Design and Implementation of a Novel Software Interface for an Adjustable Multispectral Payload

Spectral Ocean Color (SPOC) Satellite

Adam King[*1], David L. Cotten[^1,2]

[*]adamking.br549@gmail.com; [^]dcotte1@uga.edu; [1]Small Satellite Research Laboratory; [2]University of Georgia Center for Geospatial Research; University of Georgia

Overview

While using simple telecommands to control a payload is fairly straightforward, data representation and processing can vary widely between missions with the same or similar payloads. The Spectral Ocean Color (SPOC) Satellite mission of the University of Georgia Small Satellite Research Laboratory will use an smart multispectral payload that will gather Visible and Near-IR spectral data over Georgia's coast.

Approach

SPOCeye gathers multispectral data from 433 nm to 866 nm, and can provide a GSD of 130m. Incoming light to the payload will pass through a polarizing filter, a long-pass filter, a linear slit, a collimator, and a spectral grating before being focused onto the CMOS sensor. The result is a 16-bit grayscale spatial-by-spectral image spread across the 752 x 480 pixels of the CMOS, providing approximately 18ms exposure per image.

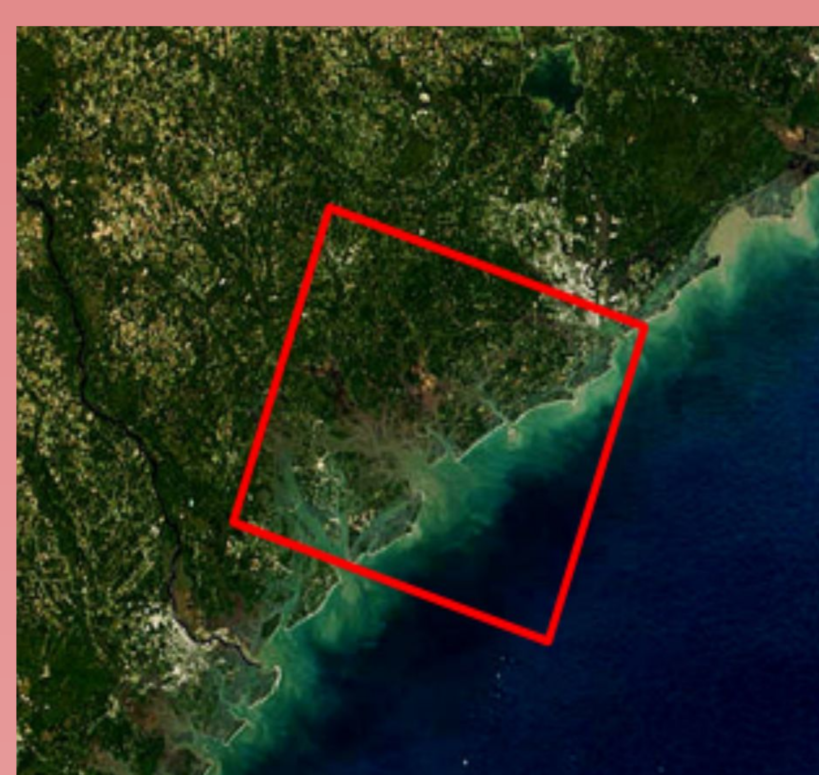

Figure 1. MODIS True-Color Image 20 November 2001. Georgia and South Carolina. Red insert represents approximately 9,500km^2.

The remaining spatial dimension is captured by the orbital motion of SPOCeye, resulting in a 752x480x1000 cube stored in 722MB of data that provides ground coverage of approximately 93.6km by 130 km, or 12,700km^2. Though this can cover one target area (such as in Figure 1), data must be gathered over time, resulting in ever larger datasets. This, combined with the limitation of our S-Band downlink only being able to provide a data rate of 1Mbps (125 kB per second), one can quickly see that transferring nearly 8GB of data is problematic. On top of this, the SNR of this 1 nm spectral resolution data results in data that is borderline unusable.

The solution is to enable versatility of the payload through software, resulting in a "smart" payload with a high level of configurability. While the payload was designed by a third party, the Small Satellite Research Laboratory led the desgin into how the data from the sensor was to be processed. These decisiosn were made based on mission requirements and to increase sensor versility.

Results

Before gathering images, exposure parameters can be uploaded of accessed from on board data storage. These parameters include the exposure time per image that the CMOS captures, the number of images to acquire, and the time delay between the start of each image, or "frame", where the CMOS exposure duration is less than this frame duration and the exposure beings at the start of each frame. While these are standard parameters of any imaging payload, the "smart" technique that SPOCeye employs is that during hardware capture time, parameters set before each image gathering session can be selected to spectrally bin the data during imaging. This results in either 1 nm, 2nm, or 4nm resolution data on the fly, where adjacent bands are summed to produce a 752x480, 752x240, or 752x120 pixel image according to the set 1 nm, 2nm, or 4nm resolution, respectively.

Wavelength (nm)	Bandwidth (nm)	SNR per 20 Pixels
443	20	181
490	20	185
510	20	171
555	20	157
670	20	139
750	20	83
865	20	63

Table 1. Estimated SNR of corresponding SeaWiFS bands.

The benefits of such a configuration include:

- Increased SNR of data depending on the target location, with the SNR for most bands being greater than 100 (see Table 1);
- Lower processing requirements;
- A significant increase in the number of images that can be stored on-board the payload, where 1nm limits the data to 1000 images per pass and 4nm only limits the data to 4000 images per pass

After an initial cube is captured, the next step in this "smart" processing of multispectral is to post process the data *on-board* the payload. Because of the spatial-by-spatial-by-spectral dimensions of the data cube, several parameters can be specified to down-select the data gathered. Specifically, adjustable parameters include spatial cropping, spatial binning, spectral band selection, and spectral averaging (see Figure 2). Spatial cropping occurs as expected, and spatial binning sums the spectral response data in the spatial dimensions.

Parameter	Description
spectral_binning	Spectral binning at acquisition time (1:1, 2:1, 4:1)
num_images	Number of image to acquire
crop_left	Leftmost spatial pixel of crop region (0 to 751)
crop_top	Topmost spatial pixel of crop region (0 to #Image - 1)
crop_width	Width of crop region (0 to 752)
crop_height	Height of crop region (0 to #Images)
spatial_binning	NxN binning of the data in the spatial dimension
band_defs[16]	Array of 16 pairs of band definitions as described below:
start_row	Start row of the first band to extract (0 to 120/240/480)
no_rows	Number of adjacent rows to average together for the first band (1 to (480/240/120 - start_row))

Figure 2. Smart parameter explanations.

The final step of this "smart" process is in the spectral band selection. Though the 752x480x1000 cube may have been greatly reduced in size thanks to the above post-processing steps on-board the payload to something such as a 376x240x500 (a data reduction factor of 8 in itself), the data is still fairly large (approximately 90MB for this example, too large for a single-pass downlink). To further reduce data size, and to provide an even greater level of versatility and configurability, up to 16 separate spectral bands can be selected, with the spectral averaging mentioned previously occurring in the step, resulting in a data cube of 376x16x500 for this example (a reduction factor from the original of over 1200 times). This step not only can use a different spectral averaging size within each band, but can allow selection of spectral bands depending on the target location or even on a whim as the research goals change. Not only this, but if the band definitions such as with a specific starting row but an averaging width of 0 will result in raw finderscope images. The result is data that can be easily downlinked in a single pass, with the important assurance that the data underwent controlled reduction which is configurable during flight.

Conclusion

Data constraints caused by large dataset requirements or caused by downlink transmission constraints can be overcome with configurable processing on-board the spacecraft before downlink. This allows robustness against changing mission requirements. Additionally, the adjustability allows for more efficient vicarious calibration with other sensors since SPOCeye can changing bands to match existing sensors.

Acknowledgements

The Spectral Ocean Color (SPOC) Satellite is funded by the NASA Undergraduate Student Instrument Project program, and the Small Satellite Research Laboratory is supported by the University of Georgia Center for Geospatial Research and the Air Force Research Laboratory University Nanosatellite Program.

Small Satellite Research Laboratory
Franklin College of Arts and Sciences
UNIVERSITY OF GEORGIA