A Surveillance System Using Small Unmanned Aerial Vehicle (UAV) Related Technologies

WADA Akihisa, YAMASHITA Toshiaki, MARUYAMA Masaaki, ARAI Takanari, ADACHI Hideo, TSUJI Hirokazu

Abstract

Following the 2011 Tohoku Earthquake, the use of small unmanned aerial vehicles (UAVs) for surveillance, such as for checking the initial situation after a disaster is attracting much interest. The NEC Guidance and Electro-Optics Division has been developing aerial surveillance systems using small motorized UAVs mounting optical sensors and image transmission modules, etc. This small UAV adopts a system that integrates a wide range of technologies involving: communication, control, sensing, image processing and networking. This paper introduces solutions being applied by the Guidance and Electro-Optics Division in the development of this new easily operated and portable tool that is capable of acquiring aerial image information expediently in a disaster situation.

Keywords

small unmanned aerial vehicle, disaster situation identification, surveillance, image transfer, communication relay

1. Introduction

The 2011 Tohoku Earthquake triggered a re-evaluation of the importance of quick appraisal of the initial situation following a large-scale disaster. Although existing aircraft are usable in a widespread disaster situation, their use immediately after a disaster may encounter problems due to the restricted number of available aircraft or of suitable sites for take-off and landing. Such issues are solved by quickly and easily identifying the actual disaster situation by the use of panoramic aerial views. Consequently, the use of small UAVs for multiple purposes including the observation of nuclear power plants and coastal surveys is attracting much attention.

NEC Guidance and Electro-Optics Division has developed a small UAV-based surveillance system (hereinafter referred to as “the system”) to enable collection of information from the sky above an area that may be hardly approachable by humans, such as from above a remote disaster site. The small UAV used in the present system has a wingspan of about 2 meters and a weight of about 4 kg, which allows it to be deployed easily in disaster sites and also to enable assessment of the situation quickly and safely.

This paper introduces the efforts being made by NEC in the rapidly developing UAV market that is expected to grow even more in the future. We include an outline of the system, the history of its development and a description of the technologies that are applied, as well as discussing the anticipated applications fields of the future.

2. UAV Business Undertakings

The Guidance and Electro-Optics Division has a plant that is licenced to manufacture aircraft under the Japanese Aircraft Manufacturing Industry Act. We have been developing and manufacturing UAVs and associated systems such as controllers, mainly for the Japanese Self Defense Forces, for about half a century. As a result, our UAV business has already shipped more than 1,000 unmanned target/reconnaissance aircraft and associated systems. As part of the Training Exercise for Civil Protection, in 2005 we flew a US-made small UAV beside the Mihama Nuclear Power Plant in Fukui Prefecture in order to demonstrate the usefulness of small aerial vehicles in disaster-prevention activities.

Based on the above experiences, the Guidance and Electro-Optics Division has been developing technologies associated with UAVs, such as compact communication systems and net-

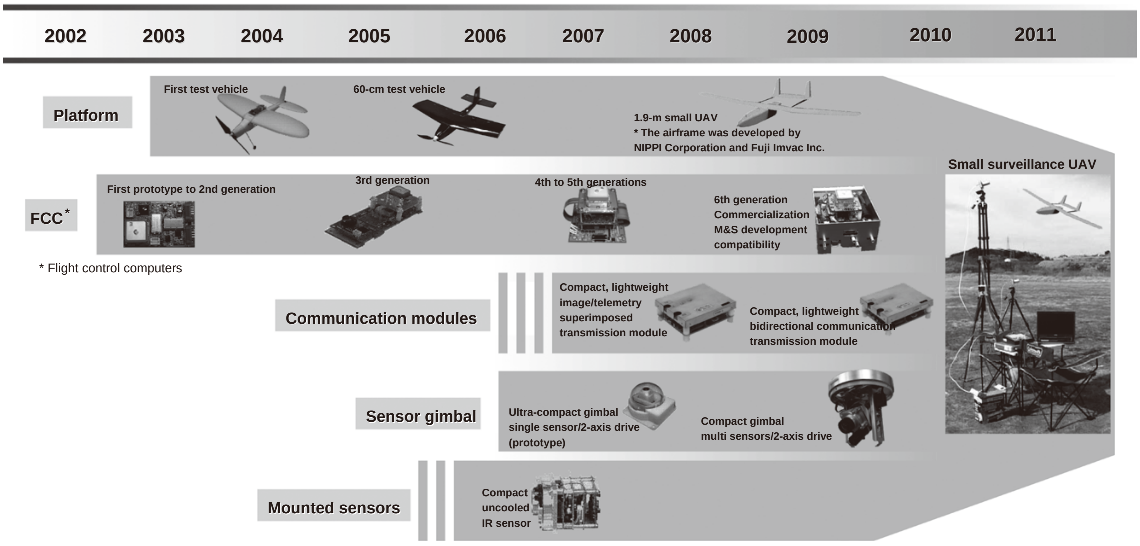

Fig.1 History of the development of technologies associated with the small UAV system.

work distribution systems, by using UAVs developed by NIPPI Corporation as the chosen platform as shown in **Fig. 1**. Below, we introduce an outline of the system, the history of its development and details of the technologies that are applied, as well as suggesting applications fields to be expected in the future.

3. Technologies Associated with Small UAVs

3.1 System Outline

This section deals with an outline of small UAV systems. The present system is composed of a small UAV, the ground system (control system and image reception system) and the launcher (weight about 5 kg). **Photo 1** is an external view of the small UAV and **Table 1** gives its main specifications.

Assuming its use for identifying the situation immediately after a disaster event, the system is designed to facilitate the transport, deployment and assembly to/in the proximity of the surveillance target area. The airframe can be dis-assembled into four parts. These are the fuselage, the two main wings and the tail unit. Reassembly is then possible by two or three persons. The flight program can be input in advance to the ground system by setting the waypoints. A bungee launcher is used to launch the aircraft so that a stable take-off is assured. The small UAV has a flight control module integrating a GPS, gyro, etc. After the launch, the craft executes auto flight along the way points by recognizing its positions. In order to deal with the difficultly of stationary flight above a fixed point, which is one of the disadvantages of a fixed-wing craft, it is equipped with a continual target capturing mode that enables loop maneuvers above a key surveillance target.

Photo 1 External view of UAV.

Table 1 Main specifications of UAV.

Item	Specifications
Overall length / Wing span	1,440 mm / 2,050 mm
Take-off weight	4.6 kg
Payload	500 g
Endurance	Max. 30 min.
Max. / min. speed	90 kmph / 60 kmph
Propulsion method	Electric motor drive
Flight method	Auto flight by pre-programming
Landing / takeoff method	Launcher / Parachute

The operator can identify the current flight position of the small UAV on the display monitor of the ground system in order to obtain the necessary video/image information. Surveying and recording of the view from the aerial vehicle and capturing the required still images from above, are also possible. The images are synchronized with the telemetry data, so the system has a position locating function that calculates the position (latitude and longitude) of the surveyed target based on the current UAV position. Furthermore, the system can transmit still images or video to a client PC in a remote location via the network. These facilities are regarded as being useful, for example, in order to advise of the position of a dam formed by a landslide during river surveillance.

When finishing a flight, the parachute is deployed by the deployment instruction so the UAV can be landed and recollected without the need of skill in maneuvering. Thanks to the slow fall rate, the parachute is a relatively safe collection method, which is also effective as a safety measure against contingencies such as significant deviation from the airway.

3.2 Compact Communication Module

Based on results obtained from the UAV demonstration operation at the Mihama Nuclear Power Plant mentioned above, we have developed an image transmission module independently for sending the video and telemetry information. **Photo 2** shows an external view of the compact image transmission module.

Although the transmission power is 10 mW (approved as specified radio equipment under Radio Act), transmission over about 2 km with a low-directivity antenna or about 5 km with a high-directivity antenna is possible. This is due to the bandwidth narrowing by applying compression to the image transmission downlink, the addition of error correction codes and the use of "diversity system" with the receiver antenna. The module also features a UHF band uplink communication function and its weight is about 60 grams, which puts it in the lightest class of the UAV industry. The frequency and transmission power are modifiable and the transmission range may be extended by obtaining a dedicated frequency.

3.3 Sensor Gimbal

In order to allow an uncooled IR sensor and a visible-light sensor both to be mounted on the UAV, we have developed a sensor gimbal that features compact size, light weight, and a 2- axis drive capability. **Fig. 2** shows an external view and the internal structure of the gimbal and **Table 2** shows its main specifications.

Fig. 2 External view and internal structure of the sensor gimbal.

Table 2 Main specifications of the gimbal.

Item		Specifications	
Material		Aluminum	
Weight		Approx. 600 g (including mounted sensor)	
Gimbal drive angles		AZ: ±95º EL: +90º to -20º	
Dimensions		130D × 130H mm	
Mounted sensors		Visible-light camera	IR camera (NEC)
	Video output	NTSC	NTSC/PAL
	Pixels	380,000 pixels	320(H) × 240(V)
	Weight	Approx. 50 grams	Approx. 150 grams
	Dimensions	25W × 25H × 28.5D mm	38W × 38H × 65D mm

The developed sensor gimbal introduces sheet metal for the internal frame in order to reduce the weight but adopts a unique integrated architecture that combines the frame with an aluminum semi-spherical dome to ensure adequate mechanical rigidity. In addition, an IR transmission insulation protection cover (a commercially available product) is fitted that is capable of providing protection from far-infrared (IR) rays as well as visible-light electro-optical (EO) rays, in order to integrate the camera window section and reduce weight.

While achieving an overall weight of about 600 grams by reducing the weight of component parts and adopting a compact, lightweight motor, the sensor gimbal still implements sufficient drive performance characteristics to enable the satisfactory flight of the UAV. The IR sensor mounted on the gimbal is an uncooled IR sensor for wavelengths of from 8 to 14 μm. This has been developed independently by us. Mounting it in combination with the visible-light sensor enables information collection even at night or against smoke. **Photo 3** shows the sensor gimbal mounted on a small multi-rotor helicopter (developed by Chiba University) in order to undertake performance assessment.

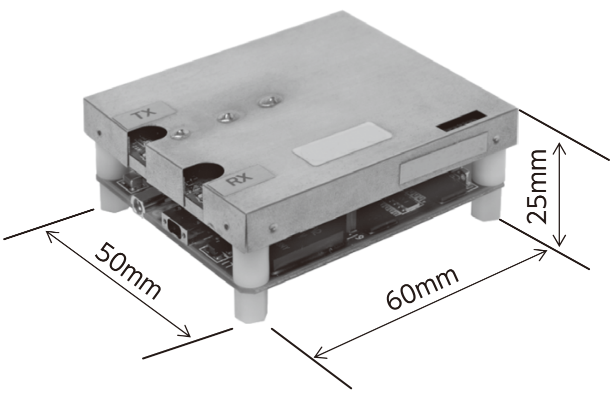

Photo 2 External view of the compact image transmission module.

Photo 3 Sensor gimbal mounted on a multi-rotor helicopter.

3.4 Information Distribution

This section describes the function for distributing the acquired image information to users. How to deliver the images and video acquired by the UAV to the users is an important issue. We made the system capable of real-time video distribution by providing the control terminal with a simplified server function that enables simple, quick video distribution from the disaster site to users.

Innovative features of the movie distribution function include the advantages that the control terminal incorporates the transmission function for working as a server and that the data is transmitted at fixed intervals (200 ms) for real-time transmission with minimal delay. In addition, the control terminal has a bi-directional communications capability so that in the future, it is expected to be suitable for directivity control of the UAV sensors from a remote location.

The movie distribution function also makes it possible to share information from the disaster site with mobile terminals such as smartphones via internet.

4. System Applications, Associated Equipment

4.1 Communication Relay

In a widespread disaster area such as that of the 2011 Tohoku Earthquake, the damage to the terrestrial information communication networks caused many areas to become isolated in terms of infrastructures, thereby hindering the rescue work and recovery activities. The communication relay system of the UAV can offer a means of providing rapid communications linkage in the network-isolated areas.

In collaboration with the National Institute of Information and Communications Technology (NICT) we have developed a UAV-mounted multi-hop communication system as part of the R&D for the "Disaster-Resilient Wireless Network" project. We demonstrated the system in the Disaster-Resilient ICT Symposium held in March 2013, using a UAV owned by NICT. **Fig. 3** outlines the communication relay system and **Table 3** shows its main specifications. With the present system, a UAV flying at 150 to 600 meters above a surveyed area relays communications between an area that is experiencing communications isolation as a result of a disaster and the backbone infrastructure. In the future, we will mount this communication relay system on our small UAV system (after evaluation) in order to support communications over a network-isolated area.

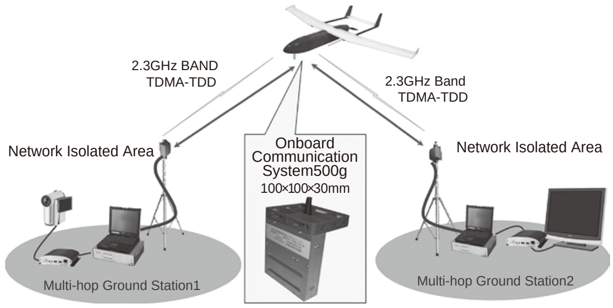

Fig. 3 Communication relay system outline.

Table 3 Main specifications of communication relay system.

Item	Specifications
Frequency	2.3 GHz band
Occupied bandwidth	8 MHz or less
Transmission power	2 W
Communication hops	2
Transmission capacity	Data rate: 6 Mbps User rate: 400 kbps
Mounted wireless equipment weight	≤ 500 grams (including mounted jigs and batteries)
Mounted wireless equipment dimensions (main body size)	approx. 100W × 100H × 30D mm

4.2 Application to Facility Surveillance/Mountain Forest Management

In addition to use in emergency situations such as disasters, the system can also be applied in usual conditions, for example in the management of dam facilities, mountain forests and coastal areas. It is not unusual in mountainous areas that flight is occasionally restricted due to sudden changes in weather and metrological conditions. With regard to application in mountainous areas, therefore, it is important to obtain imaging information of a broad area with as few flights as possible. To make the system applicable for the facility management operations of power companies, we are developing a UAV-mounted multi-eye camera unit that is equipped with three cameras mounted at the front and at both sides.

5. Conclusion

In the above, we introduced a small UAV system developed by the NEC Guidance and Electro-Optics Division and its associated technologies. The aerial information system using UAVs has an application potential in the measurement of radioactivity and for the relay of communications, as well as for the acquisition of information via images. In support of customer needs we are also studying platforms using multi-rotors as well as UAVs with fixed wings. By enhancing the development of these technologies we are gaining strength in the technologies that are introduced in this paper. We intend to continue our R&D efforts in the flourishing UAV “safety and security market,” which is expected to continue grow in the future.

Authors’ Profiles

WADA Akihisa
Senior Manager
Guidance and Electro-Optics Division

YAMASHITA Toshiaki
Senior Manager
Guidance and Electro-Optics Division

MARUYAMA Masaaki
Manager
Guidance and Electro-Optics Division

ARAI Takanari
Chief Engineer
Guidance and Electro-Optics Division

ADACHI Hideo
Chief Engineer
Guidance and Electro-Optics Division

TSUJI Hirokazu
Guidance and Electro-Optics Division

Information about the NEC Technical Journal

Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese | English

Vol.8 No.1 Solving Social Issues Through Business Activities

Vol.8 No.1

September, 2013

Special Issue TOP