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Algorithm for Automatic Acoustic Detection of Ship and Marine Mammals

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Abstract：Responding to the increasing number, size, and speed of commercial ships, the underwater noise is also increasing which could result in a possible adverse impact on marine lives. For clarifying this possible concern, a method for measurement of ship noise and marine lives is required, especially for marine mammals which are sensitive for the frequency range of ship noise. In order to enable to observe marine mammal's behavior and the ship noise simultaneously, this study developed an algorithm to detect ship noise, added to a conventional dolphin detection algorithm. The ship noise is obtained by eliminating some nature sounds and the dolphin's sonar sound. Both dolphin's sounds and ship noises can be separated efficiently so that the noise can be identified using sample data. Further improvement of monitoring system and algorithm are future tasks.

Keywords：A-tag, dolphin, acoustic data logger, Automatic recognition, Thresholds

1. INTRODUCTION

Responding to the increasing number, size, and speed of commercial ships, the underwater noise could result in a possible adverse impact on marine lives (A Report to Congress from the Marine Mammal Commission 2007, Wright, A.J. (ed) 2008). In particular, sounds are vital element for marine mammals as vision for humans because marine mammals use sound for communication, individual recognition, predator avoidance, prey capture, orientation, navigation, mate selection, and mother-offspring bonding (Wartzok and Ketten 1999). This is one of the reason why the International Maritime Organization (IMO) agreed the proposal that underwater noises from ships should be decreased at its 58th Marine Environment Protection Committee (MEPC 58) in 2008 (IMO 2008). In the future, automatic monitoring systems for underwater noises could be required. Nevertheless, few methods for measuring ship noise and marine lives are available far. This study attempts to provide a base automated measurement of ship noise and marine lives.

2. ACOUSTIC DATA LOGGER

In this study, the data of ambient noise are obtained using two stereo acoustic data loggers, known as A-tag (Little Leonardo Ltd., Tokyo, Japan, in 2006; Marine Micro Technology, Saitama, Japan, in 2007), towed by a small fishing boat (Fig.1). The A-tag is an event data logger that records 1) Sound Pressure Level (SPL) and 2) the difference in time arrival between two hydrophones.

The A-tag consists of two set of hydrophones, preamplifier with band pass filter, CPU (PIC18F6620), flash memory (128 Mbytes), and lithium battery cell (CR2). The hydrophones had a sensitivity of MHP-140 (Marine Micro Technology) -201 dB (1 V/ Pa) and a resonant frequency of 130kHz. This setting reduces noise outside the sensitive band of the hydrophone at sound reception. Hydrophone sensitivity was calibrated using an acoustical measurement tank (10 m in width, 15 m in length, and 10 m in depth) at the National Research Institute of Fisheries Engineering. The ultrasonic sound transmission system used in calibration consisted of a function generator (NF1930A, NF Corp., Tokyo, Japan) and a broadband transducer (Furuno Electric Co. Ltd, Imaizumi et al 2008); the system generated a 10-cycle tone burst for any frequency.

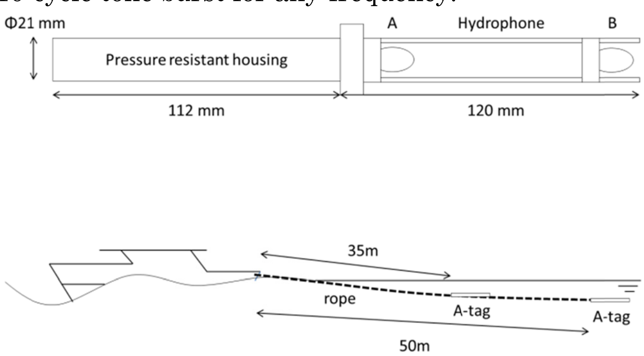

Fig.1. specification of the A-tag and layout of measurement

Each A-tag had two hydrophones, approximately 170 mm apart, which are used to identify the sound source direction. The acoustic data logger records the sound pressure at the primary and secondary hydrophones, the difference in sound arrival times between the two hydrophones and the pulse interval, every 0.5 ms (2 kHz event sampling frequency). These three data sets and the absolute time are recorded automatically only when the received sound pressure is greater than the trigger level of the primary hydrophone. Otherwise, no data are stored to conserve memory capacity. The A-tag can record information up to 30-40 h, depending on the quantity of data.

The bearing angle of a sound was calculated using the difference in time arrival between the two hydrophones. The triggering time of both hydrophones was monitored every 271 ns. Sounds traveled 0.4 mm in 271 ns, while the baseline (the separation between the two hydrophones) is 170 mm. Therefore, even this short baseline system allows a fair bearing angle resolution. Signal processing and structure are described in more detail in Akamatsu *et al.* (2005).

Usually A-tags have been used for counting the number of porpoises so that the main subject of the obtained data has been marine mammals' sound. This study applies this technology on the underwater noise and intends to contribute to development of automatic ambient noise monitoring systems. (Kimura *et al* 2009, Kimura *et al* 2010)

3. BIOSONAR SOUNDS

We developed a computer program considering the following feature of dolphin's biological sonar sound (features X1-3) as described below..

[dolphin's sonar sound] (Fig. 2)
X1 : The number of data of one train is within a certain range.
X2 : Pulse intervals are not so scattered within a train.
X3 : Pulse intervals vary smoothly

Fig.2 shows the sample of porpoise noise. The upper diagram show the SPL (Pa), the middle diagram show the difference in time arrival between two hydrophones and the lower diagram shows sound intervals (ms).

4. ALGORITHM

We discriminated and identified target sounds with the 2 procedures: one is Pulse-by-pulse Analysis and the other is Pulse Train Analysis. In Pulse-by-pulse Analysis we judge whether it is dolphin's sonar sound from one sound's feature. After Pulse-by-pulse Analysis, the data are divided into some series of sounds. We judge from the feature of one series of the pulse sounds (Train). This is the Pulse Train Analysis. More detail is as follows.

First, in the analyses, we exclude the other noises.

1) If only one hydrophone detects the sound, the difference in time arrival between two hydrophones is set as zero in the current system. Therefore we should exclude these sounds.
2) The data include reflections from the surface of the water. They appear shortly after a direct path sound detected. In this case, sound's intervals are very small. We should exclude these reflections.
3) Except for ship noise and dolphin's sonar sounds, the data include some isolated sounds. This could be created by phonating marine creatures such as snapping shrimps. These noises should be also excluded.

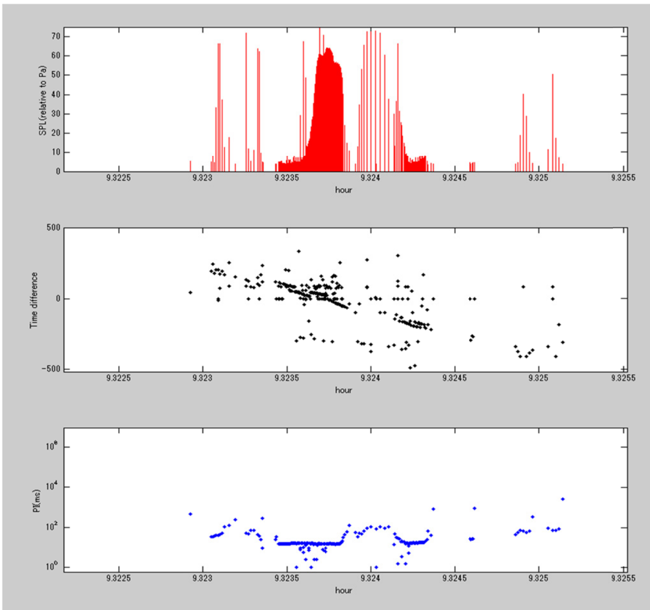

Fig.2. The sample of porpoise noise

5. SOURCE CODING

Next, for realizing the above purpose within the computer program, we attempted to distinguish the dolphin's sonar sounds by applying the following rules.

1) Whether is the number of data in a sound train large(X1)?
   If the number of data is larger than 5, it is judged a dolphin's sonar sound candidate.
2) Whether do the sound intervals which are represented "PI" vary smoothly(X2)?
   If the variance PI within a train is smaller than 0.5, it is judged a dolphin's sonar sound candidate.
3) Whether do the PIs and SPLs vary or not (X3)?
   We define the pulse intervals PI(j) and PI(j+1) like Fig. 3. Here j is a natural number.