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Design and Implementation of Control Program for EO/IR Camera mounted on Multi-Purpose Unmanned Helicopter

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Abstract

This paper proposes a design and development plan for a control program for the MX-10 EO/IR camera. This camera is a piece of mission equipment mounted on the multi-purpose unmanned helicopter (MPUH) system. Operators must be able to control the necessary functions of the camera to perform their assigned tasks. To achieve this, the function to control the camera was analyzed, and a control program was developed. In addition, the control program was linked to a joystick for convenient operation of the camera by the operator.

Key Words : MPUH, GCS, EOIR Camera

1. Introduction

Multi-purpose unmanned helicopter (MPUH) is a helicopter capable of carrying a maximum take-off weight of 200 kg. It can replace conventional unmanned helicopters such as those used for spraying agricultural pesticide or for captive flight tests (CFT) because of its improved performance and operability. Here, performance and operability include the flight time, maximum speed, and cruising range. MPUHs can be used for various military and civilian purposes.

In the military domain, MPUHs can be used to carry out missions such as transportation of supplies, communication, and surveillance and reconnaissance. In the civilian domain, MPUHs can be used for surveying disaster areas, maritime surveillance, and wildfire monitoring.

In particular, in the military domain, the demand for target detection, surveillance, and reconnaissance systems that can identify enemy forces is increasing. As a reflection of this trend, the development of aircraft that can carry out surveillance and reconnaissance missions (such as unmanned aerial vehicles, multicopters, and unmanned helicopters) is actively underway [1-3].

An aviation facility that includes a runway is required to operate unmanned aerial vehicles. However, owing to the characteristics of the military environment (including confined areas such as mountainous terrain), unmanned aerial vehicles are constrained from carrying out missions. Moreover, multicopters are constrained from carrying out missions owing to limitations on battery capability and communication distance. The need to develop unmanned helicopters to overcome these limitations has emerged [4-7].

Unlike unmanned aerial vehicles, unmanned helicopters can take off and land vertically. Hence, these are suitable for surveillance and reconnaissance missions in confined areas such as mountainous regions, which is a capability required by the military.

An MPUH's capability to carry out target detection, surveillance, and reconnaissance missions is one of the requirements for military application. To satisfy this requirement, an MPUH is equipped with an L3 WESCAM's

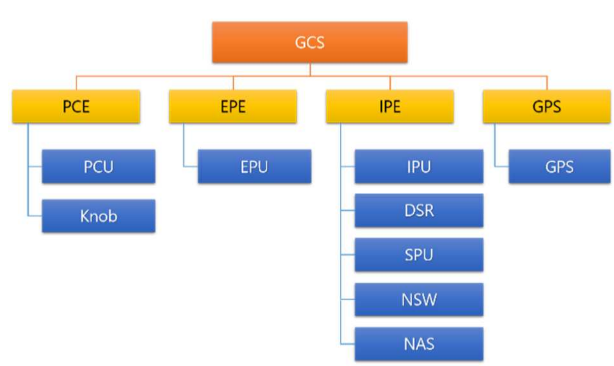

Fig. 1 GCS Configuration

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MX-10 electro-optical/infrared (EO/IR) camera [8, 9].

The EO/IR camera, which is the surveillance and reconnaissance mission equipment mounted on an MPUH, consists of an EO camera and an IR camera. The EO camera uses a visible-light optical system, whereas the IR camera identifies targets that cannot be identified with the naked eye during a nighttime mission by using an infrared sensor.

This study proposes an operational concept for the EO/IR camera to satisfy the surveillance and reconnaissance mission requirement, which is one of the military requirements of MPUHs as described above. In addition, this paper presents the analysis of the functions of the EO/IR camera and proposes the design and implementation method for the control program. Furthermore, a method to control the EO/IR camera by linking the joystick is proposed for convenient operation of the camera by the operator.

This paper is organized as follows: Section 2 examines the concept of operations for the MPUH, and Section 3 describes the EO/IR camera system. Section 4 describes the design results of the EO/IR camera control program, and Section 5 describes the test results. Finally, Section 6 lists the conclusions drawn.

2. Operational Concept of Multi-Purpose Unmanned Helicopter

2.1 MPUH Components

The MPUH consists of a helicopter, a ground system that links the helicopter with the control program, and other test equipment. Among these components, the ground control equipment is a part of the ground system. It consists of flight control equipment (PCE), external piloting equipment (EPE), interlink process equipment (IPE), and a GPS (see Fig. 1). An indoor operator can control the helicopter through the PCE, and an external operator can control it manually using the EPE. Moreover, the IPE is required to link the ground system with the aircraft, and the GPS is used to obtain the coordinates and time information of the ground system.

A program that can control the EO/IR camera is installed in the flight controller. Thereby, the flight controller can control the camera as well as helicopter. In addition, it has a function to output the image information received via multicast to an external monitor.

2.2 Operational Concept of EO/IR Camera

The main operational concept of the MX-10 EO/IR camera mounted on the MPUH is shown in Fig. 2. The EO camera utilizes a visible-light optical system, and is applied in the daytime. Meanwhile, the IR camera utilizes an infrared sensor, and is applied at night to identify the target to be observed and obtain its coordinates.

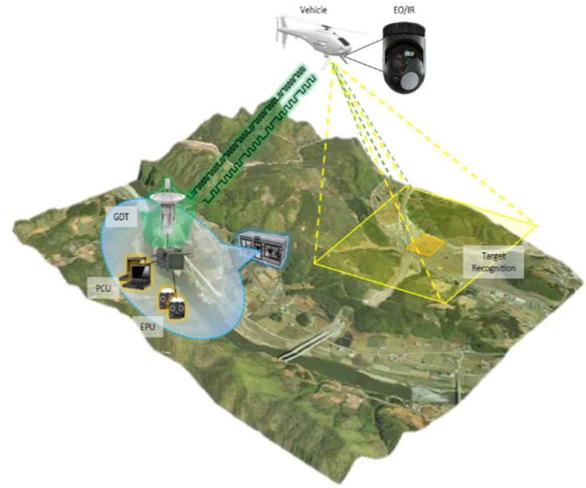

Fig. 2 Operational Concept of EO/IR Camera

Fig. 3 shows an image of an EO/IR camera mounted on an actual unmanned helicopter. The camera is mounted on the bottom of the aircraft.

Fig. 3 Mounting EO/IR Camera

3. Design of EO/IR Camera System

3.1 EO/IR Camera Integration Test Configuration

Before mounting the EO/IR camera on the MPUH, it must be linked with all equipment components. Furthermore, tests need to be conducted in the system integration laboratory (SIL). As shown in Fig. 4, the SIL consists of the ground-control equipment testbed, data link testbed, flight control system, flight control HILS, and aircraft inspection equipment.

The EO/IR camera is connected to the main link of the onboard data link installed on the unmanned helicopter via Ethernet. The control program for the camera is installed in the flight controller (which controls the unmanned helicopter).

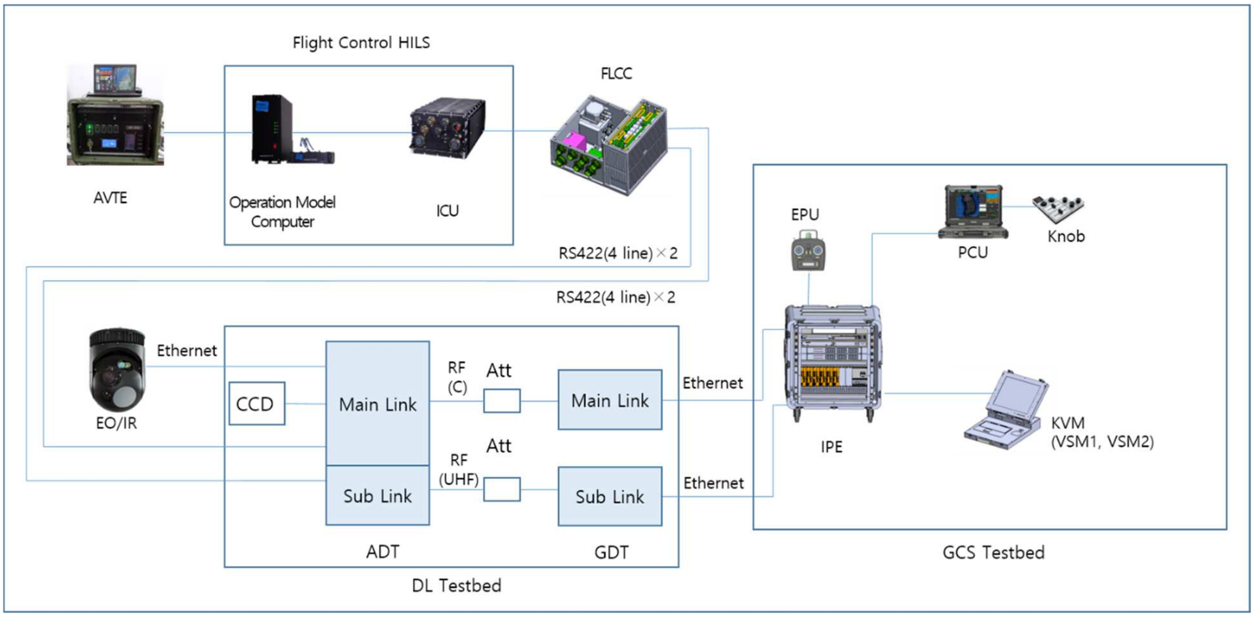

Fig. 4 EO/IR Camera SIL Test Configuration

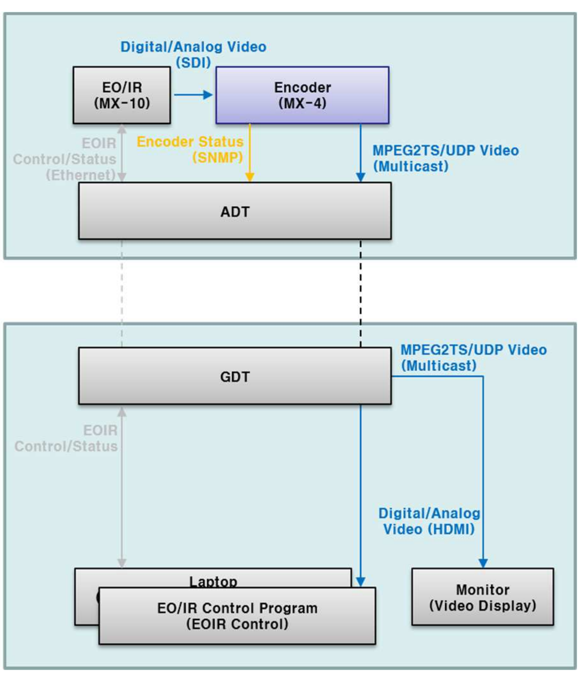

Fig. 5 EO/IR Data Sequence

3.2 EO/IR Control Data and Video Sequence

Fig. 5 shows the data and video sequence transmitted between the EO/IR camera and control program.

The EO/IR control data is sent by transmitting the control commands from the EO/IR control program to the ground data link in UDP format according to periodic/aperiodic data. The ground data link wirelessly transmits the data received from the control program to the onboard data link. The onboard data link transmits the control data to the EO/IR via Ethernet. When the EO/IR receives the data for each command, it transmits the status data matching the command to the control program in the direction opposite to that in the process described above.

For the EO/IR camera video, the video data received from the EO/IR (MX-10) is first converted into MPEG2TS packets. Then, the converted video data is sent to the video display program via an MX-4 encoder (a piece of equipment separate from the EO/IR), the onboard data link, and the ground data link. Finally, the video is displayed on an additionally configured monitor.

3.3 Definitions of Operational Modes

The operational modes of the EO/IR camera mounted on the MPUH are defined as follows:

(1) Stow mode: A mode that protects the camera lens from damage caused by debris when the aircraft takes off or lands.

(2) Forward mode: A mode that aligns the orientation of the EO/IR camera with that of the aircraft.

(3) Position mode: A mode in which the operator can align the EO/IR camera in the desired orientation by setting the azimuth and elevation in the control program.

(4) Manual mode: A mode in which the operator sets the azimuth and elevation movement rate ($-1 < r < 1$) in the control program. The camera automatically moves according to the rate.

(5) AutoScan mode: A mode in which the operator sets the width and rate in the control program with reference to the azimuth and elevation of the area that the operator wishes to observe. The camera automatically moves

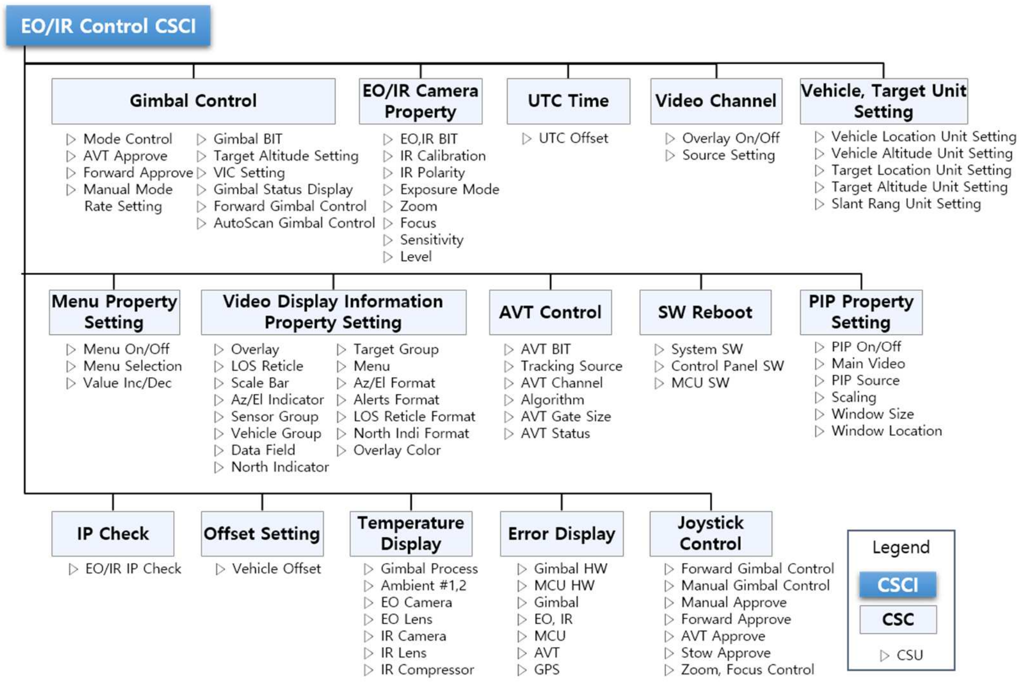

Fig. 6 EO/IR Control CSCI

according to the set rate.

(6) Auto mode: A mode in which the operator selects the target to be tracked in the control program. The camera automatically tracks the target even when the aircraft moves.

3.4 Power Supply and Precautions

The EO/IR camera power-supply is connected to the internal cable of the aircraft. Hence, power must be supplied from the aircraft. To turn on the camera's power, a separate program that controls the aircraft needs to transmit the corresponding command to the aircraft. When the camera is powered on, the default mode (the Stow mode) is maintained unless a separate operation or control is performed. Here, a precaution needs to be undertaken to protect the EO/IR camera lens. After the completion of all missions, the mode must be shifted back to the Stow mode before the power is switched off.

4. Design of EO/IR Camera Control Program

4.1 Analysis of EO/IR Camera Functions

The functions provided by the EO/IR camera mounted on the MPUH are shown in Fig. 6. The EO/IR control CSCI consists of 15 CSCs including the gimbal control CSC and EO/IR camera property CSC. Furthermore, there are multiple CSUs under each CSC.

4.2 Design of Control Program GUI

The control program is divided into tabs according to the CSC functions analyzed earlier. The GUI is developed as shown in Fig. 7.

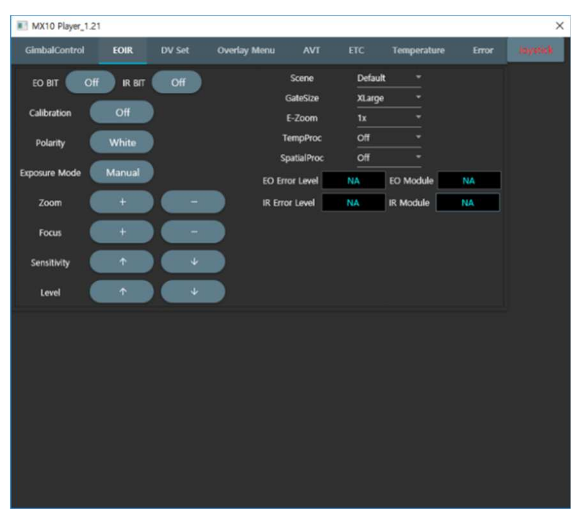

Fig. 7 EO/IR Control Program GUI

4.3 Design of Joystick Functions

After selecting and inputting the desired value in the control program GUI, the operator must click the corresponding button. However, it is difficult for the operator to operate the EO/IR camera by clicking all the buttons if an urgent scenario occurs during a mission, such as surveillance and reconnaissance. To overcome this issue, the control program and joystick have been linked so that the operator can conveniently operate the EO/IR camera.

The joystick function can be activated by clicking the Joystick button at the top right of the control program (see Fig. 8).

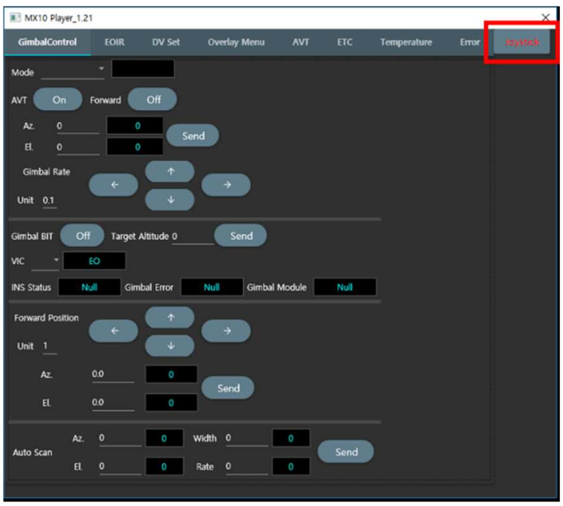

Fig. 8 Button to Activate Joystick

The functions that are primarily used while carrying out a mission with the joystick have been linked with the joystick buttons (see Fig. 9). Table 1 describes the function of each button.

Fig. 9 Joystick Design

Table 1 Joystick Functions

No.	Button	Function
①	LB	Manual Approve
②	RB	Forward Approve
③	Back	AVT Approve
④	Start	Stow Approve
⑤	X	Azimuth rate −
⑥	A	Elevation rate −
⑦	B	Azimuth rate +
⑧	Y	Elevation rate +
⑨	Right Roll - Up, Down: Elevation - Left, Right: Azimuth	Forward Gimbal Control
⑩	Left Button - Up, Down: Zoom - Left, Right: Focus	Zoom, Focus Control

4.4 Video Display Program

With regard to the EO/IR video, the video display program receives the MPEG2TS packets transmitted by the ground data link via multicast according to the data sequence described in Section 3.2 and displays it on a separate monitor.

The multicast IP can be modified through the config file for future scalability.

5. Test Results

5.1 SIL Test Results

As mentioned in Section 3.1, each function was tested in the SIL after linking the EO/IR and control program, as shown in Fig. 4. The test procedure is as follows:

(1) Apply power to the aircraft and EO/IR.

(2) Examine the initial EO/IR mode (Stow mode).

(3) Inspect mode transitions.

(4) Verify the operation of each mode.

(5) Verify the EO/IR control functions (Zoom, Focus, Exposure Mode, etc.).

(6) Verify other functions (set the unit, set the menu, PIP, AVT, receive the temperature and error, etc.).

Each function was tested as described above. In addition, we verified the normal operation through the video display program.

A peculiar observation was that although the EO camera started working immediately after power was applied to the EO/IR, the IR camera began operating after performing a cooling procedure for approximately 2 min.

5.2 Flight Test Results

We verified the control-program function tests performed in Section 5.1 by applying these to actual flight testing. In addition, using the video display program, we verified that the EO video and IR video are received effectively (see Figs. 10

and 11, respectively).

6. Conclusions

This paper describes the operational concept and control-program design of the EO/IR camera required for carrying out target detection, surveillance, and reconnaissance missions, which are requirements of MPUHs for military application. Moreover, we developed a control-program GUI based on the design and linked the control program with a joystick for user operability.

In addition, we mounted the EO/IR camera on a real unmanned helicopter and verified the operation of the control-program functions. Furthermore, we successfully verified the performance of the EO and IR screens using the video display program.

It is anticipated that the control program developed in this study would be highly effective for verifying the performance of MX-10 EO/IR cameras when these are mounted on unmanned helicopters developed in the future.

Fig. 10 EO Screen

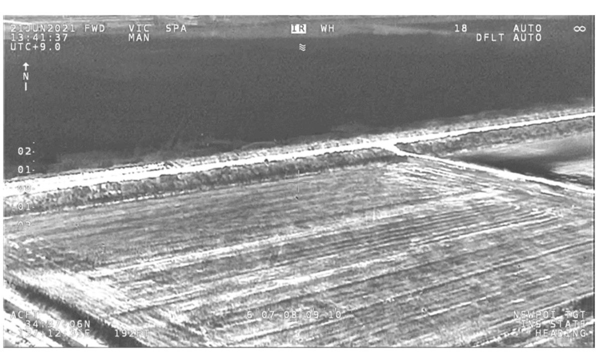

Fig. 11 IR Screen

Postscript

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