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Special Articles on Advanced Technologies

Blade-free Drone

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A "blade-free drone" is a blimp-style drone for safe indoor flying without the use of propellers or flapping wings. It stays afloat through the buoyancy of a balloon filled with helium gas and moves through the air by a propulsive force generated by microblowers that can operate as "air pumps." In this article, we present an overview of this blade-free drone and describe demonstrations in Japan and abroad.

1. Introduction

Unmanned aerial vehicles (hereinafter "drones") that can fly around freely in the air have been attracting attention in recent years and have even been called the "Industrial Revolution in the Air." This can be attributed to the rapid drop in the price of drones and improved performance following the market launch of the AR DRONE®*1 from Parrot in 2010 [1], as well as the ability of drones to fly freely in space, their wide range of application, and the many possibilities they hold. Some examples of drone applications are aerial photography, surveying and inspecting, distribution, agriculture, and rescue services plus various forms of entertainment [2] [3].

However, this expansion of drone use has been accompanied by discussions regarding safety and regulations. For example, a fast-moving propeller or flapping-wing mechanism that collides with a person or thing may not only cause serious injury or harm but also damage the drone itself. The noise generated by drones during flight and short flight times are also issues of concern.

With the above in mind, NTT DOCOMO has proposed a blade-free drone that can fly through

† Worked at Research Laboratories up to March 2019

*1 AR DRONE®: A trademark or registered trademark of Parrot, a French company.

the air using microblowers that eject air through safe and small ultrasonic vibrations as an alternative to a rotating-blade or flapping-wing mechanism [4]. These ultrasonic vibrations are very small in amplitude on the order of micrometers, which makes for safe operation without the risk of injuring a person and very quite operation as well. In addition, the blade-free drone uses these microblowers only when moving through the air in the manner of a blimp, which enables long flight times. For these reasons, we expect this technology to be applicable to people-filled environments in which flight by conventional drones is difficult, such as indoor live events and concerts over the heads of spectators, shopping malls and offices, etc.

In this article, we present an overview of this blade-free drone and describe demonstrations at International Broadcasting Convention 2019 (IBC2019), Europe's largest broadcasting equipment exhibition.

2. Overview of Blade-free Drone

An external view of the blade-free drone is shown in **Photo 1**. The blade-free drone has a maximum diameter of about 90 cm with an airframe weighing about 200 g. However, as explained later, its relative weight when in terrestrial air is 0 g as a result of filling the airframe with helium gas to obtain buoyancy equivalent to the mass of the drone.

The structure of the blade-free drone is shown in **Figure 1**. This drone can be broadly divided into the following three sections:

(1) Balloon to produce an airframe center of buoyancy
(2) Microblowers on the left and right sides of the airframe to produce propulsive force
(3) Other parts in the lower section of the airframe such as battery, control circuit, and plumb for adjusting airframe weight

Each of these sections is described in more detail below.

2.1 Balloon

Having a diameter of approximately 80 cm, the balloon is set at the center of the drone and filled

Photo 1　View of blade-free drone

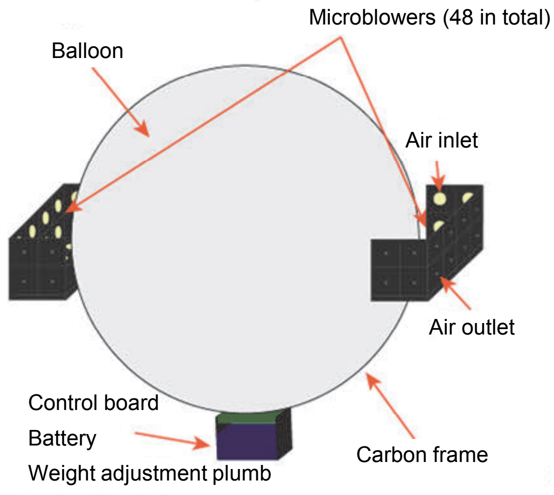


Figure 1 Structure of blade-free drone

with helium gas so as to obtain buoyancy equivalent to the weight of the airframe. It is a commercially available product that is large enough to accommodate the amount of helium gas needed to produce a 200 gworth of airframe buoyancy. The balloon is made of high-strength aluminum metallized film that makes it difficult for helium gas to escape. It is highly crack resistant so that one filling of helium gas obtains enough buoyancy to keep the airframe flying for several weeks. In addition, the balloon can be reused even if the amount of helium gas should decrease with long-term use by simply filling it with more helium, which makes for low-cost operation. The drone is also equipped with a carbon frame surrounding the balloon using tape to attach the former to the latter. Microblowers are installed on the left and right sides of the carbon frame while other parts such as battery, control circuit, and plumb for adjusting airframe weight are installed at the bottom.

2.2 Microblowers

The balloon itself simply floats and requires a separate propulsive force to move about in air on its own. For this reason, our blade-free drone uses microblowers each of which can eject air through ultrasonic vibrations generated by a piezoelectric device as an actuator*2 for obtaining this propulsive force. A piezoelectric device can generate a minute amount of vibration by applying an AC signal, and as such, it has come to be used in a wide range of devices including speakers and ultrasonic motors. The microblower shown in **Figure 2** is an air pump marketed by Murata Manufacturing Co., Ltd. using a piezoelectric device as a drive source.

A conventional air pump takes in and expels gas using a built-in fan and solenoid*3 as a drive

*2 Actuator: A mechanical element which produces a physical force using the energy applied. For example, motors and hydraulic cylinders.

*3 Solenoid: A mechanical element for converting electrical energy to mechanical linear motion using the magnetic effect produced when passing current through a coil of wire.

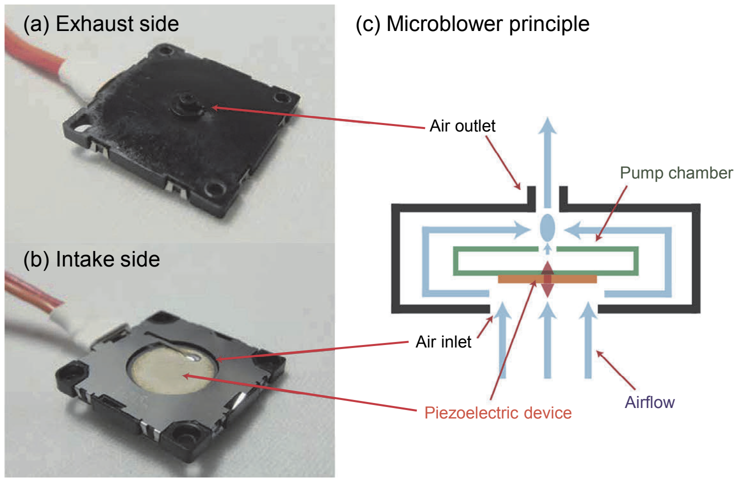


Figure 2 Structure of microblower

source, but with this microblower, the air pump operates by generating ultrasonic vibrations with a piezoelectric device. The microblower is compact and light, and the drive frequency of the piezoelectric device is 26 kHz, which is in the ultrasonic range that can barely be heard by humans resulting in extremely quiet operation. In addition, the amplitude of the built-in piezoelectric device is extremely small on the order of micrometers, which means a highly safe product that eliminates any worries about becoming entangled with fingers or hair. However, in contrast to propeller mechanisms that are frequently used in conventional drones, this microblower produces only a slight amount of airflow. Furthermore, in contrast to rotating blades, it cannot obtain a propulsive force in the opposite direction by reversing operation. To compensate for these shortcomings, we adopted a system that uses a balloon filled with helium gas to generate buoyancy corresponding to the weight of the airframe. This brings the airframe weight to essentially 0 g so that the drone can be moved with only a slight amount of force. As a result, the drone can be steered through the air by simultaneously driving multiple microblowers in the desired direction.

As shown in **Photo 2**, 24 microblowers are installed on either side of the airframe making for a total of 48 microblowers. These 48 microblowers are divided into 6 microblower groups of 8 microblowers each corresponding to the up and down, left and right, and forward and backward directions. The microblowers in each of these directions can be independently controlled, so simultaneously driving the up/down, left/right, and forward/backward microblowers in combination enables movement not only in each of these directions but also in any direction in three-dimensional space. However, pitching[*4] and rolling[*5] types of rotation cannot be performed since the center of gravity of the drone is located at the bottom of the airframe. On the other

*4 Pitching: Rotation about an axis running from left to right on the airframe.

*5 Rolling: Rotation about an axis running from back to front on the airframe.

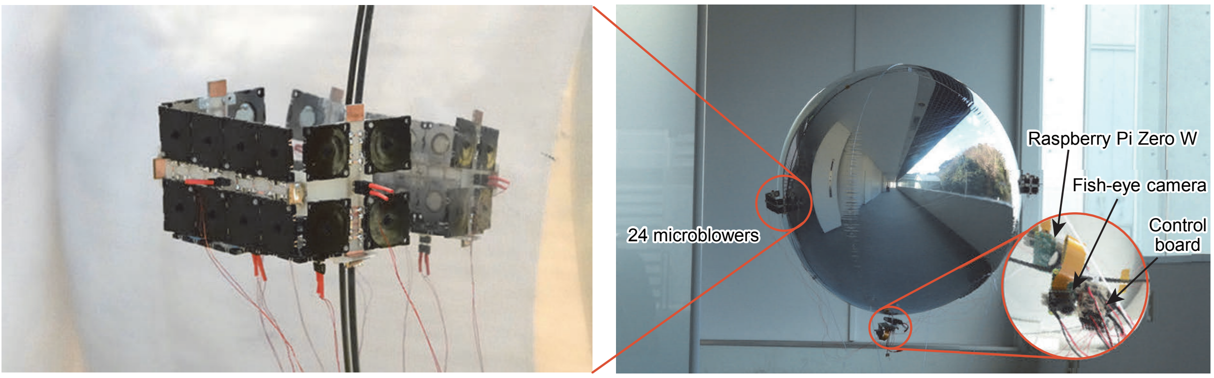


Photo 2 Installation of various parts on airframe

hand, yawing*6, or rotation in the lateral direction, can be achieved by mutually manipulating the microblowers for forward/backward motion attached on the left and right sides of the airframe.

2.3 Lower-section Parts

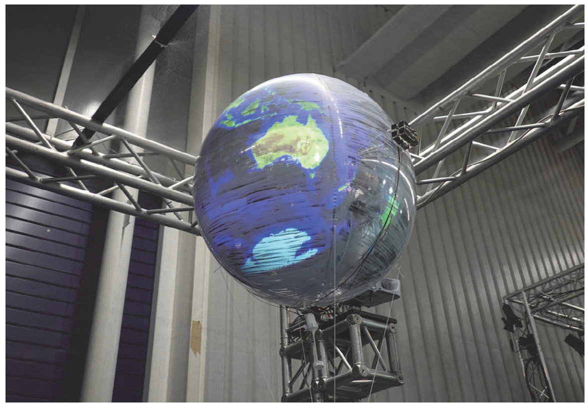
The lower section of the airframe mounts other parts such as a battery, control circuit, and plumb for adjusting airframe weight. The airframe battery is a 3S 450mAh Li-Po*7 rechargeable battery. Although depending heavily on the type of flight to be performed, a battery of this size can enable flight of about 1 – 2 hours in duration. Drone control is achieved with a Frequency Hopping Spread Spectrum (FHSS)*8 proportional system*9. The control circuit sends a maximum 22.2 V, 26 kHz AC signal to each microblower for control purposes based on signals received from a transmitter. Finally, the plumb for airframe adjustment is a lead ball 1 mm in diameter. The number of plumbs can be adjusted before flight to counterbalance the buoyancy of the airframe. Furthermore, as shown in Photo 2, a wireless camera can be mounted at the bottom of the airframe. Such a camera could be used, for example, to shoot video from above while flying the drone in a people-filled environment such as a shopping mall or office. The video obtained could then be analyzed to provide new security solutions or facilitate marketing by analyzing people flow, etc.

3. Demonstrations

After a press release issued on April 17, 2019, our blade-free drone was exhibited for the first time at "Nippon Telegraph and Telephone Corporation Mikaka Land, NTT Ultra Future Research Institute 6" at "Niconico Chokaigi 2019" held from April 27, 2019. At this exhibit, visitors were asked to pilot the blade-free drone flying within a cage-enclosed booth. The blade-free drone was also presented at International Broadcasting Convention 2019 (IBC2019), Europe's largest broadcasting equipment exhibition, held in Amsterdam from September 2013, 2019. As shown in **Photo 3** (a), this presentation included a demonstration of flying the blade-free drone within the NTT booth with visitors present to showcase its safe and quiet operation. As shown in Photo 3 (b), there was also a demonstration of projecting video onto the

*6 Yawing: Rotation about an axis running up and down on the airframe.
*7 Li-Po: A lithium-ion polymer rechargeable battery.
*8 FHSS: A type of spread-spectrum method used in radio communications that operates by rapidly changing the frequency of signals carrying data.
*9 Proportional system: A system that can steer an airframe in an amount proportional to the pilot's actions.

(a) Flight within booth



(b) Video projection

Photo 3 Demonstrations

blade-free drone from an external projector. Combining this drone technology with projection mapping in this way should enable the provision of space design solutions for displaying video in the air.

There is also a floating spherical drone display®*10 as technology for projecting high-resolution video in the air by drone. In contrast to that technology, the technology presented here requires an external projector and suffers from several problems such as low mobility and poor wind resistance. Nevertheless, we expect our blade-free drone to be applicable not only to the space above stages in indoor live performances or concerts but also to the space above spectators as well as to people-filled environments such as shopping malls or offices where the use of drones has traditionally been difficult from a safety perspective.

4. Future Issues

The blade-free drone adopts microblowers instead of propellers or flapping wings used in conventional drones thereby achieving a high degree of safety and quiet operation. Many issues still remain, though, with this technology. For example, the propulsive force of microblowers is very small, and since the drone airframe is large, even a slight breeze from air conditioning equipment can cause the drone to drift. In addition, the drone is slow reaching a maximum flight speed of only 20 cm per second. Moreover, a large balloon filled with helium gas is necessary, so while upsizing is easy, downsizing is difficult. Going forward, we aim to develop an actuator with even greater propulsive force while enhancing wind resistance and mobility so that this blade-free drone can be used to provide practical solutions.

5. Conclusion

In this article, we described a blade-free drone as a new type of drone that can fly without the use of propellers or flapping wings. Following its announcement in a press release, this technology was covered by a variety of television programs, newspapers, and Web news sites in Japan and abroad. The blade-free drone can fly even in environments with people present such as public spaces

*10 Floating spherical drone display®: A trademark or registered trademark of NTT DOCOMO, INC.

and can be used to perform sensing at any location from the air and to output video and audio content. With these capabilities in mind, we consider that the blade-free drone could contribute to the creation of a practical ubiquitous computing environment in the future.

Going forward, we aim to enhance the utility of this technology, develop actuators with even higher output, and develop applications such as projection mapping.

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