The Development of Consumable Hyperspectral Spectral Imager

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ABSTRACT:. The hyperspectral images with widely application in the research field of remote sensing, which could understand the health status of crops and estimate the nitrogen content also predict the agricultural production yield. The hyperspectral imager was expensive in the market, but some of researches were critical in the high risk of status to the instruments, such as in the UAV, underwater monitor and farming application. In this article we intend to develop a Consumable and low cost hyperspectral imager generally used for UAV and farming application. The lightweight pushbroom hyperspectral imager was below 110g, it spectral range of 380~1000nm, suitable for generally hyperspectral and fluorescence application. Here we use plastic grating film and plastics lenses for the instrument to achieve a low lost, without high order sorting filter and lightweight, of course, the structure was built by 3D printer with plastic ABS material. Here UAV fly result will be shown in this the article.

Introduction

Hyperspectal instrument had been developed and widely applied on the fields of remote sensing, astrophysics, disaster monitor and terrestrial military since 80's. According to the literature research, the hyperspectral images were effective analyzers for agricultural applications (Jackson et al., 1988, Staznz et al., 1988). But the instrument is expensive in the market, some agricultural machines hope to use hyperspectral instruments as auxiliary tools to analyze and control on the farming, such as monitoring the health of the plants and regulating the spraying machine to reduce the amount of pesticides and fertilizers for the better quality of farming product . But they gave up the project finilly, because of the expensive of hyperspectral machine. The reason is because agricultural machines are high risk on the expensive loss, and the operating environment is extremely at the high risk such as the high temperature, the high humidity and frequent shocks, in order to overcome these problems, it is necessary to reduce the cost of the instrument, reduce the weight of the instrument system, and avoid the additional problems caused by gravity and shock. As reducing the weight, its application can be widely applied to drones and unmanned loads. Of course, the lightweight instrument will lengthen the time for the farming.

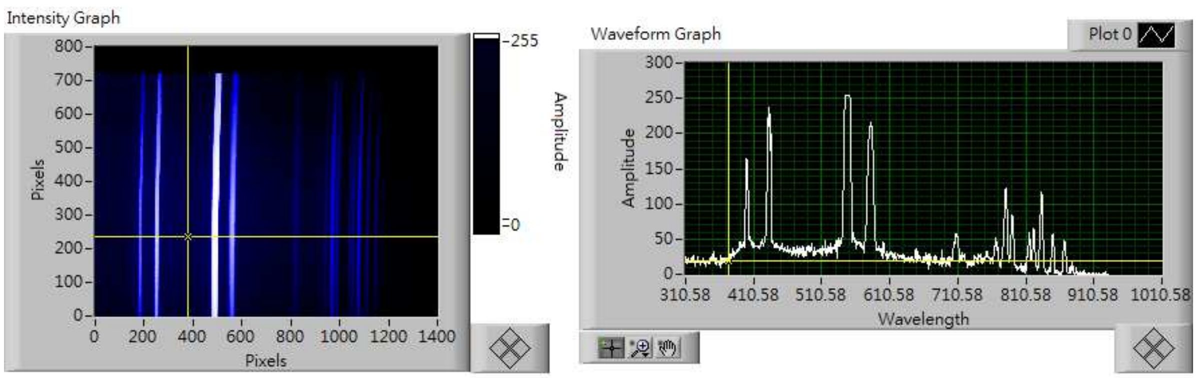
In this article we proposed to develop a consumable and low cost hyperspectral imager generally used for UAV and the some farming application. The lightweight push broom hyperspectral imager was below 110g, it spectral range of 380~1000nm, suitable for generally hyperspectral and fluorescence application. Here we used plastic grating film and small lenses with M12 threads as the parts of hyperspectral imager, to achieve a low lost, without high order sorting filter and lightweight, of course, the structure was built by 3D printer with plastic ABS material. Here the article will show UAV fly result.

SYSTEM DESIGN

The hyperspectral imager was composed by fore lenses, spectrometer and CCD sensors. UAV flying was high risk than other aircraft, especial when launched and land. In order to reduce the cost of whole system, we tried to use the model of transmission grating with both lenses to design spectral imager; the plastic lenses or small lenses (M12 threads), plastic grating, and USB camera were within it. The whole structure was built by 3D printer with the plastic material of ABS (Acrylonitrile Butadiene Styrene), the weight of hyerspectral imager at 110g, was shown as in fig 1, as the weight of image spectrometer at 50g and the weight of fore lens at 60g The spectral imager. The fore lens was chosen the Tamron lenses with 1/3 inch focus plane, the same focal plane within 400~1000nm, as the same focus plane within day and night as commercial boost. Here the fore lens and image spectrometer with USB camera, their weight was almost the same, so the weight of whole system would be reduced to 60 g when we choose the M12 lens as fore lens. The disadvantage of the M12 lens was without the iris, it could not regulate the light throughput to obtain more high quality of resolution and avoid the over exposure of CCD.

Figure 1. 110g lightweight hyperspectral imager with lens, the imager was 50g and the fore lens was 60g.

The spectral calibration of spectrometer was done by using a Oriel HgAr spectral lamp. The spectral range was between 380 nm and 1000nm, with the resolution of 4.6nm at the wavelength of 650nm. The calibration result was shown in fig.2, and its interpolation spectral in each band was fitted by secondary polynomial least-square fitting. The whole control system was programmed in LabVIEW language. The fore lenses were changeable based on the field of view needed. The data could be to the format as ENVI compatible,



a. b

Figure 2. (a) spectral image of HgAr calibration lamp (b) the profile of read line, wavelength register in each band.

and each band was also registered.

RESULT AND DISCUSSION

From the result as shown in fig. 2, the sensitivity of CCD below 370nm and above 900nm was really low, so some spectral line could be observed. The small abbreviation of smile and keystone of spectral image was also found in fig.2a, this phenomena could be accept in this kind of consumable, low cost image spectrometer. Here we can choose the more high quality of CCD, with function of binning pixels to increase the sensitivity and grabbing speed. The total net cost will be below 1000 US$.

The hyperspectral imager took the fly test by the UAV, we choose the multi rotor UAV to take advantage of multi rotor wings will stabilize the flying status as comparing to the fixed wing UAV, according to our experience of fly test result grabbed by fixed wing UAV (Lee et al 2013), The fixed wing UAV was easily shaking as the flying interference by atomspheric turbulence, the stabilizer was harder to compensate the big shaking angle, the fixed wing flying result gave the worse result and it was hard to find the solution for hyperspectral imager applied to fixed wing UAV in the comcerial market.

The multi rotor UAV flying test of hyperspectral imager with the stabilizer gave the results as shown in fig. 3, the true color image was extracted and composed with bands 475nm (blue), 530nm(green), and 630nm(red). The results give more smooth way with a little of vibration shaking than fixed wing. Of course, the previous result from 0.5Kg hyperspectral imager and now our new lightweight of hyperspectral imager at 109g . The weight difference was small, but lighter weight was easily to control by stabilizer and give the more time for grabbing image as on the fly.
From the result in fig 3, it would be seen clearly the road, car in road, the plant and the building, it was manual controlled, so the flying way was not so straight , but the result could be applied to analyze and monitor the health status of plant as our farming target.

Figure 3. Extract true color hyperspectral image grabbed and push broom by multi rotor UAV. True color image composed with bands 475nm (blue), 530nm(green), and 630nm(red).

Conclusion

The 110g lightweight hyperspectral imager was developped, and fly test as integrated on the UAV give the better results. The hypespectral imager took the pushbroom scanning as using the multi rotor of UAV flying with the stabilizer mount, so the image present was better than fixed wing UAV as the interference as atomspheric turbulence. Here the characteristic of hyperspectral imager was defined as the low cost below 1000 US$, consumable product with plastic grating and lenses and the light weight below 110g. We hope this way give the solution for many farming machine to choice the hyspectral imager as monitor tools to analyze and control on the farming, such as the health observing of the plants and regulating the spraying machine to reduce the amount of pesticides and fertilizers for the healthful quality of farming product .

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