지구관측 큐브위성용 다중분광사진기 다중필터 근사 분해

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Multi-bandpass filter coarse decomposition for CubeSat multi-spectral imager

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Introduction

Recent missions such as Planet Labs Dove have shown relatively high resolution imaging capabilities using CubeSats, with resolutions up to 5 m. Such resolutions are sufficient in capturing large characteristic features of agriculture, deforestation, or disaster. However, multi-band imaging is required in acquiring normalized difference indices, which help identify such characteristic features. Due to the limitations of mass and volume in CubeSat, a multi-bandpass filter must be applied and the image data must be decomposed. This paper discusses a simple decomposition method for an onboard imager.

Multi-band Earth Observation

In the electromagnetic spectrum, we human can see only blue, green, and red bands. To extend our vision over entire spectrum, we need multi-spectral and hyperspectral observation. In electromagnetic spectrum, the required bands are extracted using a filter or prism or diffraction grating. We can understand our earth better, using the reflected, emitted or backscatter energy in multi bands.

Normalized Difference Water Index

The NDWI delineates the water bodies in the surface of the Earth, using the Near-Infrared (NIR) and green. The NIR is absorbed by water bodies, whereas green wavelength is partially reflected back to the atmosphere. Using these properties NDWI band math able to identify the water bodies on the surface of the Earth. The resultant index ranges from −1 to 1. The positive value indicates the water features and negative value indicates the non-water features. Using, NDWI we can monitor and measure surface area of lakes, rivers, flood and drought region. An example of NDWI is shown in Fig. 1.

$$\mathrm{NDWI} = \frac{G-NIR}{G+NIR} \quad (1)$$

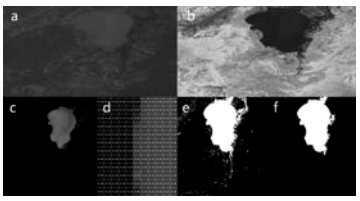

Fig. 1. Example of NDWI using decomposed green and near infrared image data

Normalized Difference Vegetation Index

The NDVI delineates healthy and stressed vegetation or forest using NIR and red. The healthy vegetation has higher NIR reflectance and lower red light reflectance. Whereas, stressed vegetation has relatively higher red light reflectance and lower NIR reflectance. The result of index ranger from −1 to 1. The vegetative region has positive value and bare

soil or water has negative value. Using, NDVI we can monitor the health of the crops, forest and measure the surface area of the vegetation, forest.

$$\mathrm{NDVI} = \frac{NIR-R}{NIR+R} \quad (2)$$

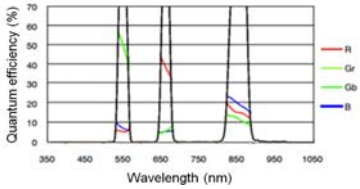

Fig. 2. MT9P031 QE after triple-bandpass filter

Mean value decomposition

Examining Fig. 2 and taking the mean value over individual bands, the total signal of red, green, and blue pixels can be expressed as equations (3)-(5).

$$R_t = 0.05\bar{R}_{550} + 0.38\bar{R}_{660} + 0.16\bar{R}_{850} \quad (3)$$

$$G_t = 0.48\bar{G}_{550} + 0.07\bar{G}_{660} + 0.12\bar{G}_{850} \quad (4)$$

$$B_t = 0.07\bar{B}_{550} + 0.05\bar{B}_{660} + 0.19\bar{B}_{850} \quad (5)$$

Equations (3)-(5) are solved after coarse assumption for unknown signal reduction. The blue and red pixels of 550 nm, and the green and blue pixels of 660 nm are assumed to be the same, and the NIR bands in all pixels are also assumed to be same. The bands are then decomposed to 550 nm, 660 nm, and 850 nm signals, as in equations (6)-(8).

$$S_{550} = \bar{R}_{550} + \bar{G}_{550} + \bar{B}_{550} \quad (6)$$

$$S_{660} = \bar{R}_{660} + \bar{G}_{660} + \bar{B}_{660} \quad (7)$$

$$S_{850} = \bar{R}_{850} + \bar{G}_{850} + \bar{B}_{850} \quad (8)$$

Table 1. Filter performance validation test

	Wavelength (nm)	Test source (nm)
Red	653-668	652-665
NIR	835-865	840-860

Multi-Bandpass Imager Calibration

In order to validate the bandpass filter performance, light sources using LTC100-B shown in Table 1 is used. The test is limited only to red (L660P120) and near infrared (L850P030) due to the unavailability of green light source.

A field test was carried out for NDVI and an example of a real image of vegetation is shown in Fig. 3.

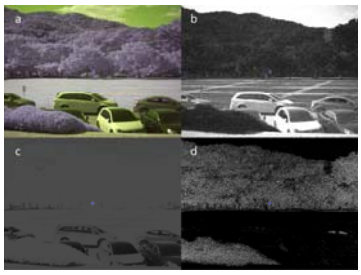

Fig. 3. Field test example of NDVI, with a) filtered image, b) red, c) NIR, and d) NDVI.

Conclusion and future work

We propose a simple mean value approximated decomposition method of multi-bandpass filter for CubeSat multi-spectral imager. Future work is to identify error due to approximations, and to use other fitting methods to improve spectral characteristics.

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