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Development of aircraft tracking camera system for sound power level measurement of aircraft noise

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ABSTRACT

In order to obtain sound power level in a single event of aircraft noise, not only successive series of noise levels in each 1/3 octave band under the flight path, but also distance between the measuring site and the aircraft is needed to measure; the sound power level is estimated by correcting for the amount of sound attenuation due to spherical spreading and air absorption based on the distance to the noise level obtained at the measuring site. As the technique for measuring this distance, we developed an aircraft-tracking camera system by combining a hemispheric camera and motion-tracking. The effectiveness of this system was examined by means of a case study, and it was confirmed that the distance can be reasonably measured just by leaving this system unattended.

Keywords: Aircraft noise, Sound power level, Motion-tracking, Hemispheric camera
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1. INTRODUCTION

Measurements of the aircraft noise in the vicinities of airports have been conducted to obtain require parameters such as (i) the sound power levels in single events for each aircraft type, (ii) representative flight paths, and (iii) the number of flights. [1].

As is shown in *Figure 1,* we have used measurements of successive series of noise and distance in field surveys to obtain the sound power levels. The noise must be recorded as the aircraft passes over the measuring site, and it is desirable to measure the distance between the site and the aircraft by tracking the aircraft position simultaneously while recording the noise. Finally, the sound power level is estimated by correcting for the amount of sound attenuation due to spherical spreading and air absorption based on the distance to the noise level obtained at the site. However, the method for measuring the distance is not unified, and triangulation in field surveys or airport-surveillance-radar monitoring has been used [2].

To detect the aircraft position from the measuring site, we have developed an aircraft-tracking camera (ATC) system by combining a hemispheric camera and the motion-tracking [3] and have examined the effectiveness of this ATC system through some case studies, one of which we present herein.

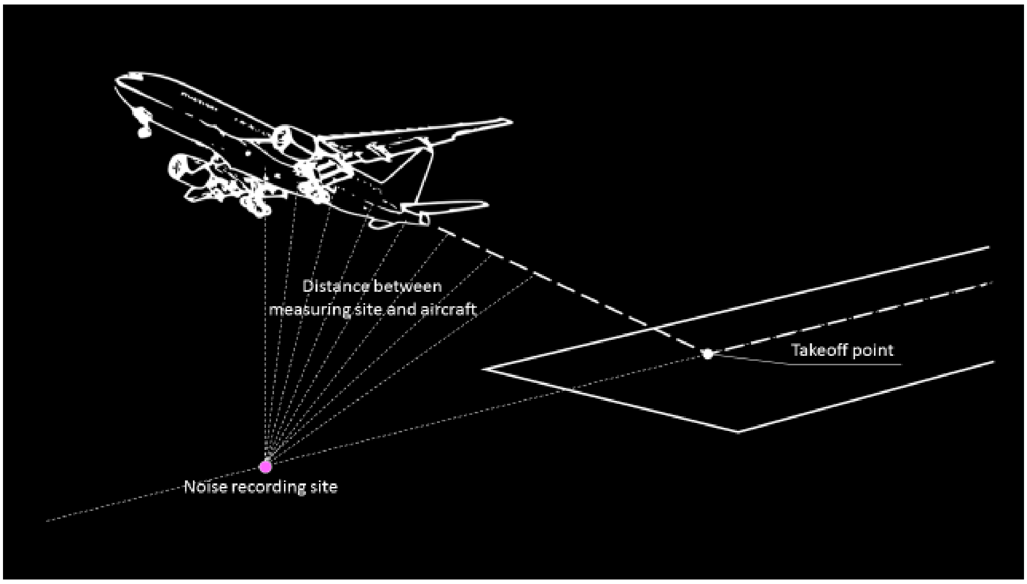

Figure 1: *Measurement of sound power level for aircraft noise*

2. AIRCRAFT-TRACKING CAMERA SYSTEM

One of our goals was to develop a simple, inexpensive, and practical ATC system that can operate unattended and be controlled remotely, which we achieved by adding network connectivity.

2.1 Hardware and Control

The composition of the ATC is shown in *Figure 2.* As the system controller, we use a Raspberry Pi 3 to control (i) the video filming, (ii) the encoding, (iii) the TCP connection via a network unit, (iv) the time management, and (v) the voltage management via an electrical power unit. Mounted on the board is a Camera module V2 (Daylight-element 14) and mounted on the camera module is an equidistant-projection fish-eye lens. These parts are protected by a purpose-built waterproof case to guard against any inclement weather during the field survey. When setting the ATC at the measuring site, the camera direction and tilt are correctly adjusted by using a compass and a level, respectively.

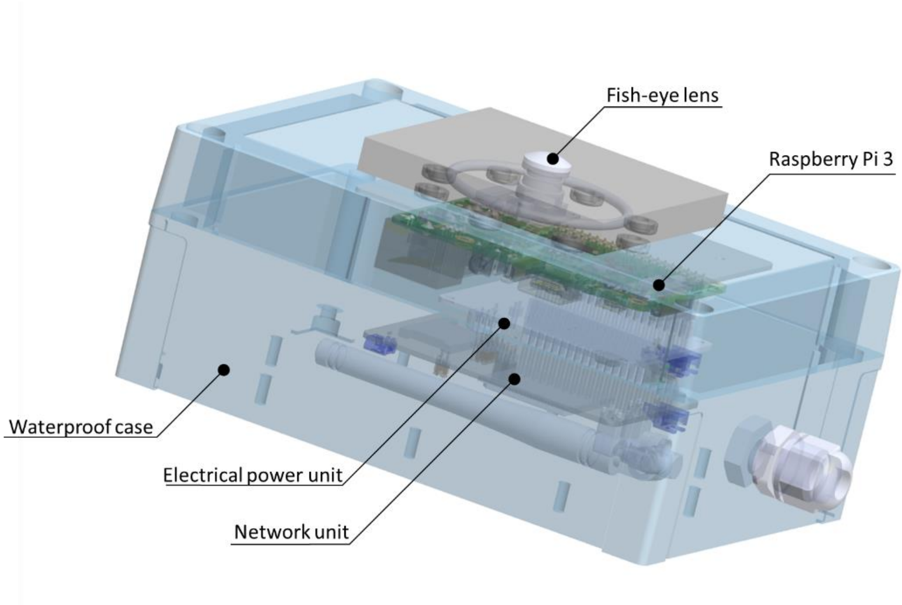

Figure 2: *Composition of aircraft-tracking camera (ATC) system*

2.2 Analysis Based on Motion-Tracking

A flowchart of the algorithm for calculating the altitude by detecting the motion from the videos is shown in *Figure 3*.

First, to correct for any mounting error of the camera lens, the circular edge of the fish-eye lens is detected from sample images taken by the camera, and the center pixel of the camera lens is estimated from that edge circle. Next, the center pixel of the moving object is detected using a very simple motion-tracking technique according to literature 4. Actually, the measurement using the ATC system must be conducted simultaneously at two measuring sites and up.

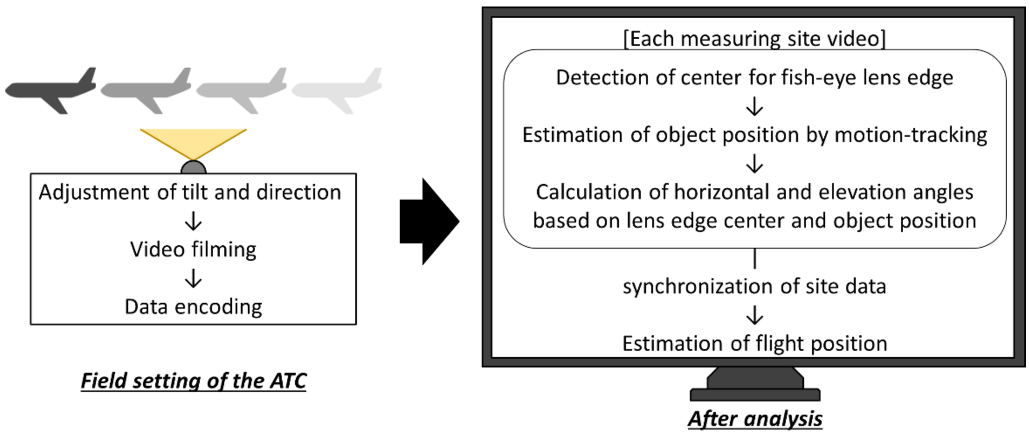

Figure 3: *Flowcharts of algorithm for detecting object motion using ATC system*

The horizontal and elevation angles are calculated at each measuring site, and the position of the aircraft as it passes over the measuring sites can be estimated by synchronizing the angles and time information from each measuring site, as shown in *Figure 4*.

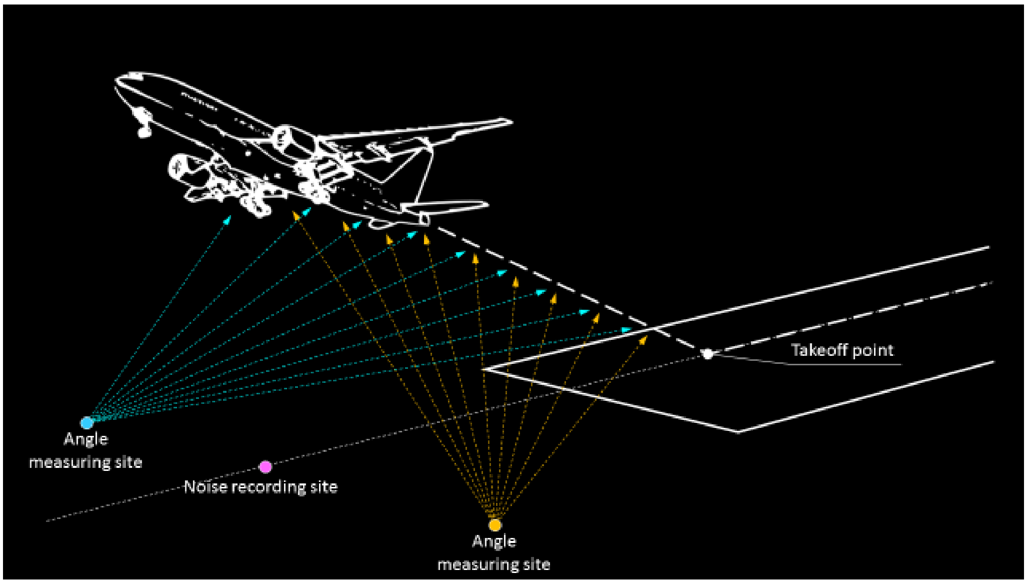

Figure 4: *Synchronization of the data measured at each site*

3. CASE STUDY

To assess the effectiveness of the ATC for field measurements, a case study was conducted near an airport. The altitudes of ascending aircraft at a given point were measured using the ATC and compared with those estimated using the method described in Section 3.1.

3.1 Comparison System

The previous system used for comparison with the ATC is shown in *Figure 5*. As shown in *Figure 5 (a)*, an inclinometer with a scope was mounted on a tripod and set at a given distance from the noise recording site. The elevation angle was measured by sighting the aircraft passing above the noise recording site as shown in *Figure 5 (b)*. Simultaneously, the same measurement was conducted on the opposite side across the flight path as shown in *Figure 4*, and the altitude of the aircraft at the noise recording site was calculated.


(a) Inclinometer *(b) Example of measurement*

Figure 5: *Pictures of measurement using inclinometer*

3.2 Airport and Measuring Sites

In the summer of 2018, we had the opportunity to measure aircraft noise at Da Nang International Airport in Vietnam. The measuring sites around the airport are shown in *Figure 6*. This airport has two runways, but only the right-hand one shown in the picture was used in the measurement period. Both of the aforementioned methods were used to measure the altitudes of taking-off aircraft at the two sites at the north end of the runway.

As shown in *Figure 7,* the ATC system was positioned so that it could monitor most of the flight path, with the tilt and direction of the system adjusted using the method described in Section 2. The direction of the scope mounted on the inclinometer was also adjusted using the compass.

Ⓐ *: Angle measuring sites; yellow line: flight path*

Figure 6 Measuring sites at Da Nang International Airport

(a) Site A1 *(b) Site A2*

Figure 7: *Location of each measuring system at angle measuring site*

3.3 Results

The altitudes calculated by both methods are compared in *Figure 8,* where the horizontal and vertical axes correspond to the results obtained using the previous method and the ATC, respectively. Most of the data lie on the 45° line, suggesting that the two sets of results are almost identical.

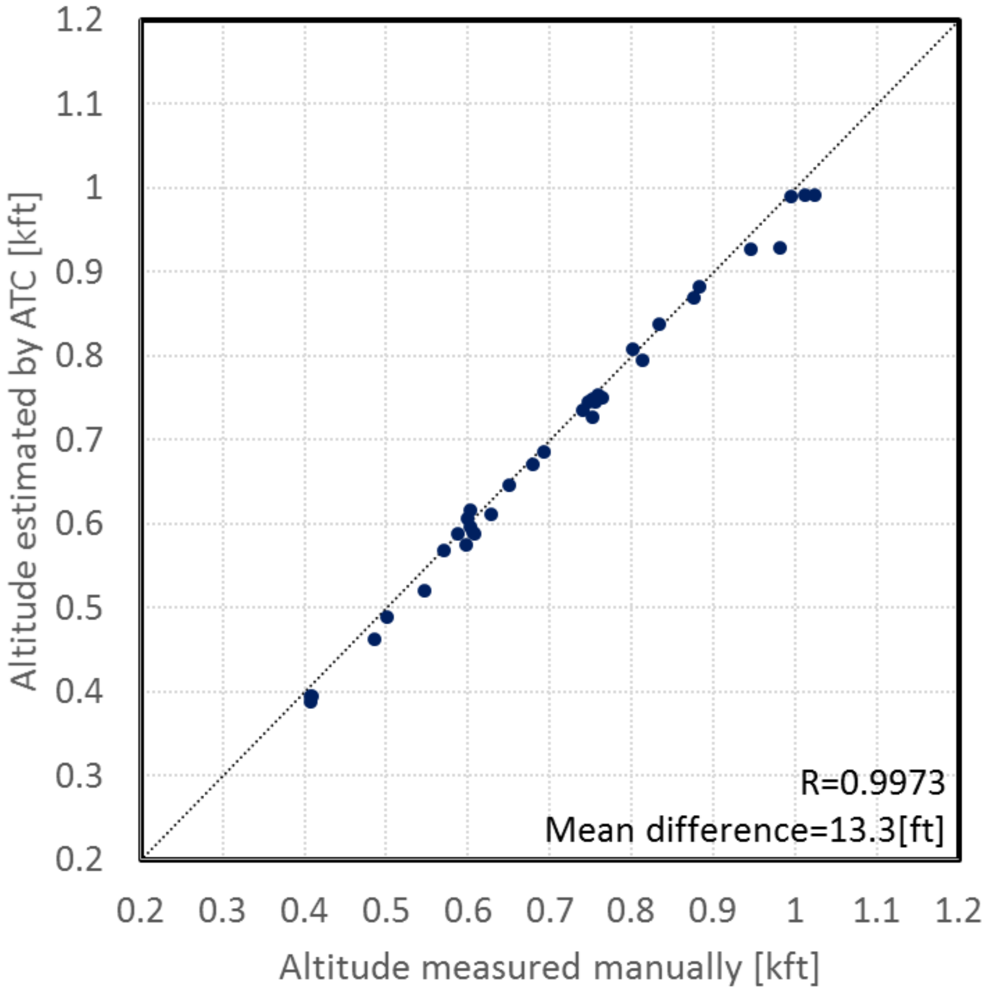

Figure 8: *Comparison of altitudes obtained manually and with the ATC*

4. DISCUSSION

In this paper, the ATC is shown to be effective, but various issues remain to be clarified in future work, as discussed below.

4.1 Successive Series of Aircraft Positions

Although the aim of the present study was to estimate the altitudes at a given site, in theory the ATC should also be capable of estimating successive aircraft positions. In the near future, we plan to compare successive aircraft positions estimated using the ATC with those obtained from monitoring by airport surveillance radar.

4.2 Accuracy Verification

Although the ATC has been shown to be effective for measuring aircraft altitudes, the present case study did not address the accuracy of the system. Consequently, we are planning laboratory experiments in which we will conduct static verifications of measuring the altitudes of fixed objects and dynamic verifications of tracking the positions of moving objects projected onto a screen.

4.3 Detection Limits and Weather Conditions

Sometimes, the ATC cannot detect an aircraft because of issues including (i) excessive speed, (ii) excessive distance, (iii) assimilation of target and background, and

(iv) rainfall. For the dynamic experiments mentioned in Section 4.2, a laboratory study is planned in which moving objects will be projected onto a screen while changing characteristics including the speed, the size, and the contrast ratio between the object and the background. Additionally, rainfall will be simulated in the laboratory.

5. CONCLUSIONS

Measuring the sound power level of aircraft noise requires not only the noise to be recorded also the distance between the measuring site and the aircraft to be measured. As a technique for doing the latter, we developed an ATC system that combines a hemispheric camera and a motion-tracking technique, and examined its effectiveness by means of a case study. The ATC system was used to estimate the altitudes of taking-off aircraft passing over the measuring site, and these altitudes were compared with those obtained manually. The two sets of results were almost identical, suggesting that this system is effective and could be used for future investigations.

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