FLIGHT TESTS OF SYNTHETIC TERRAIN AND FLIR IMAGES ON HELMET-MOUNTED DISPLAY

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Abstract

JAXA (Japan Aerospace Exploration Agency) has been conducting a research project named SAVERH (Situation Awareness and Visual Enhancer for Rescue Helicopter) with Shimadzu Corporation and NEC since 2008. SAVERH aims at inventing a method of presenting suitable information to pilots to support search and rescue missions. An integrated system comprising an HMD (Helmet-Mounted Display) and a FLIR (Forward Looking Infrared) sensor were installed in a JAXA research helicopter and a series of flight tests conducted to evaluate the benefit of presenting Synthetic Terrain and FLIR images on the HMD. An effectiveness of Synthetic Terrain and FLIR images presented on an HMD for terrain following and road (path) following was evaluated through a series of flight experiments. As results, FLIR image was effective for recognizing targets or navigation features such as road. And a finding that synthetic terrain with generic 3D objects is superior to without the objects was obtained.

1 Introduction

The importance of helicopters in disaster relief and their roles in search and rescue (SAR) and emergency transportation operations are widely recognized. Since helicopters play such vital roles, it is desired to further increase their effectiveness by extending their operational limits, particularly the ability to operate in low visibility conditions and at night. One method to do is to enhance the pilot's situation awareness by presenting suitable visual cues constructed from sensors and databases [1].

In SAVERH project, some types of display mode with synthetic terrain images and a FLIR image can be presented to the pilot, not only to warn of ground proximity but also to show how much clearance from the terrain existence. Terrain images are generated from a terrain database and GNSS position data. During the SAVERH project, synthetic/ enhanced vision system (S/EVS) symbologies, sensor image presentation techniques and related display technologies have been developed and evaluated by flight experiment. One research activity is to evaluate the comparative effectiveness of each type of display mode to identify the limitations and advantages of each and to seek the possibilities of using them in combination. This paper reports an outline and the results of a flight experiment to evaluate usability of SVS.

2 System Configuration

Fig.1 shows the SAVERH system integrated into MuPAL-ε, JAXA's research helicopter based on a Mitsubishi MH2000A (see Fig.2) [2]. A symbol generator PC receives flight data from MuPAL-ε's instrumentation system, including position, attitude, air data and engine data, and generates flight symbology. The symbol generator PC also receives FLIR images from an infrared camera installed under the nose (see Fig.4) and overlays it with the flight symbology and a synthetic terrain image. The combined image is then presented on an HMD (see Fig.3) be used by the left- seated pilot, while the right-seated pilot acted as a safety pilot during evaluations.

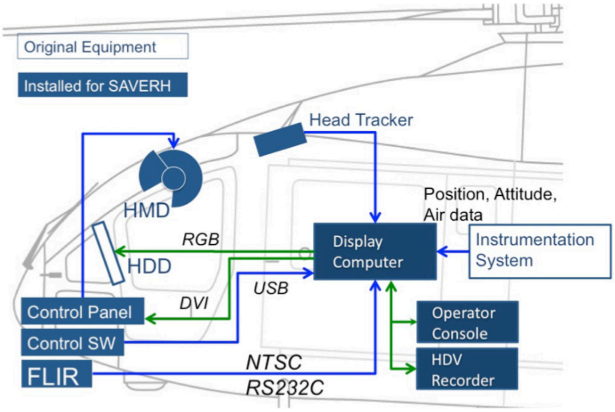

Fig. 1. System Configuration.

Fig. 2. JAXA Research Helicopter “MuPAL-ε”.

2.1 HMD System

Fig. 3. Helmet-Mounted Display.

A binocular HMD made by Shimadzu Corp. was used in the experiment. The display image generated by the symbol generator PC is output to the HMD as an DVI video signal. A pilot control unit is installed at the left side of instrument panel. A set of tracker cameras mounted on the cabin ceiling detects pilot head motions[3] which are communicated to the symbol generator PC via an RS422 serial link.

2.2 FLIR System

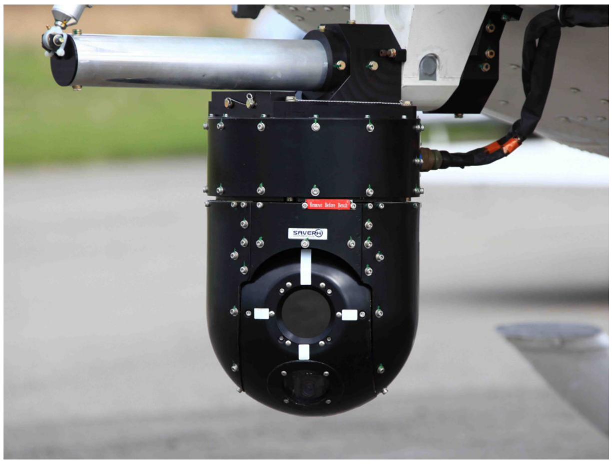

Fig. 4. FLIR installed on helicopter in a turret.

An uncooled FLIR sensor, “AEROEYE” made by NEC Corp., was installed in front of the nose of the helicopter in a turret. The turret allows the FLIR is to be head-slaved or controlled manually, with maximum slew rates of 45 deg /s in azimuth and 60 deg/s in elevation. The 640x480 pixel composite video signal from the FLIR camera is captured by the symbol generator PC. Contrast and brightness (sensor gain) are automatic or can be manually adjustable from the cabin and by the pilot. Although many other parameters such as White-Hot / Black-Hot reversion and digital zoom were available and controllable by the pilot, these were not used during the pilot evaluation flight experiments.

3 Experiment Method

Flights were broken down into two missions “Terrain Following” and “Road Following”. “Terrain Following” is to evaluate an effectiveness of Synthetic Terrain image “Mesh” and “Tree” (see Fig.5 and Fig. 6), and “Road Following” is to do an effectiveness of FLIR image.

3.1 Display Mode

Three types of display mode were experienced. Two types of terrain images were tested, namely, “Mesh” and “Tree”. Snapshot of a FLIR image presented on an HMD is shown in Fig.7. In “Tree” 3D objects with a shape of tree are added to give a pilot more sense of moving, acceleration and getting closer to the surface.

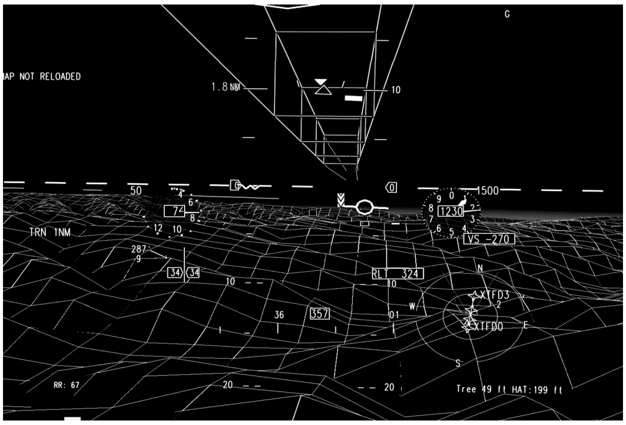

Fig. 5. HMD snapshot: Synthetic Terrain “Mesh”

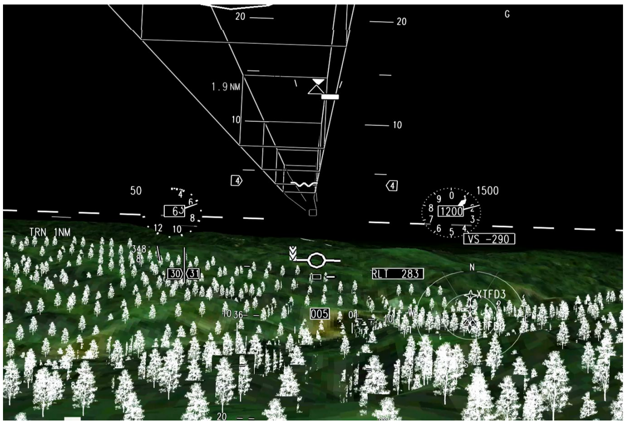

Fig. 6. HMD snapshot: Synthetic Terrain “Tree”

Fig. 7. HMD snapshot: FLIR

3.2 Pilot Task

3.2.1 Terrain Following

In “Terrain Following”, pilots were requested to follow surface of the terrain maintaining constant altitude above the terrain and speed. This mission is conducted in mountainous area and in the daytime. Pilots wear an opaque cover over an HMD visor to prevent seeing outside-the-window. To evaluate an effectiveness of synthetic terrain images, pilots were also requested to compare the display mode and to rate them for five indices.

3.2.2 Road Following

Previous experiments have shown that it is necessary to assign definite pilot tasks to evaluate the effectiveness of FLIR images [4][5][6]. Therefore we set the task of flight along a major road using the FLIR image presented on an HMD. Pilots were requested to keep the track along the route solely by reference to the FLIR images maintaining constant altitude and speed. This mission is conducted at night.

To evaluate an effectiveness of FLIR images, pilots were asked to assign a subjective score on a four-point scale after each flight: “Very Good”, “Good”, “Poor” and “Very Poor” or “Very Useful”.

3.3 Subject Pilot

Three pilots participated in this experiment. All three pilots were well experienced with the MH2000 helicopter type, and had more than 10 hours of actual flight experience with HMD including night flight.

4 Results

4.1 Terrain Following

An example of vertical trajectories flown by one pilot is shown in Fig.8. From this figure, it is observed that the case with “Tree” shows lower altitude than “Mesh”, where the former case is considered to provide better terrain awareness than latter.

The comparative ratings and reasons for the ratings between two display modes given by the three pilots are shown in Table 1. The rating and comments supports that the "Tree" provided better terrain awareness than "Mesh".

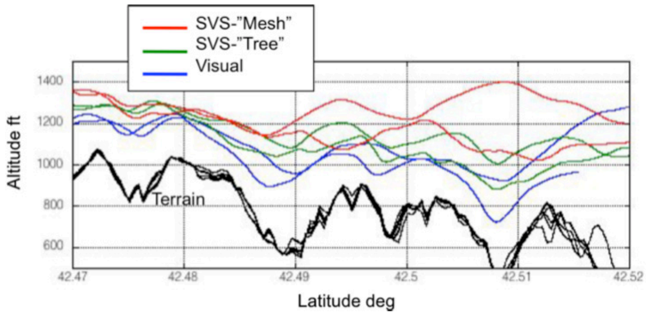

Fig. 8. Flown trajectory from Terrain Following.

Table 1. Pilot Ratings of Terrain Awareness

Pilot	Display Mode	Reason of Rating
A	T>M	No comment.
B	T>M	Tree type objects give me the sense of moving and accelerating.
C	T>M	Tree type objects are effective.

T:Tree, M:Mesh, "a>b": a is rated better than b.

4.2 Road Following

The trajectories flown are shown in Fig.9. In this figure, the road is shown by a black line, and green circles indicate residence areas. There are few street lights or traffic along the road outside these areas. The comparative ratings (with FLIR image vs without FLIR image) given by the three pilots are shown in Fig.10.

The figures show six legs for each case: two legs for each of three pilots. Fig.9 shows that pilots were able to the road exactly when using FLIR, and larger deviations from the road are observed without FLIR, particularly at corners and curves.

Pilot ratings of position awareness and terrain awareness are shown in Fig.10. All of three pilots rated better when using FLIR.

As results, FLIR image was effective for recognizing targets or navigation features such as road.

Although scores of "Good" or "Very Good" were obtained for position awareness when using FLIR, Fig.10 shows that for terrain awareness by two of three pilots rated "Poor" even with FLIR. They commented that shapes of forests or woods in FLIR images were not helpful in determining obstacle clearance.

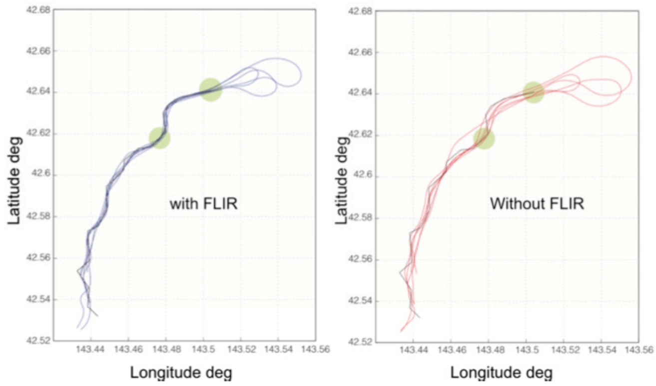

Fig.9. Flown trajectory from Road Following

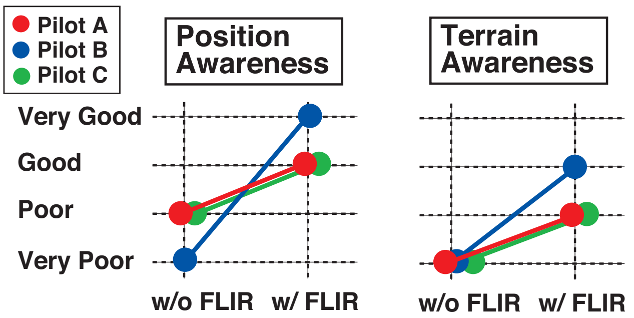

Fig.10. Pilot Ratings of Position Awareness and Terrain Awareness with FLIR and without FLIR.

5 Conclusions

An effectiveness of Synthetic Terrain and FLIR images presented on an HMD for terrain following and road (path) tracking were evaluated through a series of flight experiments. Some results obtained are as follows:

- Synthetic Terrain "Tree" is more useful than "Mesh" for terrain awareness.
- The effectiveness of FLIR images for position awareness and terrain awareness was proved.

Considering the above findings, a series of experiments is being scheduled to evaluated terrain awareness by using improved Synthetic Terrain images for lower altitude flights. And the evaluation of effectiveness of S/EVS using the information from some sensors other than FLIR and terrain database is being planed.

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