Low-power Dolphin Sound-triggered Underwater Acoustic Recorder Based on Energy Spectrum and Cross-correlation Analysis

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Abstract

In order to study how dolphins transmit information through sound, a dolphin sound triggered underwater acoustic recorder was designed to collect sound samples of dolphins communicating. When working underwater for a long time, the dolphin voice signal recorder often faces the problem of insufficient power and limited storage space. In response to this problem, this paper proposes a dolphin sound signal recorder with STM32F407 as the main processor and MSP430F5438A as the coprocessor, which can work on the seabed for a long time and store sufficient samples of dolphins' communication sounds for scientific analysis. The paper specifically introduces the design of acoustic triggering algorithm and the design of dolphin sound signal recorder.

Introduction

The purpose of collecting sound samples of dolphins communication is to study how dolphins transmit information through sound . Dolphin cognition and communication research is a significant sub-field of marine mammalogy. Communication signals of animal groups can give valuable insight into their social structure . The acoustic signal of dolphins is of great significance to dolphins' predation, perception of the environment and group communication. The recording of dolphin sound signals is the prerequisite for the study of dolphin sound signals. The dolphin sound signal recorder, as a device for collecting and storing sound signals, plays an important role in studying dolphin sound signals and analyzing the characteristics of dolphin sound signals, and provides important evidence for in-depth understanding of the biological behavior and living environment of dolphins .

The frequency of the sound signal of dolphins is high, and the frequency band involved in the sound signal of dolphins is relatively wide, so the signal sampling rate, storage speed and storage space have high requirements . The existing underwater acoustic signal recorder do not have the sound recognition function, and there are shortcomings of insufficient power and limited storage space in long-term work on the seabed. It is difficult to complete long-term recording of underwater dolphin sound signals. Therefore, this paper proposes an acoustic trigger dolphin sound signal recorder with low power consumption, small size, large capacity, and relatively low cost, which can work on the seabed for a long time and store a lot of dolphin sound samples.

ACOUSTIC TRIGGER ALGORITHM DESIGN

In this paper, the recorder uses a hydrophone to convert the sound signal into an electrical signal, and then passes through the filtering, amplification and A/D conversion of the analog module, and finally the digital module is processed. Pre-processing is performed in the digital module first, and then short-term energy is used to detect whether the dolphin is coming. If the short-term energy of 3 consecutive frames is higher than the set threshold, it is considered that the dolphin is coming.

Then uses the similarity of the characteristic parameters of the sound signal detected by cross-correlation to trigger sound recording. The similarity value is compared with the set similarity threshold. If the similarity value is greater than or equal to the threshold, the sound signal is stored in the SD card. If the similarity value is less than the threshold, it will not be stored. If there is no short-term energy for 3 consecutive frames higher than the set threshold, the microcontroller will always be in a low power consumption mode. The process diagram of acoustic triggering algorithm is shown in Fig.1.

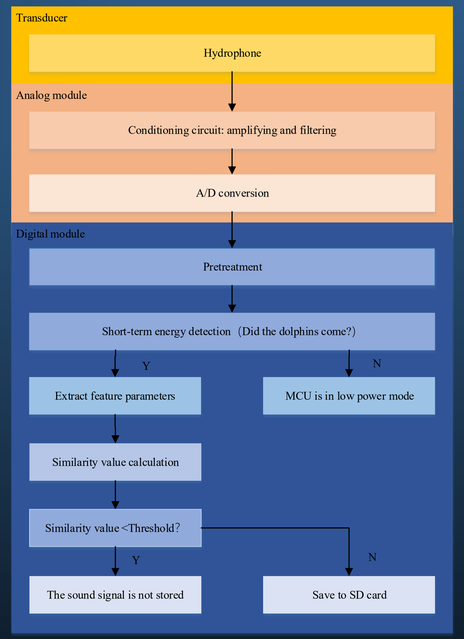

Fig. 1. Process diagram of acoustic triggering algorithm

Use actual dolphin sounds to verify the effectiveness of the algorithm, and the output trigger result of the algorithm is shown in Fig.2. It can be obtained from the figure: 10 click sound signals are detected, and the detection rate is over 85%.

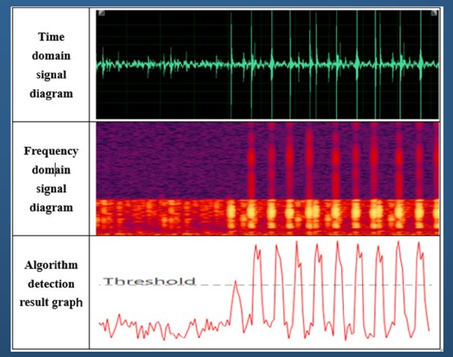

Fig. 2. Trigger result graph

DESIGN OF DOLPHIN SOUND SIGNAL RECORDER

The overall design of the acoustic trigger dolphin sound signal recorder includes two parts: hardware design and software design.

The signal output by the hydrophone enters the low-power signal conditioning circuit for amplification and filtering, and then performs A/D conversion under the control of the coprocessor MSP430F5438A. The approximate measurement value of the acoustic signal and the click sound of the dolphin is obtained through the coprocessor calculation and processing. If the approximation measurement value of 3 consecutive frames is higher than the set threshold, it is considered that a dolphin sound signal is detected. At this time, the STM32F407 main processor will be awakened, and the sound A/D conversion rate will be increased to 200Ksps under the control of the main processor, and the sound signal will be stored in the SD card at the same time. If the approximation measurement value is always less than the threshold, the main processor will not be activated, and the coprocessor will perform low-power dolphin click sound detection, and no data storage will be performed. The overall composition of the system is shown in Fig.3.

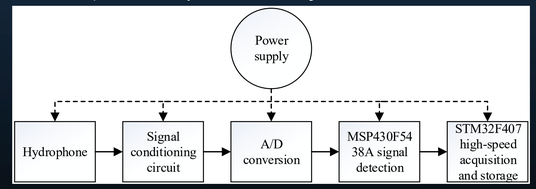

Fig. 3. Overall structure diagram

The circuit board and hydrophone of the recorder are shown in the Fig.4.

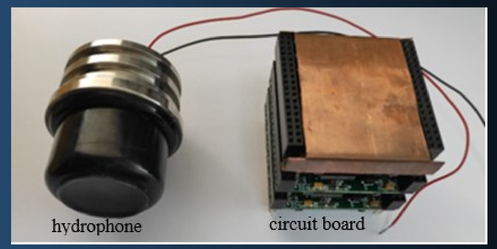

Fig. 4. Physical picture

The key design parameters of the recorder are shown in the Table Ⅰ.

Table Ⅰ. RECORDER DESIGN PARAMETERS

Index	Dolphin Sound Signal Recorder
ADC Resolution	16-bit
Sampling Rate	200 kHz
Hydrophone Sensitivity	-180dB re 1 V/ μPa
Amplifier Gain	20-60 dB
Combined Sensitivity	-160 dB re 1 V/ μPa
Dynamic Range	40 dB
Static Power Consumption	30mW
Dynamic Power Consumption	300mW
Storage Capacity	64G*n (n is the number of stacked boards)

CONCLUSIONS

This article uses STM32F407 as the main processor and MSP430F5438A as the co-processor to design an acoustic trigger dolphin sound signal recorder. The design uses algorithms based on short-term energy and signal similarity to detect the arrival of dolphins and trigger high-sampling-rate sound recording. The dolphin sound signal recorder can record effective dolphin sound signals very well, and provides a reliable basis for in-depth understanding of the biological behavior and living environment of dolphins. It is hoped that the analog front-end circuit can be improved in the future to achieve high-fidelity sampling and further increase the AD sampling rate. At the same time, it is possible to conduct sea trials in multiple sea areas to obtain more dolphins communication samples.