Autonomous Vehicle Simulation (AVS) Laboratory, University of Colorado

Basilisk Technical Memorandum

Document ID: Basilisk-CSS Sensor Data

CSS COMM

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Status: Initial Version
Scope/Contents
The CSS Sensor Data module is responsible for correcting course sun sensor output data using a pre-computed residual function.

Rev	Change Description	By	Date
1.0	Initial Version	J. Martin	20190209

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1 Model Description

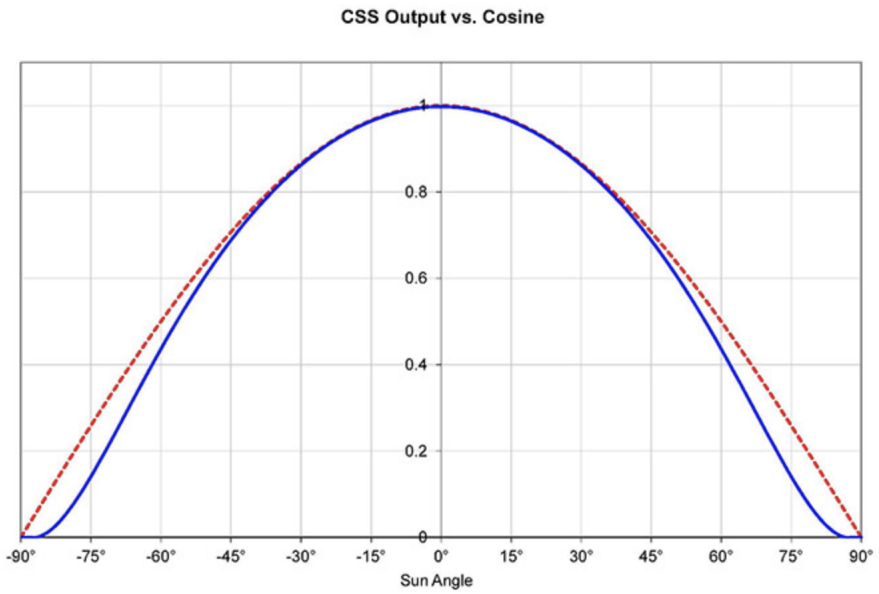

Fig. 1: Example of CSS output (blue) relative to a cosine curve (red).[1]

This module

- Reads in raw CSS measurement from the `CSSArraySensorIntMsg` message type.
- Iterates through each raw CSS measurement, normalizing the measurement and checking that the input is within sensible bounds.

- Corrects the measurement based on calibrated residual function based on Chebyshev polynomials.
- Outputs a `CSSArraySensorIntMsg` with the corrected CSS Measurements.

1.1 Equations

1.1.1 Residual Function

The correction applied to each CSS measurement is based on a function that maps a raw CSS measurement to the expected cosine response for that measurement (i.e. the distance from red curve to the blue curve in Fig.1). This function is modeled using a Chebyshev polynomial series to the N-th power represented by the following form:

$$\delta x = \sum_{i=0}^{N} C_i * T_i(x_{\text{meas}}) \tag{1}$$

where $T_i(x)$ represents the Chebyshev polynomials, and C_i are the pre-determined scaling factors.

This correction to the raw measurement is then applied using:

$$x_{\text{corr}} = x_{\text{meas}} + \delta x \tag{2}$$

1.1.2 Chebyshev Polynomial Computation[2]

The procedure to compute the Chebyshev polynomials, $T_i(x)$, is as follows:

1. Suppose we want to evaluate Chebyshev polynomial of order i at x_0, $(T_i(x_0))$
2. The first two order of Chebyshev polynomials can be evaluated using the following form

$$T_0(x) = 1 \tag{3}$$

$$T_1(x) = x \tag{4}$$

3. The Chebyshev polynomial of order $i > 1$ can be computed using the values of Chebyshev polynomials of order $i - 1$ and $i - 2$ and the following recursive formula:

$$T_{i+1}(x) = 2xT_i(x) - T_{i-1}(x) \tag{5}$$

4. Apply this formula up to the order i to evaluate Chebyshev polynomial of order i at x_0.

2 Module Functions

- **Corrects Raw CSS Output Data**: This module maps the raw CSS measurement to the correct CSS cosine behavior.
- **Outputs Calibrated CSS Data**: This module outputs a `CSSArrayIntMsg` for subsequent guidance modules.

3 Module Assumptions and Limitations

The Chebyshev residual function is calibrated to a single distance from the sun. As the spacecraft moves farther away from this distance, the Chebyshev model loses accuracy. These model discrepancies grow increasingly apparent at high sun angles.

4 Test Description and Success Criteria

The unit test checks for proper functionality of the module for various CSS configurations and input values, both within and outside expected bounds. The three test cases run include:

1. Checking for appropriate correction to raw CSS sensor data while also handling too many sensor inputs. The number of sensor values is larger than the number of sensor devices. The extra data should be returned as a zero value.
2. Ensuring the a zero message is returned if zero sensors are configured.
3. Ensuring that if the number of sensors is set to a value larger than the allowable number of sensors, then this value is set to the maximum number of sensors.

5 Test Parameters

The unit test verify that the modules output cosine values match expectation.

Table 2: Error tolerance for each test.

Output Value Tested	Tolerated Error
`cosValues`	1e-06

6 Test Results

The unit test results are shown in Table 3. All tests should be passing.

Table 3: Test results

Num Sensors	Num Inputs	Pass/Fail
4	5	PASSED
0	5	PASSED
33	5	PASSED

7 User Guide

Input required:

- `CSSConfigData.NumSensors`: sets the number of sensors to iterate over.
- `CSSConfigData.MaxSensorValue`: sets the max CSS raw sensor value.
- `CSSConfigData.ChebyCount`: determines the max order for the Chebyshev series.
- `CSSConfigData.KellyCheby`: the list of pre-determined Chebyshev coefficients.
- `CSSConfigData.SensorListName`: name of the input `CSSArrayIntMsg` which contains the raw cosine values of the CSS array.
- `CSSConfigData.OutputDataName`: name of the output `CSSArrayIntMsg`

REFERENCES

[1] Adcole Corporation. Coarse sun sensor detector (cosine type).

[2] Makoto Nakajima. Note on chebyshev regression. 2006.