Princeton SATELLITE
SYSTEMS

Spin Axis Attitude Determination Module

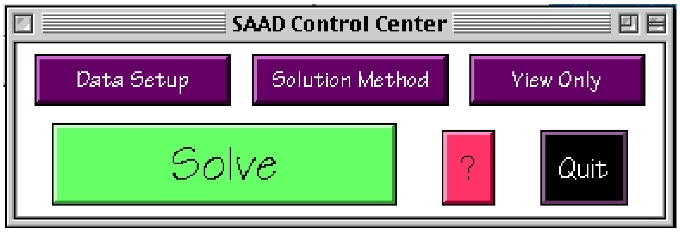
for the Spacecraft Control Toolbox, Professional Edition

The Spin Axis Attitude Determination Module for use with the Spacecraft Control Toolbox (Professional Edition) provides you with a complete, integrated set of tools needed to perform spin-axis attitude determination using horizon sensor and sun sensor measurements.

Features

The Spin Axis Attitude Determination Module provides a comprehensive set of features and capabilities including:

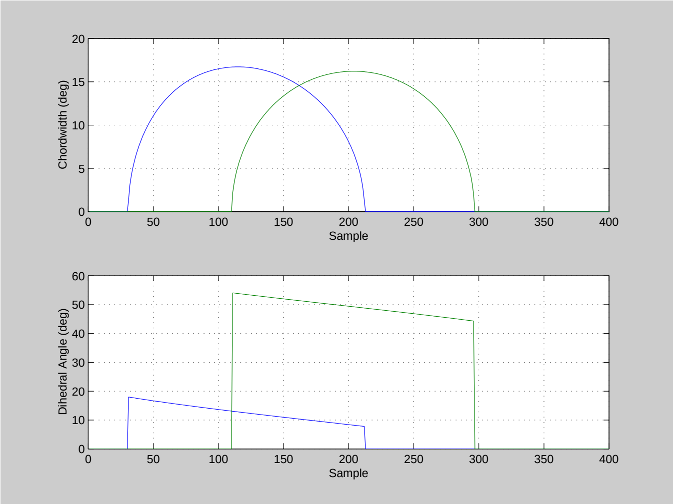
- Differential-corrector, Conjugate Gradient and Nelder-Meade batch attitude determination algorithms
- Iterated extended Kalman Filter for real-time applications
- Cone intercept, and chordwidth plus dihedral angle attitude determination methods
- Singular value decomposition least squares solver for ill-conditioned data
- Data quality evaluation tools
- Horizon sensor dynamics models
- GUI or script interfaces



The Spin Axis Attitude Determination Module makes extensive use of the MATLAB graphics capabilities, which makes analyzing your data an easy task. Plots of measurement data make evaluating data quality and effectiveness of data culling a snap. You can also see how well the measured data matches predictions before and after solutions, as in the plot below. Solutions are also presented numerically (as errors and residual statistics) for all of the solution methods.

Each attitude determination method can compute any combination of angles, sensor biases and Earth width bias. The latter is necessary due to the uncertainty in the trigger altitude for CO_2 atmosphere layer based horizon sensors.

The following plot show chordwidth and dihedral angle data derived from the horizon sensor model which computes leading and trailing edge times for the horizon sensor. Using dihedral angles greatly improves attitude determination accuracy but it is necessary to estimate dihedral angle biases whenever they are used.



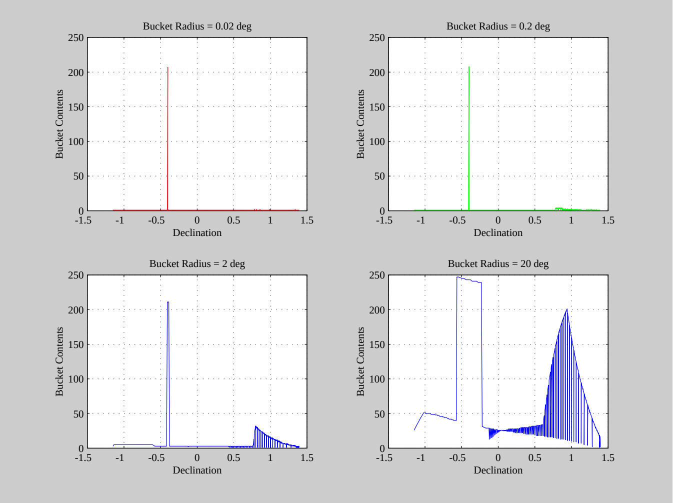
Flexibility

The Spin Axis Attitude Determination Module can process any combination of data that is available on your system. It accepts horizon sensor inputs as either leading and trailing edge times or as dihedral angles. Midscan, leading or trailing dihedral angles are handled with equal ease. The data can even be processed without dihedral angles or without chordwidths. With the recursive estimator even a succession of sun angle can improve your solution.

This feature was useful on a recent mission when a temporary glitch made the leading edge times, and therefore the chordwidths, unavailable. We were able to continue attitude determination using only the sun angle and the trailing edge dihedral angles.

The graphics tools allow you to easily evaluate the quality of the data and discard obvious outliers. On one mission Sun reflections were causing the horizon scan to terminate prematurely resulting in short chords. The telemetry system processor would only check each set of 5 scans for consistency so these scan sets were not eliminated from the data. The graphics tools were used to plot the measured chordwidths against the estimated chordwidths maked the short chordwidths obvious. The bad data was eliminated and the rest of the data processed to get good solutions. This saved considerable mission time since the Earth Sun geometry was not going to improve for several days.

You can apply all of the tools to any set of data thus giving you additional insight into the problem. The following figure shows the processing of attitude data using the single frame Schuster method. Each set of horizon sensor chordwidths and sun angles provides two solutions. One is the correct solution and the other an artifact of the solution method. The true attitude will not change as you change the data so the algorithm sorts the solutions into buckets with successively narrower bounds. The progression is shown in the figure.



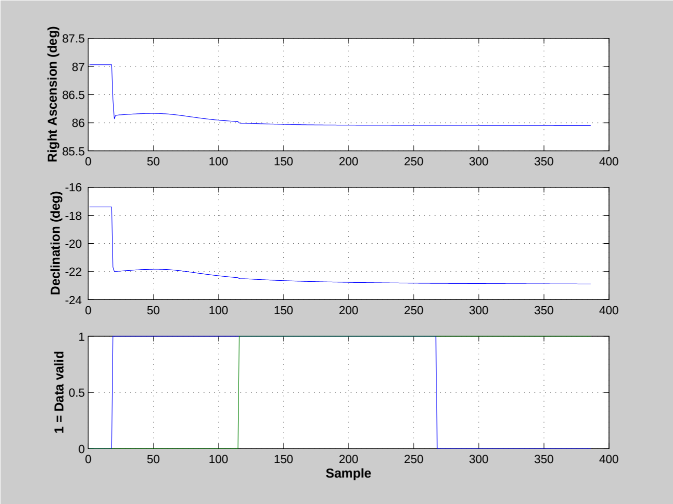
Full source code is provide for all functions so you can customize them to fit your particular application. Of course, the full power of MATLAB is available to you for pre or post processing of your data.

Methods

The Spin Axis Attitude Determination Module provides three batch algorithms, two single frame algorithms and a recursive method. The first two batch methods use analytical partials of the measurement equations and iterate to converge to a solution. These are inherently locally optimal methods and if your initial guess is not close you may converge to a local minimum which is not the correct solution. If your guess is reasonably good they converge very quickly.

The Nelder-Meade method, also known as downhill simplex, is a globally optimal method that does not use the partials of the measurement equations. It has proven to be very reliable. The Nelder-Meade algorithm uses the built-in MATLAB fmins function.

The recursive method is an iterated extended Kalman Filter. This method incorporates measurements as the arrive and does not need simultaneous sun and horizon sensor measurements. The following figure shows a typical solution.



All methods allow you to solve for any combination of sensor biases, Earth width bias and attitude. Solving for too many parameters simultaneously can cause any algorithm to arbitrarily move errors from one parameter to the other producing an unreliable estimate.

Flight Experience

We've used this package on four missions for three different types of spacecraft with excellent results! On the most recent mission our predictions, from all of our algorithms, matched post apogee burn attitude predictions (generated by the orbit determination software) to within two tenths of a degree.

Compatibility

This module is compatible with MATLAB version 7, Windows XP/NT/2000, UNIX, and MacOS. It requires the Spacecraft Control Toolbox Professional Edition.