RESEARCH ON VISION SYSTEM FOR DEGRADED VISUAL ENVIRONMENT

Kohei Funabiki, Hiroka Tsuda, Kazuho Tawada and Kaname Hasebe

Japan Aerospace Exploration Agency, Shimadzu Corporation (JAPAN)

e-mail: funabiki.kohei@jaxa.jp

Abstract
JAXA (Japan Aerospace Exploration Agency) has been conducting a research project named SAVERH (Situation Awareness and Visual Enhancer for Rescue Helicopter) since 2008. SAVERH aims at inventing a method of presenting suitable information to pilots to support search and rescue missions in Degraded Visual Environment. An integrated system comprising an Helmet-Mounted Display (HMD) and some vison sensors were installed in JAXA research helicopters and series of flight tests conducted to evaluate the benefit of presenting synthetic and sensor images on the HMD. An effectiveness of images presented on an HMD for road following and landing was evaluated through the series of flight experiments. As results, both synthetic and sensor image were effective for recognizing targets, navigation features such as road and terrain.

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 Degraded Visual Environment (DVE). One method to do is to enhance the pilot's situation awareness by presenting suitable visual cues constructed from sensors and databases [1].

JAXA together with Shimadzu Corp. and NEC Corp., has been conducting a research project named SAVERH (Situation Awareness and Visual enhancer for Rescue Helicopter) to develop vision and sensor system to support helicopter operation in DVE, since 2008 [2]. In SAVERH, some types of display mode with synthetic terrain images and sensor image can be presented to the pilot terrain images are generated from a terrain database and GNSS position data. During the SAVERH project, S/EVS (synthetic/enhanced vision system symbologies, sensor image presentation techniques and related display technologies have been developed and evaluated by flight experiment. This paper reports an outline of SAVERH activities, by describing the prototyped system and results from the flight experiment.

Fig. 1 Research Helicopter "MuPAL-ε"

Fig. 2 Research Helicopter based on BK117C-2

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2. SYSTEM

2.1. System Installation

A research helicopter "MuPAL-ε" [3] (see Fig.1) based on MH2000A has been used till 2012, and the other one based on BK117C-2 (EC145) (see Fig.2) is in operation since 2014. The latest experimental setup on the BK117C-2 is described from this point.

Fig.3 shows the SAVERH system integrated into the research helicopter based on a BK117C-2. A display computer receives flight data from instrumentation system via UDP, including position, attitude, air data and engine data, and generates flight symbology. The display computer also receives image from sensors installed in a turreted sensor pod, which is installed under the nose (see Fig.4) and overlays it with the flight symbology. Based on stored digital terrain database, synthetic topographic image can be also generated. The combined image is then presented on an HMD (see Fig.5) and HDD (see Fig.6) be used by the left-seated pilot, while the right-seated pilot acted as a safety pilot during evaluations.

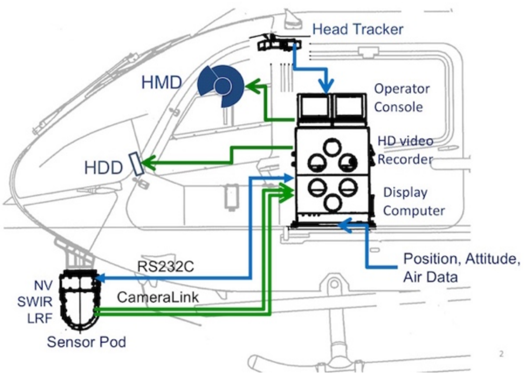

Fig.3 System Configuration

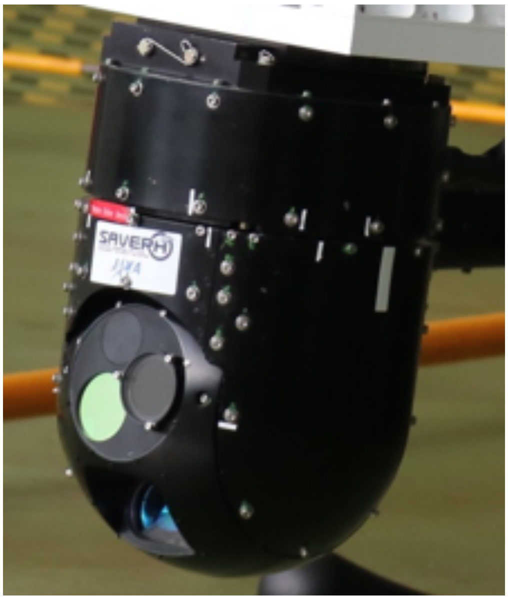

Fig. 4 Sensor-pod

Fig. 5 HMD

Fig. 6 HDD (Lower Monitor)

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2.2. HMD

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 a digital video signal. A pilot control unit is installed in the center console. A set of tracker cameras mounted on the cabin ceiling detects pilot head motions [4] which are communicated to the display computer via an RS422 serial link. Since 2008, in total four different types of HMD have been integrated into the system and evaluated in the fight test. The latest type was equipped with NV (Night Vision) sensors on the helmet, and the helmet-NV image can be overlaid on the computer-generated image.

2.3. Sensors and Sensor-Based Image

At maximum three image sensors and a laser-range finder can be installed in the sensor pod. The sensor pod allows the involved sensors are to be head-slaved or controlled manually, with maximum slew rates of 45 deg/s in azimuth and 60 deg/s in elevation. Since 2008 to 2014, An uncooled LWIR (Long Wave Infra-Red) sensor "AEROEYE" made by NEC Corp. (from this called FLIR camera), and a visible light camera installed have been utilized. Fig.7 shows a snapshot from FLIR camera, and Fig.8 shows the corresponding image from visible light camera. In the latest configuration, a SWIR (Short Wave Infra-Red) camera and a NV sensor were installed in the sensor-pod.

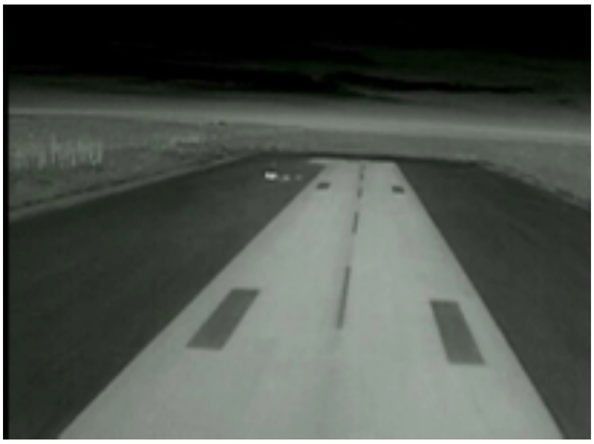

Fig. 7 FLIR camera image

Fig. 8 Visible light camera image

2.4. Synthetic Image

Major part of synthetic image is synthetic terrain based on digital elevation map that is stored in the display computer. The synthetic terrain was presented in several manners, such as wire-frame or photo texture mapped (see Fig.9). Additionally, "Tree" objects were artificially planted on the mountainous ground surface to enhance ground proximity awareness (see Fig. 10). Although the flight simulation and flight test demonstrated that the sense of height clearance was enhanced by the "Tree", the sense of absolute distance cannot be conveyed by the objects as it has been expected.

Digital elevation map was used not only to generate topographic terrain, but also to augment the legibility of sensor image. It is sometimes difficult to select the image gain and contrast to give best legibility of FLIR. For example, while a higher gain setting reveals details of cooler objects, it also makes warm objects appear "mostly-white", and if there are many warm objects in the field of view the whole FLIR image can become mostly white. It sometimes happens shortly after the sunset, where grate temperature difference between ground and sea exits as shown in Fig. 11. To enhance the legibility of the FLIR image, the invented method utilizes a 2D mask generated from topographic terrain of interest data, and overlays the raw image as shown in Fig.12. The flight tests confirmed the enhanced image legibility brought by the method [5].

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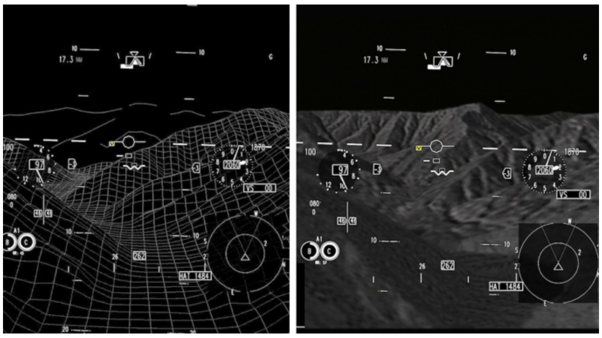

Fig.9 Synthetic terrain "Mesh" and "Texture"

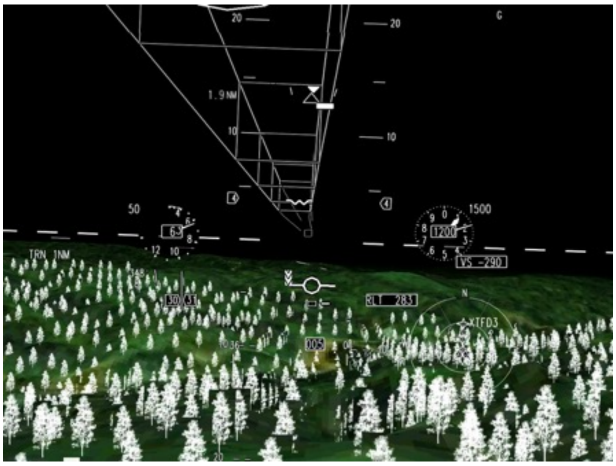

Fig.10 Synthetic terrain with "Tree"

Fig. 11 Raw FLIR image from offshore

Fig. 12 Masked FLIR image

3. FLIGHT EXPERIMENT

3.1. Ground Path Following

Initial experiments have shown that it is necessary to assign definite pilot tasks to evaluate the effectiveness of sensor images. Therefore we set the task of flight along a major road using the FLIR image presented on an HMD [6][7][8]. 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.

The trajectories flown are shown in Fig.13. 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 figure shows six legs for each case: two legs for each of three pilots. Fig.13 shows that pilots were able to follow the road exactly when using FLIR, and larger deviations from the road are observed without FLIR, particularly at corners and curves.

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

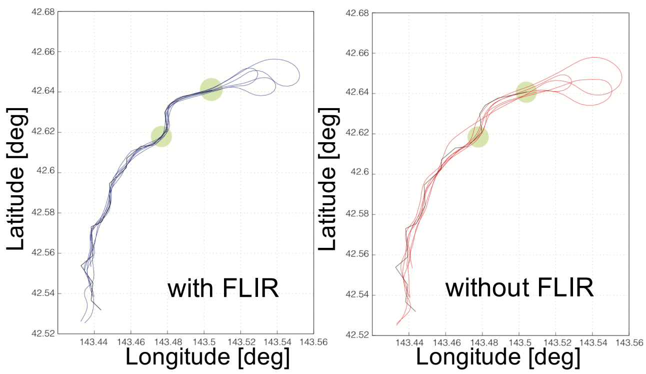

Fig. 13 Flown trajectory from road following

3.2. Approach

Approach with Synthetic and Sensor-based vision system were tried repeatedly both in flight simulation and flight test. The hypothesis was that the synthetic and sensor-based image could work as out-side-of-the-window scene, and the task could be performed in the same way as the visual approach. The hypothesis was not very well supported by the flight test, especially deceleration to hover was not always successfully performed. Other unsuccessful approach were thought to be caused by degraded quality of the image. To compare with approach to a well facilitated airport, it is sometimes difficult to distinguish the runway from without lighting from the surrounding fields or woods, even less than

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3NM before. It falls also in synthetic image, where outline of the runway was not enhanced. Once the outline of the runway and approach path to the runway, such as in the shape of tunnel-in-the–sky, are clearly shown, the flight task were always successfully performed.

3.3. Landing

Low altitude hover relaying on the sensor or the synthetic image without out-of-the-window scene was tried with FLIR image in the night. The trial was unsuccessful, and the following factors were suspected as causes;

a. Relatively poor stability of the aircraft
b. Small field of view of image
c. Image transfer delay

The difference with the simulation, where that hover task was successfully performed, was c. Image delay. Due to the several stages of legibility enhancement on the image, the total delay was tuned out to be nearly 200ms, which was not simulated in the simulator setting.

The next trial was then conducted and successfully performed with good stability aircraft, wider FOV and image with delay less than 100ms. The FOV was reduced to the setting in the former trial, but did not significantly degrade the performance.

Fig. 14 shows NV image and Fig. 15 shows SV image on the HMD at the flight test. In the both cases, path guidance from approach to hover were provided by tunnel-in-the-Sky. The pilot commented that the grained texture of the virtual runway surface on SV image was visible on the HMD, and provides good cue for the hover and landing.

Fig. 14 NV image at hover

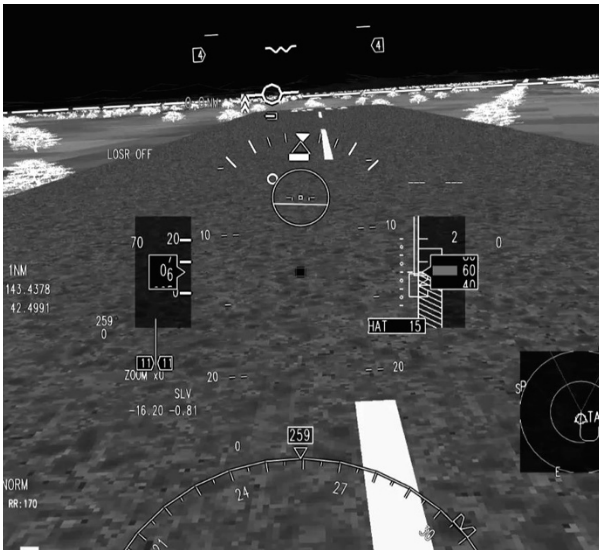

Fig. 15 SV image at hover

4. CONCLUSIONS

Method of presenting synthetic or sensor image to pilots to support search and rescue missions in DVE was invented. An integrated system comprising a Helmet-Mounted Display (HMD) and vision sensors were installed in JAXA research helicopters and series of flight tests conducted to evaluate the benefit of presenting synthetic and sensor images on the HMD.

An effectiveness of the prototyped system for terrain awareness were evaluated and proved through a series of flight experiments. Approach and landing aided with the system under DVE was successfully performed.

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