International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

A model for predicting noise source-receiver distance based on an object detection function

Kang Dongshik [1] *, Iha Moritaka [1] and Thu Lan Nguyen [2]

[1] *Department of Computer Science & Intelligent System, Faculty of Engineering, University of the Ryukyus, Japan*
[2] *Department of Architecture and Production Design, Interdisciplinary Faculty of Science and Engineering, Shimane, University, Japan*

International Journal of Science and Research Archive, 2024, 13(01), 541–548

Publication history: Received 31 July 2024; revised on 08 September 2024; accepted on 10 September 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.1.1667

Abstract

An accurate aircraft noise prediction model is necessary to predict the damage caused by expanded and new-constructed airport projects. Some widely-used models are constructed based on noise-power-distance (NPD) data appointed for each aircraft model. However, the lack of NPD data for some types of military aircraft makes it challenging to predict noise around airports that serve both civil and military purposes. Since NPD data were obtained based on manual measurement and often spends required much of human labor and dedicated measuring equipment, therefore, it is desirable to have an automatic system for this effort. This study proposes a model that estimates the distance from the recording point to the airplane, or noise source-receiver distance, based on the video that captures the flight movements around the airport and then provides reliable NPD data of a specific aircraft. In this study, the time-series data of the flight movement were separated into sound and image components. Then, the time-series images were analyzed and input to M2det for object detection. Finally, the noise source-receiver distance was estimated based on the length of the airplane in the image identified by the object detection function.

Keywords: Aircraft noise; Prediction model; Noise power distance (NPD); Object detection; M2det

1. Introduction

In response to the fast-growing economies, many countries are actively promoting the development of air transport infrastructure to meet increasing air travel demand [1]. In tandem with the increase in flight operations, a drastic change in urbanization around the major airports in recent years have various negative impacts on the environment around the airport. In particular, the high level of aircraft noise has an especially severe impact on the quality of life and health of communities living near the airport [2-4]. An accurate aircraft noise prediction model is necessary to calculate noise due to arriving and departing air traffic and the damage caused by expanded and new-constructed airport projects. The noise contours maps produced by the noise prediction models are useful for noise compatibility planning, approval of airport noise restrictions, and environmental impact assessments impact in the airport's vicinity. Some widely-used models are constructed based on an acoustic database of noise vs. power vs. distance, noise-power-distance (NPD) values, appointed for each aircraft model, augmented by a database of spectral characteristics [5,6]. For example, the Integrated Noise Model (INM), a noise model developed by the Federal Aviation Administration (FAA), was widely used for evaluating aircraft noise impacts in the vicinity of airports [7].

However, the lack of NPD data for some types of military aircraft makes it challenging to predict noise around airports that serve both civil and military purposes. The noise released from military aircraft is assumed to be more severe than civil aircraft due to its high frequency and its long low-flying time. Since NPD data were obtained based on manual

* Corresponding author: Kang Dongshik

measurement and often spends required much of human labor and dedicated measuring equipment, therefore, it is desirable to have an automatic system for this effort. In response to this requirement, this study aims to propose a model that estimates the distance from the recording point to the airplane, or noise source-receiver distance, based on the video that captures the flight movements around the airport by using object detection technique. The purpose of this study is to support the establishment of reliable NPD data by a video of flight movement recorded at a specific airport. We conducted field measurements to obtain necessary data for this study at Cam Ranh International Airport, the fourth largest airport in Vietnam, and used by both civil and military aircraft.

2. Concept and method

In this section, M2det, a type of object detection technology, an existing manual process for measuring the elevation angle of the aircraft, and the method for automatically calculating the distance from the shooting point to the airplane, will be described.

2.1. Object detection, M2Det

Object detection is a technique for detecting the target objects in the image in which the object exists and what the object is. The recently invented object detectors use deep learning methods such as Single Shot MultiBox Detector (SSD)[8], and You Only Look Once (YOLO)[9]. The unattended system proposed in this study refers to object detection techniques M2det, an object detection technology announced in 2019 [10]. This method was evaluated to be better than previously invented detectors such as SSD and YOLO in the aspects of accuracy and data processing speed. The network structure of M2Det is shown in Figure 1.

2.2. Manual measurement method

The horizontal distance from the angle measurement point P_0 to the airplane and the elevation angle θ_1 from the measurement point to the airplane are required to estimates the noise source-receiver distance. The elevation angle was measured using an inclinometer, as shown in Figure 2.

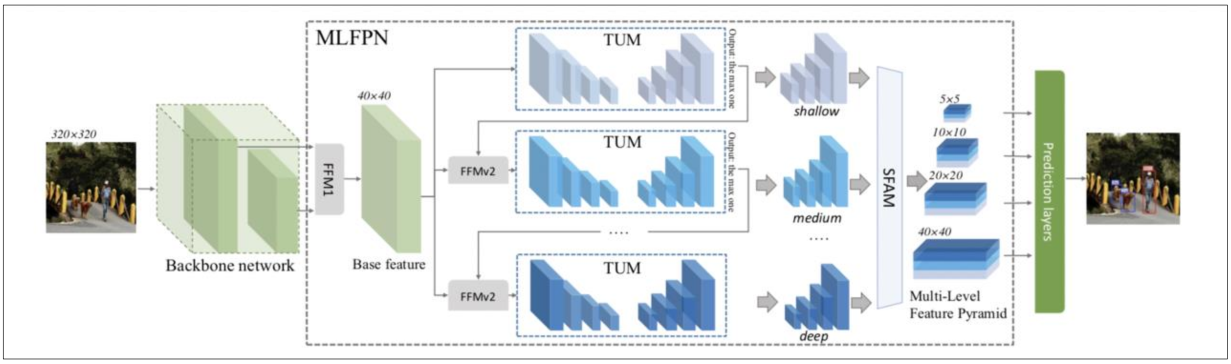

Figure 1 The network structure of M2Det: A Single-Shot Object Detector based on Multi-Level Feature Pyramid Network

(a) Inclinometer *(b) Measuring the elevation angle*

Figure 2 An existing manual process for measuring the elevation angle of the aircraft

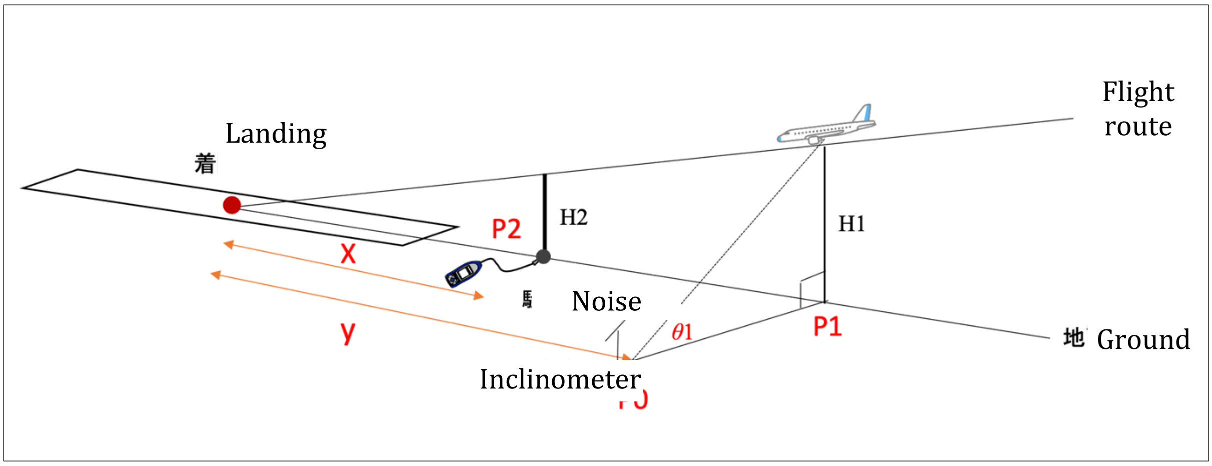

Figure 3 A diagram of the manual measurement of elevation angle with the inclinometer

Figure 3 shows a diagram of the manual measurement of the elevation angle with the inclinometer. The elevation angle θ_1 was measured when the airplane passed by P_1, the foot of the perpendicular line from the location of the inclinometer to the line extending from the runway that the aircraft will fly along for landing. The horizontal distance P_0P_1 was calculated based on the Global Positioning System (GPS) data. H_1 was calculated based on the distance P_0P_1 and the measured elevation angle θ_1 using a trigonometric function.

A sound level meter was placed under the flight path. H_2 is a distance between from the sound level meter to the airplane or a noise source-receiver distance at the time the airplane passes right above the sound level meter. The noise level at this time was recorded by the sound level meter. The distance H_2 is calculated from H_1 by the similarity ratio of X and Y (Equation 2.1). The distance between X and Y could be obtained from the GPS position information.

$$\frac{X}{Y} = \frac{H2}{H1} \tag{2.1}$$

Figure 4 shows an example of a pinhole camera model. Assuming that there is no lens distortion, the distance can be easily estimated. In Figure 4, Equation (2.2) holds from the similarity of triangles. And if all of $F1$, $F2$, $X1$, and $X2$ are known, the distance can be estimated even if the target object moves and the distance changes.

$$F1 = F2 \cdot \frac{X1}{X2} \tag{2.2}$$

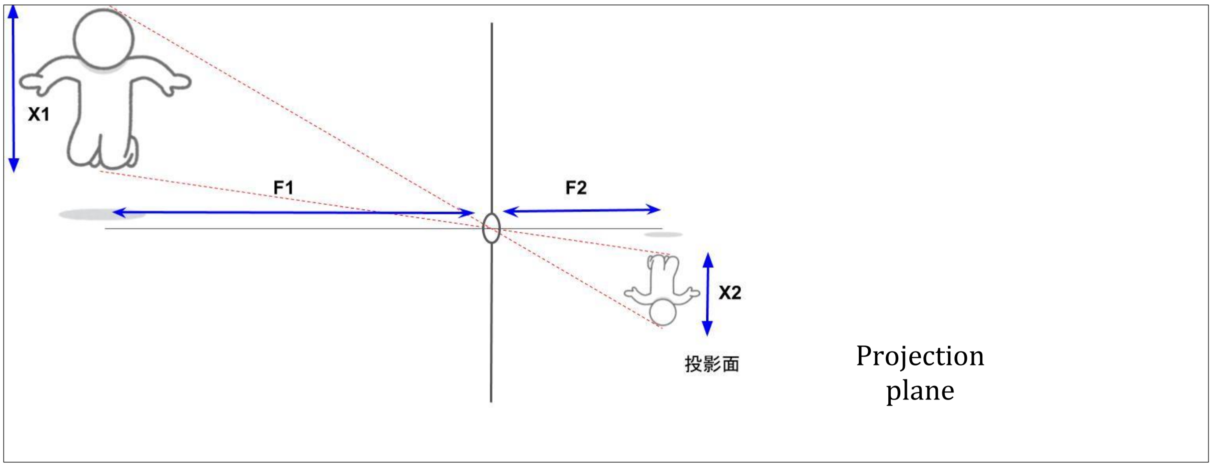

Figure 4 An example of a pinhole camera model

3. Proposed system

In this section, the structure of the system that estimates the distance from the shooting point to the airplane based on the image of the airplane is proposed. Then, the obtained data will be used to estimate the noise-power-distance relationship.

3.1. System overview

The outline of the proposed system is shown in Figure 5. First, the image of an airplane was divided into sound and sequential images. Next, the continuous images were divided into images one by one and input to the M2Det for object detection. The distance from the shooting point to the airplane was estimated based on the length of the airplane in the image identified by object detection. Also, the sound is analyzed into time-series volume and frequency components. Finally, the estimated distance data is matched with the volume to investigate the relationship between noise and distance.

3.2. Separation of video and audio

In object detection by M2Det, it is necessary to input a continuous image as an input, so the video is separated into a continuous image and audio. In order to this process, the free software *ffmpeg* [11] was used in this study.

3.3 Object detection

The continuous image was input to M2Det frame by frame, and the airplane which is the target object was detected. Figure 6 shows an example of detected airplane.

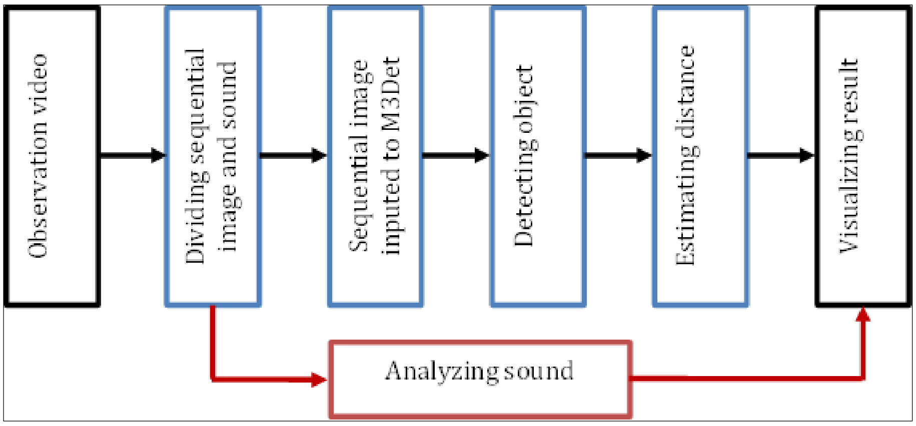

Figure 5 The process diagram of proposed system

Figure 6 The image illustrating the detection of the airplane

3.3. Distance estimation

3.3.1. Calculating the pixel size of an airplane

In the input image, the total length pixel size of the detected airplane was calculated by assuming two-dimensional coordinates with the origin (0,0) at the upper left in Figure 6. The pink square shows the image illustrating the detected of the airplane's length. The pixel size with the largest total length of the airplane in all images was used as the value when applying to the pinhole camera model.

3.3.2. Calculation of the closet distance

Figure 7 shows a model that calculates the actual distance from the camera to the airplane. In this model, the total length of the actual airplane is S, the focal length of the camera is f, and the length of the airplane reflected in the image sensor is s. The actual total length of the airplane was obtained from the airline's published model information. And the focal length of the camera is fixed at *25mm*. Furthermore, assuming that the length per pixel is about *0.1 mm*, the length of the airplane reflected on the image sensor can be calculated by using the model shown in Figure 7.

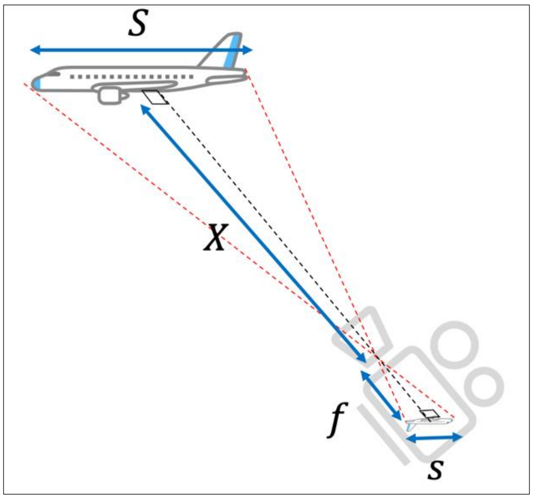

Figure 7 The model that calculates the distance from the camera to the airplane based on the total length of the airplane and the focal length of the camera

3.4. Analysis of airplane sound

The frequency spectrum was obtained by performing a short-time Fourier transform on the audio files separated by the *ffmpeg* function. This spectrum was depicted in a three-dimensional graph of time, frequency, and volume by frequency. An example is shown in Figure 8. The built-in microphone of camera was used for the audio data of this system, but this microphone does not accurately record high frequencies above *16k*Hz. However, it is possible to investigate the tendency of the noise generated by airplanes.

3.5. Analysis of airplane sound

Finally, the relationship between the distance from the camera to the airplane and the fluctuation of noise is visualized in a graph. The observation data used in this study is sampled about *30* times per second for video and *48,000* times per second for audio. In Figure 8, the average volume for a distance interval of *0.5* seconds is plotted, which shows the relationship between distance and noise. Finally, the volume of the sound and the total length of the airplane were shown on the video and visualized. The results are shown in Figure 9.

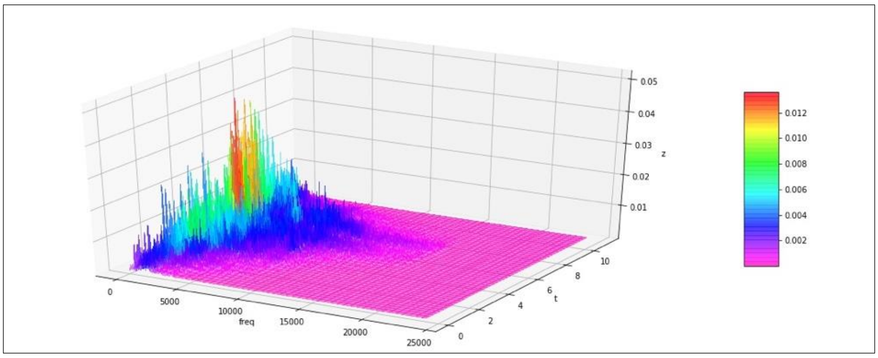

Figure 8 An example of the three-dimensional graph of time, frequency, and volume by frequency performed by a short-time Fourier transform on the audio files separated by the ffmpeg function

Figure 9 The volume of the sound and the total length of the airplane were shown on the video and visualized

Table 1 Comparison between the distance calculated manually with the distance estimated by the system proposed in this study (Unit : meter).

Airplane length	Manual calculation	Proposed method	Error
37.6	52.75	46.47	-6.28
44.51	51.76	52.82	1.06
44.51	51.87	51.29	-0.57
37.57	52.85	49.51	-3.33
54.9	52.29	45.47	-6.81
44.51	53.12	47.82	-5.29
39.5	53.30	47.11	-6.18
44.51	53.55	49.15	-4.39

4. Experiments

In this section, the accuracy of the distance estimation of the proposed system was verified. These relationships between distance and noise data was also considered.

4.1. Experimental environment

The observation image used in this experiment was taken with RICOH's 360-degree camera Theta-S, which is equipped with two fisheye lenses. The image taken by this camera is a 360-degree image and cannot be used as it is. Therefore, an application called Insta360 Studio 2019 was used to extract the area from the 360-degree video so that the side of the airplane can be seen. In addition, this system was built with a python program, and a series of processes are executed by Google Colaboratory.

4.2. Accuracy of distance estimation

The accuracy was verified by comparing the distance calculated manually with the distance estimated by this system. In this experiment, eight images taken at Da Nang Airport in Vietnam were used, and the results are shown in Table 1. In this comparison, the distance when the airplane was closest to the observation point was targeted. The error is the estimated value of the system minus the manually calculated value, with a minimum value of approximately 0.57 meters, a maximum value of approximately *6.81* meters, and an average of *4.24* meters. From the table, it can be seen that this system estimates *7* of the *8* data with a shorter distance than the manually calculated value.

4.3. Relation between distance and noise

The overall trend of the noise-distance relationship is that the noise is louder when the distance between the plane and the camera becomes closest, and lower when the airplane is farther from the camera. As for the volume by frequency, the low frequency sound around *500*Hz is loud. This result could be interpreted that low frequency sound might contain many environmental sounds other than airplanes. In Figure 8 of volume by frequency, it can be considered that the loud noise before the airplane approaches most is low frequency, that is, the environmental sound is recorded loudly. In addition, when comparing the distance and the volume by frequency, the frequency tends to be higher near the time when the distance between the airplane and the camera is the shortest than at other times. According to Figure 10, we can see a loud noise before the airplane comes closest.

Regarding the volume by distance and frequency, there was a tendency for higher frequencies to be included when the distance between the airplane and the camera was the shortest than at other times. However, as a result of comparing the distance data estimated by this system with the distance data calculated manually, the accuracy varied. The reason is that the lens of the camera Theta-S used to calculate the distance uses a fisheye lens, which was possibly affected by distortion. Besides, although the focal length of the camera was set to *25mm*, the actual focal length is not known accurately because the internal information of the product is not disclosed for Theta-S camera.

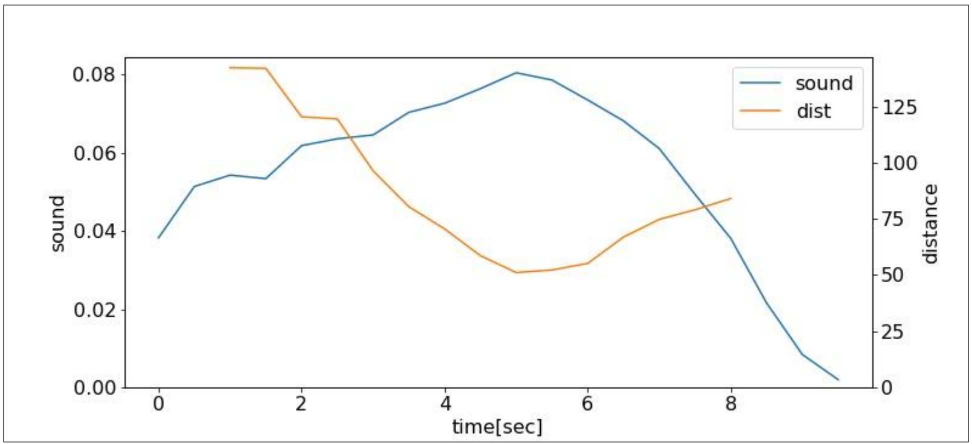

Figure 10 Comparison between the sound and the distance

5. Conclusions

While the existing manual method of measuring the distance to an airplane requires much labor and measurement equipment, this distance can be obtained with only a camera by the system proposed in this study. Besides, the accuracy of the distance estimation of this system, which was *5* meters or less on average when compared with the manually calculated value, indicated the reliability of the system. However, since the sound is data measured by the microphone mounted on the camera, the high-frequency component is attenuated. In a further study, it will be necessary to verify the estimated sound with those of the sound level meter.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] *Airports Council International. World Airport Traffic Forecasts, 2018–2040*; ACI World: Montreal, Canada, 2018. Available online: https://store.aci.aero/product/annual-world-airport-traffic-report-2019/ (accessed on 27 March 2020)

[2] Hansell, A.L.; Blangiardo, M.; Fortunato, L.; Floud, S.; de Hoogh, K.; Fecht, D.; Ghosh, R.,E.; Laszlo, H.E.; Pearson, C.; Beale, L.; et al. Aircraft noise and cardiovascular disease near Heathrow airport in London: Small area study. *Br. Med. J.* **2013**, *347*, f5432.

[3] Brink, M.; Wirth, K.E.; Schierz, C.; Thomann, G.; Bauer, G. Annoyance responses to stable and changing aircraft noise exposure. *J. Acoust. Soc. Am.* **2008**, *124*, 2930–2941.

[4] Fidell, S.; Silvati, L.; Haboly, E. Social survey of community response to a step change in aircraft noise exposure. *J. Acoust. Soc. Am.* **2002**, *111*, 200–209.

[5] International Civil Aviation Organization (ICAO), Recommend method for computing noise contours around airports, Doc 9911, First Edition (2008).

[6] SAE AIR 1845 Ed. STABILIZ (2012) Procedure For The Calculation Of Airplane Noise In The Vicinity Of Airports.

[7] Integrated Noise Model (INM) Version 7.0 User's Guide (2007).

[8] Wei Liu, Dragomir Anguelov, Dumitru Erhan, Christian Szegedy, Scott Reed, ChengYang Fu, Alexander C. Berg . SSD: Single Shot MultiBox Detector, https://arxiv. org/abs/1512.02325 , 2019/2/19.

[9] Joseph Redmon, Santosh Divvala, Ross Girshick, Ali Farhadi. You Only Look Once: Unified, Real-Time Object Detection, https://arxiv.org/abs/1506.02640 , 2019/2/19.

[10] Qijie Zhao,Tao Sheng,Yongtao Wang,Zhi Tang,Ying Chen,Ling Cai,Haibin Ling (2019/01/19) .「M2Det: A Single-Shot Object Detector based on Multi-Level Feature Pyramid Network」, AAAI2019, https://qijiezhao.github.io/imgs/m2det.pdf, 2019/11/19.