Development of Rescue Operation Support System for Helicopter

To prevent fire-fighting and rescue helicopters from crashing during rescue operations in mountain areas, we have developed a rescue operation support system for helicopters to help the pilot properly recognize risk when hovering during rescue operations or landing on uneven terrain.

We prototyped a system for demonstration and assessment to examine the system, check the man-machine interface, assess the obstruction detection sensor in advance and verify the effects of wireless LAN on the fuselage before starting full-fledged development of the system.

Introduction

Rescue operations with helicopters are effective when it is difficult or takes a long time to reach accident survivors by land or sea. Particularly in Japan, where mountain areas account for 70% of its land, approx. 60% of all rescue operations involving fire-fighting and rescue helicopters are for mountain rescue activities.

1 Background

One type of rescue operation is lifting survivors with a cable extending from a helicopter's hoist as it maintains a fixed altitude and position. While this rescue operation procedure is extremely effective in places without a space to land, there is always a risk of crashing.

After some fire-fighting and rescue helicopters crashed during rescue operations in mountain areas, to prevent recurrence of such accidents the Fire Defense Agency issued the "Study Group Report on Mountain Rescue Methods by Fire-fighting and Rescue Helicopter" in March 2012. In response to this report, each rescue corps clarified flight safety standards such as: (1) increase the number onboard assistants who watch outside the helicopter such as the rear-left area; and (2) when hovering, maintain clearances of 10 m or more in the horizontal direction from obstacles, and 6 m or more from objects below. Some air rescue corps have made it mandatory to operate a helicopter with two pilots on board in all rescue activities. These measures are taken to enhance safety by watching outside the helicopter, and they highlight the difficulties of mountain rescues.

2 Policy for developing a rescue operation support system for helicopters

This rescue operation support system for helicopters presents surrounding-view images (rear-view images in particular), downward-view images, and distance information on surrounding obstacles on a dedicated display unit while hovering during rescue operations or landing on uneven terrain. This reduces the burden on operators by supporting the work of watching nearby obstacles. Our plan is to develop a low-cost system that is easy to install in a helicopter.

(1) Reducing the cost of obstruction detection sensors

Although general aircraft radars can obtain information on obstacles and weather several kilometers away, they are extremely expensive. This system reduces costs by limiting the scope to watching surrounding obstacles when hovering during rescue operations and landing on uneven terrain. Developing this low-cost system is possible by using obstruction detection sensors and cameras developed for automated vehicle operations.

(2) Easy to install in a helicopter

To make it easy to install the system in a helicopter, we minimized wiring by applying a wireless local area network (LAN) system for communication between the dedicated

† Realized the world lowest level of noise in its class, better hovering performance and longer lifetime through adoption of a new tail rotor and other components.

display unit and the computer. Specifically, the system is installed as follows:

- Install a sensor for detecting starboard-side obstacles and a camera for capturing rear-view images on the rear end of the entry step on the helicopter's starboard side; and install a sensor for detecting port-side obstacles and a camera for capturing downward-view images on the rear end of the entry step on the port side.
- Install an image-generating computer and a wireless LAN master unit in the rear of the cabin.
- The dedicated display unit is supposed to be portable; the cockpit is not to be modified.

Figure 1 shows the system configuration, and **Fig. 2** shows a helicopter equipped with these devices.

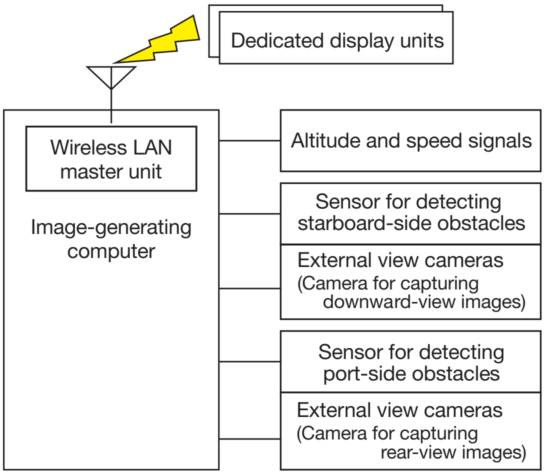

Fig. 1 System configuration

3 Fabricating a prototype system for demonstration and assessment

Before producing a full-fledged version of the system, we developed a prototype for demonstration and assessment. The main pieces of hardware are described below.

(1) Obstruction detection sensors

Obstruction detection sensors detect distances between the helicopter and obstacles as well as their directions. Although it would be ideal to detect all obstacles in the sphere around the helicopter, we assigned priority to securing clearances between obstacles and the main and tail rotors (see **Fig. 2**) and obstacles around the helicopter (particularly in the rear and lateral directions). On an actual helicopter, two obstruction detection sensors would be fitted to the rear of the fuselage, each covering 180 degrees horizontally on each side. To demonstrate and assess the system, however, we attached the sensors beneath a small unmanned helicopter body. The sensor chosen for this purpose was Velodyne's laser radar (VLP-16), which has a coverage range of 360 degrees horizontally. **Table 1** shows its specifications.

(2) External view camera

The external view camera captures images around the helicopter. **Figure 3** shows the camera's video acquisition range. Ideally, it should capture images all around the helicopter (circumferential view) and downward, wide-angle images (bird's-eye view).

For this system, we mounted two web cameras on a small unmanned helicopter. One camera was for rearward views; and another was for bird's-eye views, and they were connected to a computer. This setup evaluated the effect of vibrations.

Fig. 2 Image of installation

Table 1 Specifications of laser radar from Velodyne

Sensor type	16 lasers and detectors
Detection range/angle	360° horizontally; all directions 30° vertically (+15° to −15°)
Detection distance 〔m〕	Approx. 100 (1 to 100)
Number of measurement points 〔points/s〕	Approx. 300,000 points/s
Measurement accuracy	± 3 cm (1 σ @25m)
Laser class	Class 1 Eye Safe
Laser wavelength 〔m〕	903
Weight 〔g〕	Approx. 830
Size 〔mm〕	H 71.7 × ϕ 103.3

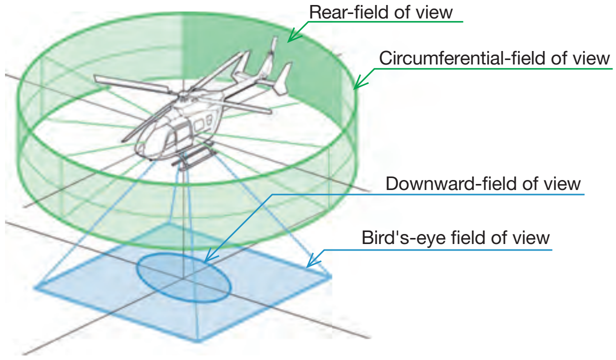

Fig. 3 Field of view of the external view camera

(3) Dedicated display unit

We used a general-purpose tablet-type display and a head mount display (HMD) as dedicated display units, in order to be independent of the helicopter's power supply. To minimize the cost of installing this system in an actual helicopter, this system employs a wireless LAN system for communication between the displays and the image-generating computer. These devices are not to be permanently installed in an aircraft; they are completely portable.

(4) Image-generating computer

The image-generating computer generates images for each crew member based on: (1) the inertia sensor signals representing the helicopter's attitude, location and speed, which are critical for understanding the situation during hovering; (2) the information from the obstruction detection sensors; and (3) the images from the external view cameras. This is a dedicated computer specialized for the environment of aircraft-installed devices.

A laptop PC with an equivalent capability was used for this system for demonstration and assessment.

4 Prior confirmation of the system for demonstration and assessment

The following describes the results of element tests carried out with the system for demonstration and assessment.

(1) Inspection information presented by the dedicated display unit

Referring to the opinions of helitack crews, we designed what information should be presented on the dedicated display unit.

Figure 4 shows examples of display screens. In the display for hovering situations, helicopter sits at the center, surrounded by a series of concentric rings that indicate the distance of obstacles from it. The system color-codes obstacles on the screen according to their distance from the helicopter: red is 5 to 15 m from the helicopter; yellow is 16 to 25 m; and green is 26 to 36 m. Obstacles beyond 36 m are not displayed. A blue line indicates the horizontal movement vector showing the helicopter's direction and speed. On the right is a vertical movement speed bar and altitude information. In addition, the vertical movement speed is displayed in the upper right, and the horizontal movement speed in the upper left, both numerically.

The lower half of the screen shows images from the rear-view and downward-view cameras. The rear-view images are reversed in the same way that drivers see an image in their rear-view mirror. When displaying downward-view images, the system superimposes a silhouette of the helicopter (CG) to assist with perspective. Touching the small image frame in the bottom-left corner switches between the rear view and the downward view.

The HMD only displays information during hovering situations.

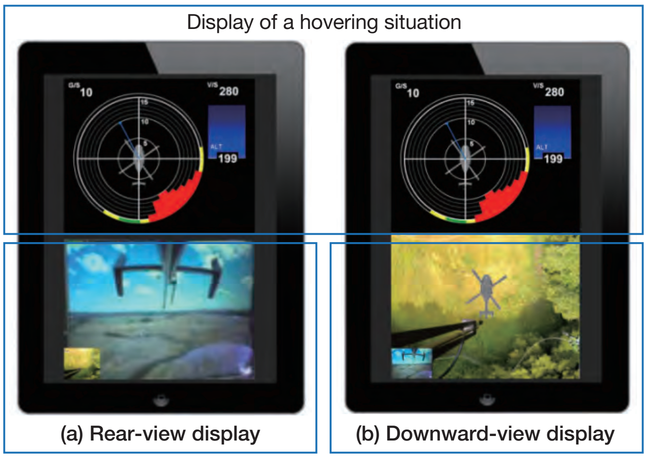

Fig. 4 Display example of the dedicated display unit

(2) Checking the performance of Velodyne's laser radar

By checking the accuracy of distance measurements between the laser radar and a target, we confirmed that the error was 50 cm or less at ranges of 1 to 100 m.

To check how different materials affect system performance, we captured field data confirming detection of buildings and trees. **Figure 5** shows radar data and a photograph of the corresponding site.

The laser radar also detects snowflakes and large rain drops as obstacles. Although this system has been designed for visual flights, its data-processing capability can reduce interference from flying objects such as snowflakes, taking into account temporary bad weather that rescuers may encounter in a mountain area. This processing algorithm ignores observation data within point-blank range such as the space directly under the rotating main rotor. Also, the decision criteria for obstacles, i.e. the number of detection events in a certain time interval, are weighted according to distance from the sensor. At close ranges, the system classifies detection events as obstacles only when detections are made many times at the same position. For greater distances, the number of detection events, or the criteria, is smaller. Moreover, the criteria vary according to the speed of the helicopter; for example, they increase when the speed is lower than a certain value.

Figure 6 shows the obstacle-detection results when the criteria are varied according to distance when in a

Fig. 5 Comparison between data acquired by radar and photo

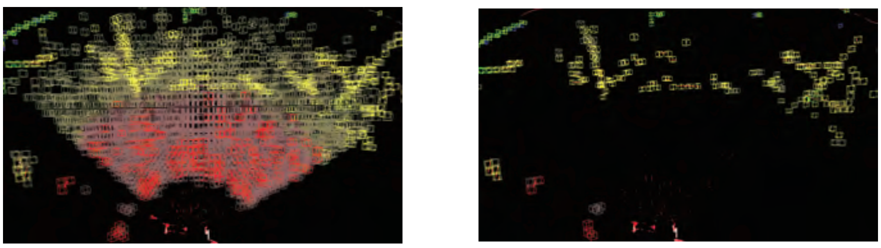

Fig. 6 Obstruction detection results in snow

hovering state. Obstacles are detected without being affected by snow.

The validation of criteria in states of movement will be evaluated in the future.

(3) Flight test with a radio-controlled helicopter

To evaluate the impact of vibrations on the laser radar and cameras, we installed this system for demonstration and assessment on a radio-controlled helicopter, and conducted a flight test.

Figure 7 shows the experimental equipment. Web-cameras for rear and downward views were installed on the helicopter, and a laptop PC and an inertia sensor were set up inside a box attached beneath the helicopter body.

In real-life situations, the dedicated display unit would be inside the helicopter to monitor nearby obstacles and flight conditions. However, in this test these monitoring data from the radio-controlled helicopter were received on the ground.

The results show that the vibrations from the helicopter did not greatly affect the camera images or the laser radar detection.

Figure 8 shows some images captured in this test and displayed on the dedicated display unit's screen. The graphic in the upper left shows hovering situation data when the tail rotor gradually approached the hill, and the bottom-left image shows a rear view. The hovering situation data shows that obstacles are approaching the helicopter from the rear starboard direction. The large image is a picture of this helicopter captured from a remote location.

(4) Checking the effects of the wireless LAN system on an actual helicopter

This system uses wireless LAN as a way to transmit data from the image-generating computer to the dedicated display unit. Although this is effective for reducing weight and wiring work, it may affect the helicopter's electronics. For this reason, we conducted a demonstration and assessment test with part of the system under

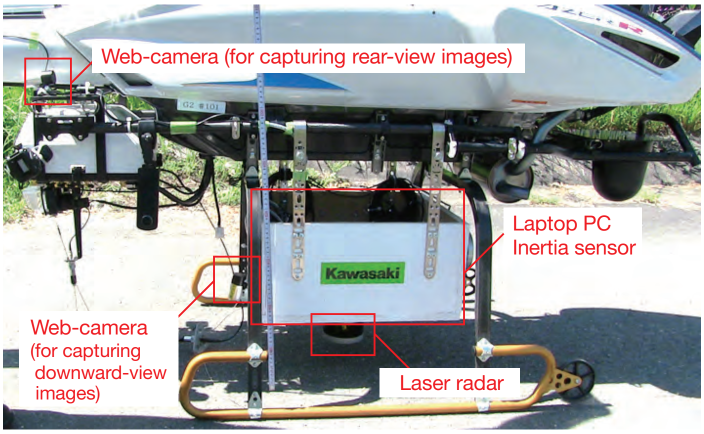

Fig. 7 Equipment of the system for demonstration and assessment

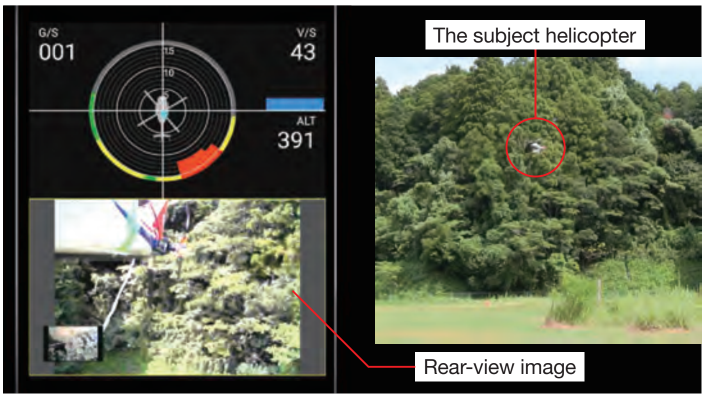

Fig. 8 Image of the dedicated display unit (left bottom) and flight movie (right)

development.

This test used 2.4-GHz band wireless LAN equipment, which was set up near the cockpit, which may contain several electronic devices. An external monitoring web-camera was installed on the right side of the back seat, and another camera was used to visually check whether the wireless LAN would be shut down.

The test results showed that the wireless LAN's radio waves did not adversely affect the helicopter's electronic systems such as the display device, the intercom system, the GPS device, or the external radio communication device. Furthermore, when the helicopter's electronic systems were operated while the dedicated display unit was constantly running, its display and image switching operations worked normally.

Conclusion

To build a prototype of this system for installation in an actual helicopter, we are now selecting small and inexpensive obstruction detection sensors and image-acquisition cameras that can be installed in a helicopter. We plan to install this prototype in a BK117 helicopter to conduct a flight test in the latter half of fiscal 2019. While issues including cost and size remain to be solved, we are now developing this system with the aim of commercializing it.

To develop this system, we received valuable opinions from personnel of the Gifu Disaster Prevention Air Corps, the Saitama Disaster Prevention Air Squadron, the Ehime Disaster Prevention Air Corps, the Tokushima Fire Fighting Disaster Prevention Air Corps, and the Kagawa Disaster Prevention Air Corps. They provided invaluable feedback and advice perspectives from operators' points of view. We would like to express deep gratitude to all of them.

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