DEVELOPMENT OF HYPERSPECTRAL IMAGING SENSOR, WHICH MOUNTED ON UAV FOR ENVIRONMENTAL STUDY AT COASTAL ZONE

Genya SAITO[1,3], Haruyuki SEKI[1,3], Kuniaki UTO[1,3], Yukio KOSUGI[1,3] and Teruhisa KOMATSU[2,3]
[1]Innovative Research Initiatives, Tokyo Institute of Technology
J3-153, 4259 Nagatsuta-cho, Midori-ku, Yokohama, 226-8502, Japan
E-mail: saito.g.aa@m.titech.ac.jp
[2]Atmosphere and Ocean Research Institute,The University of Tokyo
5-1-5, Kashiwanoha, Kashiwa, 277-8564, Japan
[3]Japan Science and Technology Agency, CREST,
4-1-8 Honcho, Kawaguchi, Saitama, 332-0012, Japan

KEY WORDS: Hyperspectral imaging sensor, UAV, Low altitude observation, Coastal zone, Environmental study

ABSTRACT:
Seagrass and seaweed beds are very important for fish’s growth, but the beds are sensitive to environmental changes and human activities. Coastal zone monitoring is necessary for the conservation of seagrass and seaweed beds. Satellite data are used for the coastal zone monitoring. There are large atmospheric effects at the satellite data, and low altitude observations using UAV have the benefits of small atmospheric effects. Hyperspectral image data are powerful tools for determination of seagrass and seaweed species, and we want to develop a hyperspectral imaging sensor on UAV for the environmental study of coastal zone.

In our previous studies, a hyperspectral array sensor system for an unmanned radio-controlled helicopter was developed. The specifications of the hyperspectral sensor were 400-1000 nm spectral range, 121 bands, 5 nm spectral resolution, and 11 kg weight. This system is too heavy for ordinary UAV and very expensive system. The hyperspectral imaging sensor on UAV has to be compact, lightweight and low cost.

Last year, at the 34th ACRS, we presented the measurement system, and it could observe only nadir and the observed data were on flight line. Now we are making the prototype of hyperspectral image sensor, which can get area data using swing mirror. The spectral data of target ground or sea-surface are gathered at one side of glass fibers bundle. At the other side of glass fibers bundle, the spectral data are sequentially given to seven glass fibres by the swing mirror. The swing mirror is controled by a stepping motor and the swing speed of the mirror are variable. Eight Mini-Spectrometers manufactured by Hamamatsu Photonics are prepared. Each Mini-Spectrometer is connected one glass fibre. One Mini-Spectrometer is used for sky light monitoring and sevmeters are used for spectral data of target earth surface. The total weight of the the prototype of hyperspectral image sensor is about 5 kg. The system loaded to unmanned airplane in this summer and we got early phase results.

1. INTRODUCTION

Seagrass and seaweed beds play very important ecological roles such as spawning, nursery and feeding grounds for many marine organisms[1)]. However, they are sensitive to environmental changes and human impacts[2)]. Coastal zone monitoring is necessary for the conservation of seagrass and seaweed beds[3)]. Satellite data are used for the coastal zone monitoring[4)]. There are large atmospheric effects at the satellite data, and low altitude observations using UAV have the benefits of small atmospheric effects. Hyperspectral image data are powerful tools for the determination of seagrass and seaweed species, and we want to develop a hyperspectral imaging sensor on UAV for the environmental study of coastal zone.

In our previous studies, a hyperspectral array sensor system for an unmanned radio-controlled helicopter was developed. The specifications of the hyperspectral sensor were 400-1000 nm spectral range, 121 bands, 5 nm spectral resolution, and 11 kg weight. The system was controlled by note PC and total weight was about 20 kg. The unmanned radio-controlled helicopter was RMAX 18 (Yamaha Co.,), the mass of vehicle was 64 kg, and the payload was 30 kg. The unmanned radio-controlled helicopter hanged the hyperspectral array sensor system on bottom of the helicopter body. We used the system using the unmanned helicopter for agricultural studies about growth estimation and nutritional diagnosis.

Targets of coastal zone are very large, and it is necessary for long flight range. To use the hyperspectral array sensor system at coastal zone is difficult for the usage of the helicopter in long time, and also have risk of dipped in sea water. We determined to use automated and unmanned airplane, and to develop low-cost, waterproof, lightweight hyperspectral imaging system.

2. DEVELOPING SENSOR SYSTEM

A hyperspectral measurement system is made up about two years ago, and it could observe only nadir and the observed data were on flight line. Now we are making the prototype of hyperspectral image sensor, which can get area data using a swing mirror[5),6),7)]. The spectral data of target earth surface are gathered at one side of glass fibers bundle. At the other side of the glass fibers bundle, the spectral data are conducted to be given to seven glass fibres by the swing mirror. The swing mirror is controled by stepping motor and the swing speed of the mirror is variable. Eight Mini-Spectrometers manufactured by Hamamatsu Photonics are prepared. Each Mini-Spectrometer is connected to one glass fibre. One Mini-Spectrometer is used for sky light information and seven Mini-Spectrometers use for spectral data of target earth surface. The total weight of the the prototype of hyperspectral image sensor including waterproof case is about 5 kg. Fig. 1 shows the outline of the developed hyperspectral imaging system. The system using a swing mirror is composed of the following elements;

1) Hyperspectral sensors: A reflection light from the ground is captured by eight Mini-Spectrometers, C12666MA, manufactured by Hamamatsu Photonics. One is used for the sky light information and seven Mini-spectrometers use for spectral data of target earth surface. The spectral response range, the spectral resolution and the weight are 340-780 nm, 15 nm and 5 g, respectively (Fig. 3).

2) Lenses: Two optical lenses for the visible and near infrared are installed in the system. One is the telescopic front of the system and another is faced to the swing mirror (Fig. 2-4).

3) Fixed mirror: A fixed mirror turns the light pass to 90 degrees and passes it to glass fibers (Fig.2).

4) Swing mirror: A Swing mirror is installed to scan the ground along a direction perpendicular to the flight direction. The mirror is controled by a stepping motor and the swing speed of the mirror is variable (Fig. 2).

5) Glass fibers: To make small size system of the hyperspectral image sensor, we use glass fibers to guide light path compactly. While low altitude observation is capable even under cloudy condition, the real-time observation of skylight radiation is required because of the temporally, spatially unstable radiation condition. One optical fiber transmit skylight radiation collected by a diffuser attached on the upper side of the unmanned airplane to the spectrometer (Fig. 2).

6) Diffuser of skylight radiation: The skylight radiation transmitted from the optical fibers is scattered in diffuser for reducing the intensity. The spectral profile of the skylight radiation is measured when the diffused light is transmitted to the spectrometer (Fig.4).

7) GPS sensor: The position information is acquired by a GPS sensor. The acquisition period is 1 sec. The position and time information is sent to the data logger (Fig. 4).

8) Data logger: The data from the eight spectrometers and the GPS sensor are integrated and, then, stored in a 32 GB flash memory (Fig. 3).

9) LCD touch screen: A LCD touch screen displays, i) profiles of the observed spectral data and ii) a control panel of the sensor parameters, e.g., the exposure time and data acquisition period (Fig. 3).

10) Battery: A lithium ferrite battery, 12 V and 14 A*hour, is the power source for the hyperspectral sensor system. The current consumption is less than 1A; thus, 14 hours of continuous observation is possible (Fig. 3).

11) Start-up switch: Control buttons of start/stop the data acquisition is out of waterproof case, and we can switch on or off after boarding the platform. (Fig. 4)

12) Movie Camera: A drive recorder for automobile is used, and it named Yupiteru DRY-FH52WG made by Yupiteru Corporation in Japan. The camera gets footprint images automatically (Fig. 2-5).

3. ONBOARD TESTS

On 20-21 August 2014, we performed onboard test at Fuji River gliding field. We used an unmanned airplane developed by Japan Aerospace Exploration Agency (JAXA) and Vision Tech Inc.(VTI). To the airplane, size is 2.6 m long and 4.2 m wide, mass is about 50 kg, the payload was 10 kg, and flight speed is about 100 km/hour. The hyperspectral imaging system that is waterproof packaged, was loaded at the front of the unmanned airplane. Frist, a hole for the observation was opened at the floor of the airplane. Next, the sensor system set on the floor, and then performed flight tests (Fig.5-7).

The preliminary results of onboard tests, the system of hyper spectral imaging was well operated. Now we move to develop the hyperspectral image system for actual use.

4. ACKNOWLEDGMENT

This study is performed in the project of “Development of three dimensional mapping system of marine macrophyte beds using hyper- and multi-spectral remote sensing from air and seasurface” in the research area of “Establishment of core technology for the preservation and regeneration of marine biodiversity and ecosystems”. We thank to all the members of the project. This research was supported by JST CREST.

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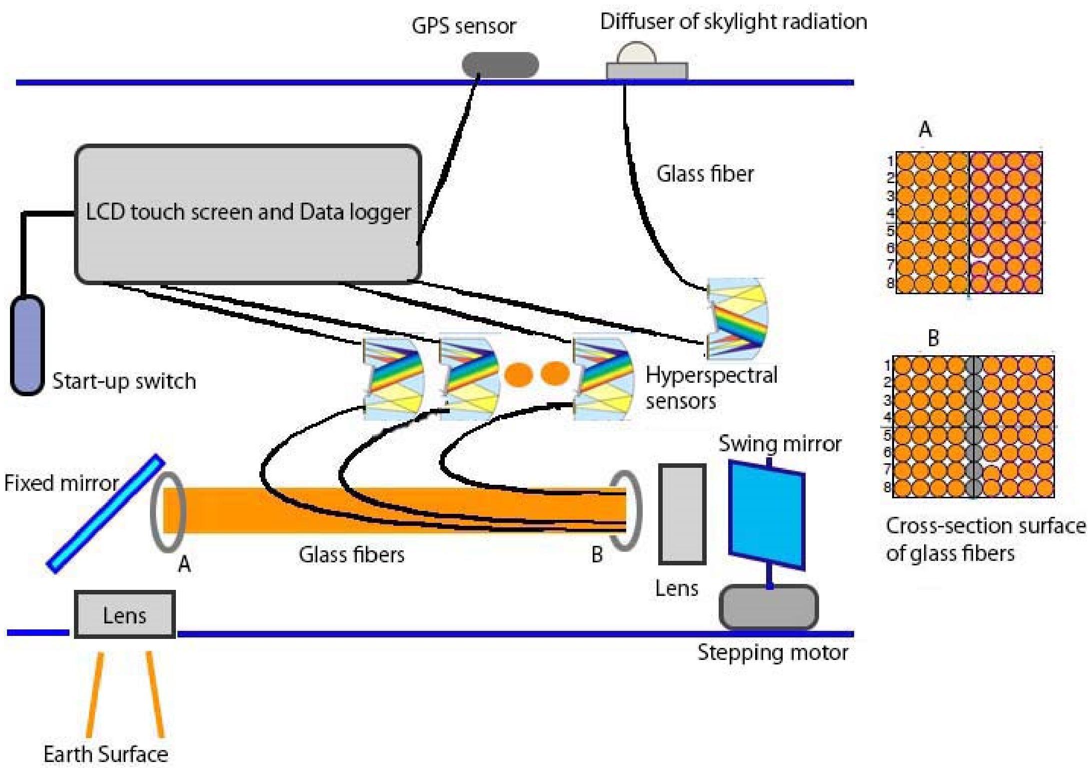

Fig. 1 Outline of the developed hyperspectral imaging system using glass fibers and a swing mirror

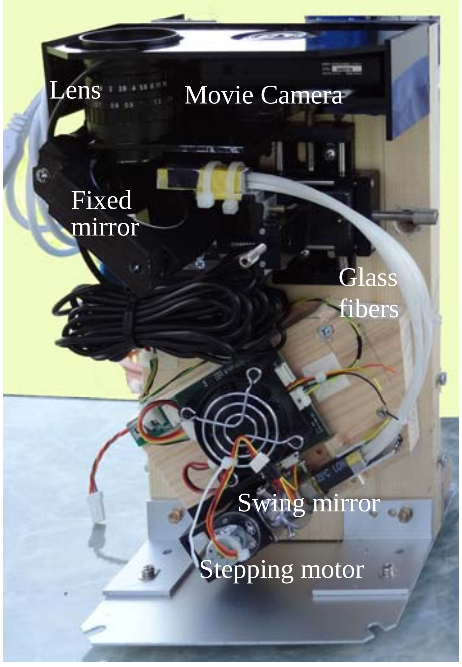

Fig. 2 Front side photo of the hyperspectral image sensor (Upper is observing side)

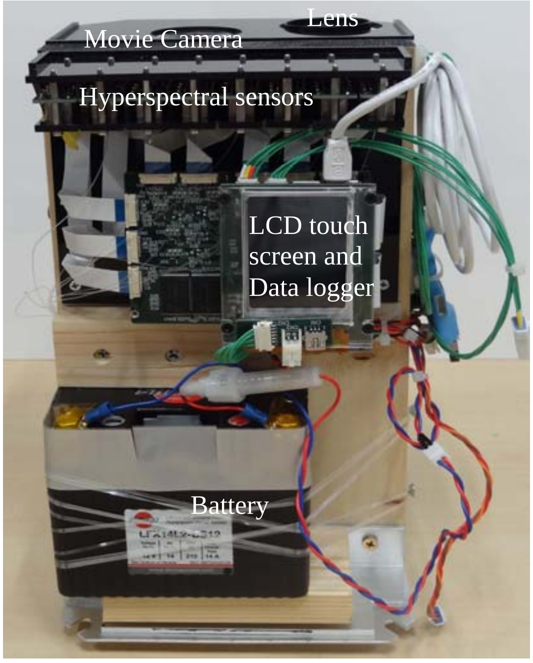

Fig. 3 Back side photo of the hyperspectral image sensor (Upper is observing side)

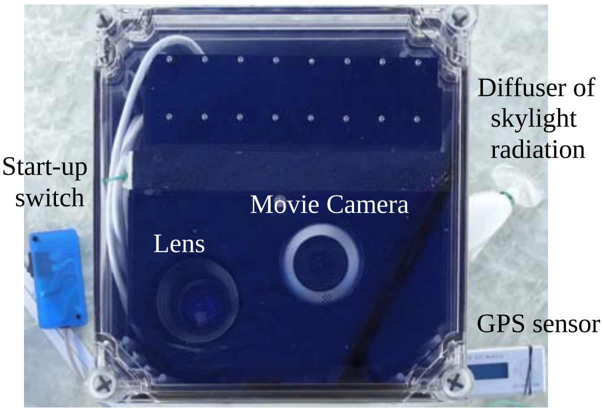

Fig. 4 Upper side photo of the hyperspectral image sensor in the waterproof case


Fig. 5 Front side photo of the unmanned airplane and observing hole

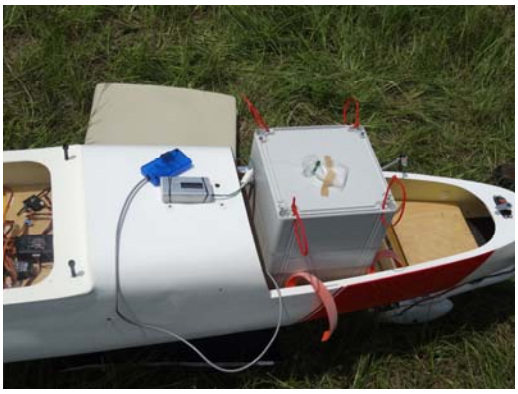
Fig. 6 Front side photo of the unmanned airplane and hyperspectral image sensor in the waterproof case.


Fig. 7 Take off photo of the unmanned airplane