.1: *This is an example table. Here one can see the effect of the custom table alignment options.*

Column 1	Column 2	Column 3
x	10	Some very long text that is constrained in width by the `C{}` alignment option to 2 cm

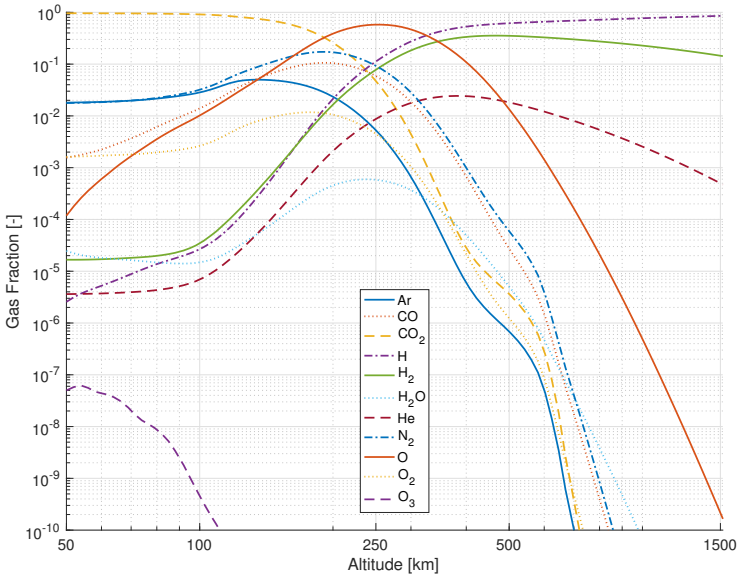

Figure 1.1: *This is an example figure. You can also refer to the author of this figure (Facchinelli, 2018). This figure, by the way, shows the gas concentrations as a function of altitude, for the atmosphere of Mars.*

Bibliography

Facchinelli, M., “Aerobraking Guidance, Navigation and Control,” Master Thesis, Delft University of Technology, October 2018.

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A
This is the Appendix Title