DEVELOPMENT OF HYPERSPECTRAL IMAGING SENSOR AND UAV FOR COASTAL ZONE STUDIES

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ABSTRACT:
Seagrass and seaweed beds play very important ecological roles such as spawning, nursery and feeding grounds for many marine organisms. However, they are sensitive to environmental changes and human impacts. Coastal zone monitoring is necessary for conservation of seagrass and seaweed beds. Although satellite data are used for coastal zone monitoring, atmospheric effects on the satellite data degrades classification. Low altitude observations using UAV can avoid such large atmospheric effects. Hyperspectral image data are powerful tools for detection of seagrass and seaweed species. Thus, we develop a hyperspectral imaging sensor and a UAV as a platform of the hyperspectral sensor for environmental study of coastal zone, especially, mapping seagrass and seaweed species**.**
Hyperspectral imaging sensor is designed to be light weight and low cost for payload and wide use, respectively. The sensor scans an area and acquires data using optical fibers and swing mirror. Spectral data of a target ground or sea-surface are gathered at one side of optical fibers bundle. At the other side of optical fibers bundle, the spectral data are sequentially sent to optical fibers, which connected micro-spectrometer, by the swing mirror. The swing mirror is controlled by a stepping motor and the swing speed of the mirror is variable. Maximum eight micro-spectrometers manufactured by Hamamatsu Photonics are prepared. Each micro-spectrometer is connected optical fiber. One micro-spectrometer is used for sky light monitoring, and maximum seven micro-spectrometers are used for spectral data of target earth surface. The total weight of the proto-type of hyperspectral image sensor is less than 3kg.
Recently, multicopter type of UAV is being developed in a rapid pace. Then, we developed a multicopter as a platform of hyperspectral imaging sensor in collaboration with Prodrone Co., Ltd., Japan. The multicopter has waterproof ability and can put the sensor into sea/water. The multicopter also has the ability of autonomous flight. This system is applied for mapping seagrass and seaweed species around Sado Island in the Sea of Japan and Izu Oshima Island facing the Pacific Ocean in summer 2016 to obtain their hyperspectral data for coastal zone monitoring.

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 determination of not only land plants but also marine macrophytes such as seagrass and seaweed species on the shallow bottom. Thus, we developing a hyperspectral imaging sensor on UAV for the environmental study of coastal zone. At the 36th ACRS in 2015, we presented the outline of hyperspectral imaging sensor[5)].
There are two type of observing requests: one is long flight range to target broad area and the other is easy operation and low cost to target near and narrow area. The first and the second requests led us to use an automated and unmanned airplane to fly in the gasoline engine and a multicopter (Drone) driven with electric motor and battery, respectively. In our project, an automated and unmanned airplane is developed by the members of the Japan Aerospace Exploration Agency (JAXA) and a multicopter by

2. DEVELOPING SENSOR SYSTEM

A hyperspectral measurement system is made up about five years ago, and it could observe only nadir and the observed data were on flight line. New hyperspectral image sensor under development can get area data using a swing mirror[5),6),7),8),9),10)]. The spectral data of target earth surface are gathered by lens at one side of optical fibers bundle. At the other side of the optical fibers bundle, the spectral data are conducted to be given to optical fibers, which connected to micro-spectrometer, by the swing mirror. The swing mirror is controled by stepping motor and the swing speed of the mirror is variable. Hamamatsu Photnics manufactured micro-spectrometers with high performance (Mini-Spectrometer C12880MA) upon our special request. Maximum eight micro-spectrometers are prepared. Each micro-spectrometer is connected to one optical fiber. One is used for sky light information and the others are used for spectral data of target earth surface. The total weight of the hyperspectral image sensor including waterproof case is less than 3.0kg. Figure 1 shows the outline of the developed hyperspectral imaging system. The system using a swing mirror is composed of the following elements;

1) Micro-spectrometers: A reflection light from the ground is captured by four (in this case) micro-spectrometers. One is used for the sky light information and three micro-spectrometers use for spectral data of target earth surface. The spectral response range, the spectral resolution and the weight are 340-850nm, 10nm and 5g, 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 (Figs. 2 and 3).

3) 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 (Figs. 2 and 4).

4) Optical fibers: To make small size system of the hyperspectral image sensor, we use a bundle of optical fibers to guide light path compactly. The bundle is 16 fibers times 16 fibers at front end, and 16 fibers times 17 fibers at swing mirror end. At swing mirror end of optical fibers, center (9th) column of 17 columns connect with micro-spectrometer. 6 fibers connected 3 micro-spectrometers and 10 fibers are extra at the machine. (Fig. 2).

5) 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.7). 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 UAV to the spectrometer.

6) GPS sensor: Position information is acquired by a GPS sensor (Fig. 7). The acquisition period is 0.1 sec. The position and time information is sent to the data logger.

7) Embedded CPU system and data logger: Embedded CPU system for managing data logger and swing mirror motor is located at data logger board. The data from the four spectrometers and the GPS sensor are integrated and, then, stored in a 32 GB flash memory (Fig. 3). The Embedded CPU system and data logger board is connected with micro-spectrometers board.

8) 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 without changing battery (Fig. 3).

9) Wired remote controller: A start/stop switch for data acquisition is out of waterproof case, and we can switch on or off after boarding the platform (Fig. 7).

10) Tablet for system control and data display: A tablet displays profiles of the observed spectral data and input sensor parameters, e.g., the exposure time and data acquisition period optionally.

11) Bluetooth Transmitter and receiver: Connecting Embedded CPU system in waterproof case and tablet for system control by Bluetooth wireless technology,

12) Movie camera: A drive recorder for automobile (Model KNA-DR300, Kenwood Corporation, Japan) is used for obtaining footprint images automatically (Figs, 2 and 5).

13) Waterproof case: The sensor system puts into the waterproof case. The case is wrapped in aluminum foil at side area for preventing the disturbance radio waves (Fig, 6)

Figure 8 indicates that the hyperspectral measurement system was setup in waterproof case.

3. DEVELOPING MULTICOPTER FOR SENSOR PLATFORM

Recently, a multicopter type of UAV is being developed in a rapid pace. Thus, we decided to develop a multicopter as a platform of the hyperspectral imaging sensor that enable easy operation at low cost. We are developing the multicopter in collaboration with Prodrone Co., Ltd., Japan. The multicopter also has the ability of autonomous flight. This system is applied for mapping seagrass and seaweed species around Sado Island and Izu Oshima in summer of 2016 to obtain the hyperspectral data for coastal zone monitoring. The specifications of the multicopter are listed in Table 1, and the images of the multi-coper are shown in Figs. 9 -11.

Innovation of this multicoper is that it can land on and take off from not only the land but also the sea surface, thanks to waterproof housing. This innovation permits us to observe underwater bottom from the sea surface without sun glint (Fig. 11). Next strong point is an automated navigation system that enables to acquire hyperspectral data of 100% cover on target area with designed overlap between observation lines, while manual operations are used at the take-off and landing times. The automated navigations are used by the waypoints system. The hyperspectral measurement system in the waterproof case attached to the multicopter could be beneath the sea surface without leaking (Fig. 11).

4. HYPER SPECTRAL OBSERVING TEST USING MULTICOPTER

Hyper spectral sensor attached multicopter was operated at Izu Oshima Island on 25 and 26 February, 2016. At the time, our multicopter was under the developing, and a private company's multicopter was used for the flight. The flight courses are shown in Fig.12. Natural color composite image was produced using the hyperspectral data of the observing (Fig. 13).
Our developed multicopter and hyperspectral system was applied to costal observations off Shirase in Sado Island in the Sea of Japanese from July 25 to August 5 in 2016, and in Izu Oshima Island facing the Pacific Ocean from September 5 to 12 in 2016. The flights of the observing were very well, and automated navigation system performed perfectly.

5. ACKNOWLEDGMENT

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Table 1 Multicopter (Drone) Specifications

Maker: PRODRONE (Japanese company)	Rotor Type: Hexacopter
Specialty 1: Water-Resistant	Specialty 2: Automated navigation system
Motor Distance: 900mm	Propeller Length: 432mm
Weight: 5.5kg	Height Size: 750mm
Maximum speed: 76km/hour	Flight Time: 10-30min
Flight Possible Wind Speed: < 10m/sec	Battery: 22.2V 12000mAh x 2
Flight Possible Elevation: < 5000m	

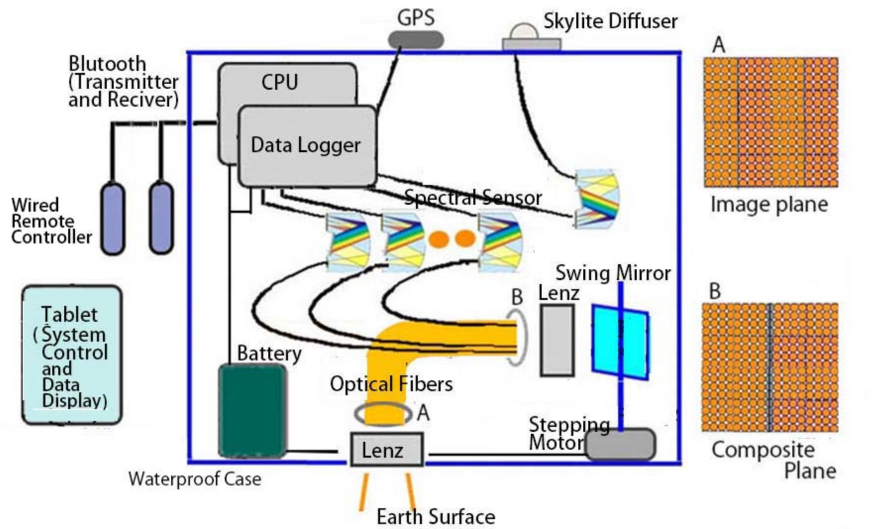

Fig. 1 Outline of the developed hyperspectral imaging system using glass fibers and a swing mirror

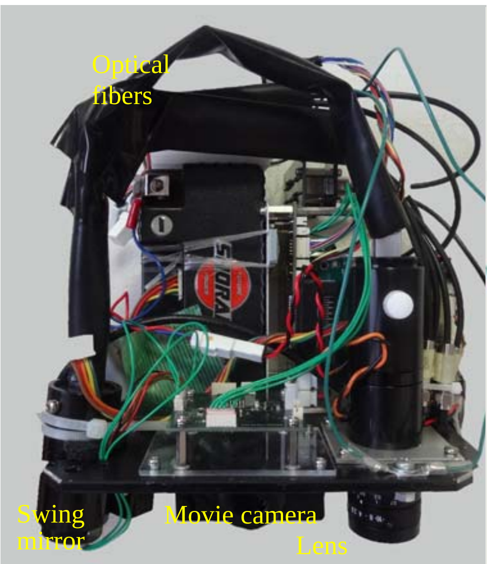

Fig. 2 Front side photo of the hyperspectral image sensor

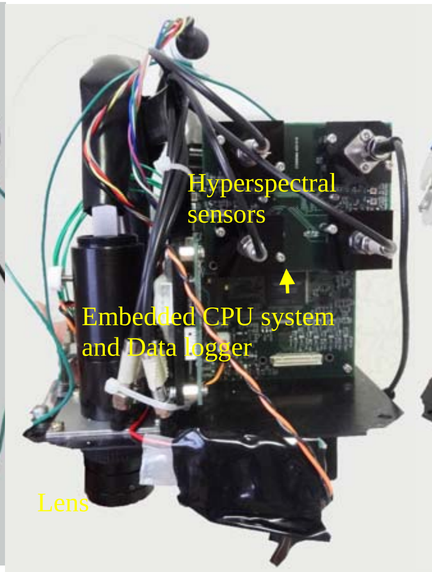

Fig. 3 Left side photo of the hyperspectral image sensor

Fig. 4 Right side photo of the hyperspectral image sensor

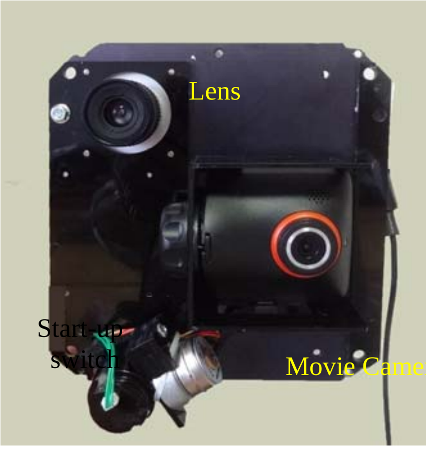

Fig. 5 Bottom side photo of
the hyperspectral image sensor

Fig. 6 Waterproof case

Fig. 7 GPS, Skylight diffuser and Switch

Fig. 8 Setting the hyperspectral imaging sensor
in the water proof case

Fig. 9 Hyperspectral sensor with Muticopter

Fig. 10 Observing at Oshima Coastal area

Fig. 11 Observing in sea water

Fig. 12 Trace of flight course at Izu Oshima Island on 25 and 26 February, 2016

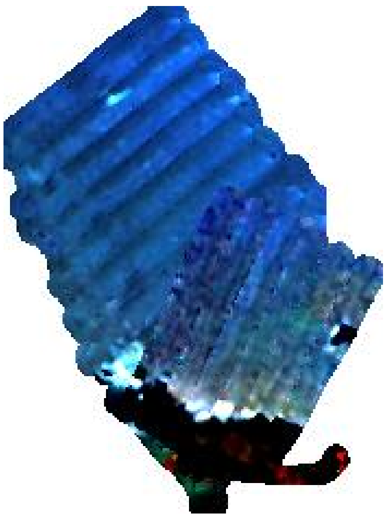

Fig. 13 Natural color composite of the hyper spectral data.