Evaluation of Acoustic Data Communication for Fish Farm Monitoring

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Abstract: One of the promising sensor network application is for the primary industry and there have been a lot of researches in this area. Although undersea sensor networks have been less studied compared to terrestrial sensor networks, sensing modules of fish and communication modules in undersea environment have been developed in recent years. In this paper, we propose a fish farm monitoring system. In the proposed system, sensor nodes are attached to all or a part of fish for monitoring health status of fish in a preserve. The sensor data monitored at the fish-mounted sensor node is transmitted to a sink node by using acoustic communication which is generally assumed in the undersea environment. In this paper, as one of evaluations of our proposed system, we evaluate acoustic data communication between the fish-mounted sensor node and the sink node through experiments using a fish model. Through experimental evaluations, we show that body of fish affects to performance of communication.

Key–Words: fish farm, undersea sensor networks, monitoring, acoustic data communication

1 Introduction

In recent years, sensor network technologies have attracted a lot of attentions from many developers and researchers. One of the promising sensor network applications is for the primary industry such as animal repellent, the livestock industry [1], fish farm monitoring [2–6] and so on. For example, in [1], the authors considered to attach a sensor/actuator on a bull to prevent fighting among bulls. In [2], the authors proposed and developed a low-cost ubiquitous buoy for monitoring temperature information in fish farms.

On the other hand, sensing modules for attaching on fish have been developed in recent years. In the area of bio-logging research, they use commercially-available sensor units for sensing fish or undersea animals [7, 8]. Here we note that acoustic communication is normally assumed in undersea environment, although other physical layer technologies such as visible light communication [9], radio communication [5, 10, 11], are also assumed depending on applications. Although current underwater communication modules [12] or fish sensing modules [7, 8] are expensive compared to terrestrial modules, low-cost modules have been proposed in recent years [13, 14]. Therefore, in the future fish farm, it is expected that sensor modules are attached to expensive fish, such as tuna, for monitoring health status of fish so that production rate and quality of fish can be improved.

In this paper, we propose a fish farm monitoring system as shown in Fig. 1. In the proposed monitoring system, sensor nodes are attached to all or a part of fish for monitoring health status of fish in a preserve. Here, we assume that the costs of sensor and communication modules are sufficiently low compared to the value of fish. The sensor data monitored at the fish-mounted sensor node is transmitted to a sink node by using acoustic communication. Here, in this paper, we assume single-hop wireless network among the sink and fish-mounted sensor nodes. After collecting the monitoring data from fish-mounted sensor nodes, the sink node transmits the monitoring data to the monitoring server by using satellite or mobile networks. By monitoring fish using the system, we can detect and countermeasure for fish disease, or we can improve the efficiency of fish farming.

The situation of our proposed system is different from previous researches. In the proposed system, a number of fish-mounted sensor nodes move in a relatively small environment, which is different from the situation in the bio-logging researches where a small number of fish-mounted sensor nodes move in a relatively large environment. In this paper, we evaluate acoustic communication between the fish-mounted sensor node and the sink node as the first step of our research project. Here, we note that real experiments

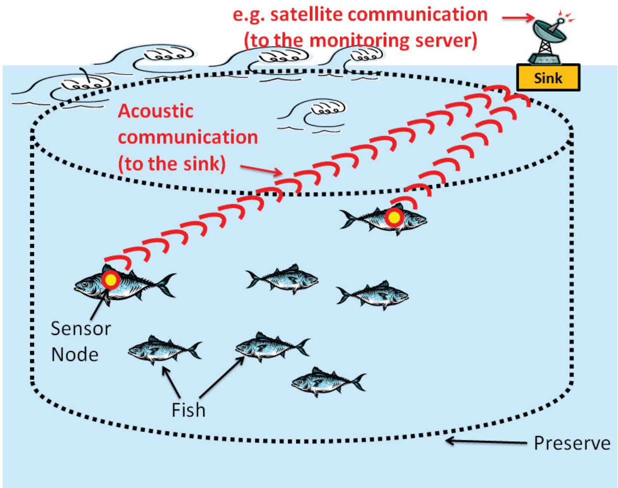


Figure 1: Fish farm monitoring system

using real fish in undersea environments is difficult since it requires expensive costs for modules or it is difficult to controlling the position of fish. Therefore, in this paper, we make an acoustic data communication system mounted on a fish model in an indoor environment for evaluation. Then, by using the system, we evaluate the performance of acoustic communication through experiments.

The rest of this paper is organized as follows We explain the fish farm monitoring system intended in this paper in Section 2. Next, in Section 3, we introduce the experimental system for evaluating acoustic communication. Then, we show the evaluation results in Section 4. Finally, we conclude this paper with an outlook on future work in Section 5.

2 Fish farm monitoring system

Figure 1 shows the fish farm monitoring system intended in this paper. The fish farm monitoring system is composed of fish-mounted sensor nodes and a sink installed at a preserve. We assume that the preserve is a cuboid whose radius is R [m], and depth is D [m]. A sensor node consists of a sensor module and a communication module. Sensor nodes are attached to all or a part of fish for monitoring health status of fish in the preserve. Here, we assume that the costs of sensor and communication modules are sufficiently low compared to the value of fish. The sensor data monitored at the fish-mounted sensor node is transmitted to a sink node by using acoustic communication which is generally assumed in the undersea environment[1].

[1]We evaluated WiFi communication for fish farm monitoring in [11], and confirmed that the transmission distance of WiFi communication is too short in undersea environment.

Table 1: Modules of experimental system

Name	Model
(Sensor node)	
Node	Raspberry Pi 2 Model B
Battery	Elecom DE-M01L-5230
Speaker	Elecom ASP-5MP050BU
Fish model	NAT Tuna Soft Figure
Stand	Bag Hanger (w 29×d 15×h 33 cm)
(Sink node)	
Node	Raspberry Pi 2 Model B
Battery	Elecom DE-M01L-5230
Microphone	Sanwa Supply MM-MCUSB22
Stand	Bag Hanger (w 29×d 15×h 33 cm)

In this paper, we assume single-hop wireless network among the sink and fish-mounted sensor nodes. After collecting the monitoring data from fish-mounted sensor nodes, the sink node transmits the monitoring data to the monitoring server by using satellite or mobile networks.

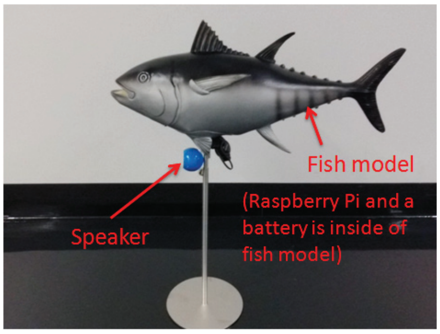
In the monitoring system, a number of fish-mounted sensor nodes move in a relatively small environment, which is different from the situation in the bio-logging research where a small number of fish-mounted sensor nodes move in a relatively large environment. For example, in a fish farm in our university, thousands of tunas move in a preserve whose radius is 30 m and depth is 10 m. In this paper, as the first evaluation of the proposed monitoring system, we evaluate acoustic communication between the fish-mounted sensor node and the sink node in our fish farm monitoring.

3 Experimental system for evaluating acoustic data communication

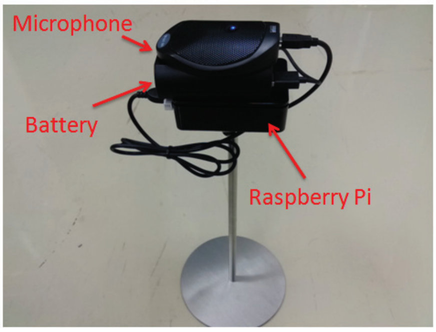
Evaluation through real experiments using real fish in undersea environments is difficult since it requires expensive costs for modules or it is difficult to controlling the position of fish. Therefore, in this paper, we make a fish-mounted sensor node and a sink node in an indoor environment. In this section, we explain experimental system for evaluating the performance of the acoustic data communication in a fish farm.

3.1 Experimental system

Figure 2 shows the experimental system in this paper. As a sensor node, we use a Raspberry Pi [15] node with speaker and battery modules attached at a fish model with a stand as shown in Fig. 2(a). The size



(a) Sensor node



(b) Sink node

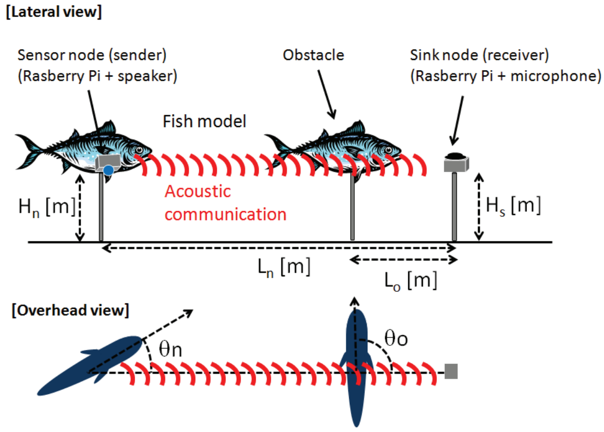
Figure 2: Experimental system

Table 2: Specification of Raspberry Pi

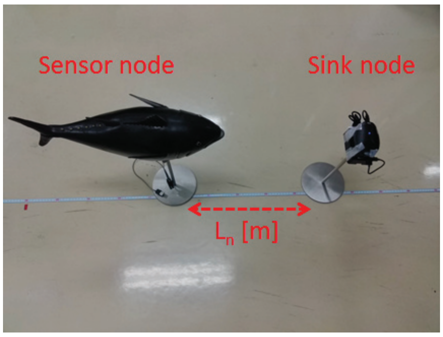
Name	Spec.
CPU	ARM Cortex-A7
Memory	1 GB
Disk	Apotop microSDHC 32GB CL10
Case	RS 819-3655
OS	RASPBIAN JESSIE (2015-09-24 Release)

of fish model is 0.13 m × 0.45 m × 0.23 m, and the stand is around 0.33 m tall. The Raspberry Pi node is installed inside of the fish model. In this paper, we assume that sensor is attached at abdominal region of fish, and the speaker is installed at the lower part of the fish model. Here, we note that the position of sensor is varied depending on the purpose of monitoring. For example, in [16], they attached a sensor node at the second dorsal fin of tuna.

As the sink node, we also use a Raspberry Pi node with microphone and battery module. The sink node is attached at a stand as shown in Fig. 2(b). Table 1 summarizes the used modules in the experimental system and Table 2 summarizes the specification of Raspberry Pi node.



(a) Model



(b) Photo (without obstacle)

Figure 3: Evaluation environment

3.2 Acoustic data communication

In the experiments, we use `minimodem` [17] version 0.22 as modem software for demonstrate acoustic communication. Minimodem is a software acoustic modem and it supports for various FSK protocols. Although there are some ways for achieving acoustic data communications among nodes by using softwares and general-purpose computer [18, 19], we use minimodem because it is public and it can be easily introduced. We modified original minimodem a little to output signal-to-noise ratio (SNR). We set the baud rate to 100 and the space frequency to 1250 Hz.

4 Evaluation results

In this section, we describe experimental results. The evaluation environment is illustrated in Fig. 3. We use one sensor node, one sink node, and one obstacle (fish model) in the experiment.

We first evaluate the performance of acoustic data communication without obstacle. In this experiment, the height of sensor node H_n is set to 0.33 m We measure SNR at the sink node by changing the distance L_n and height of sink node H_s. In the following, all

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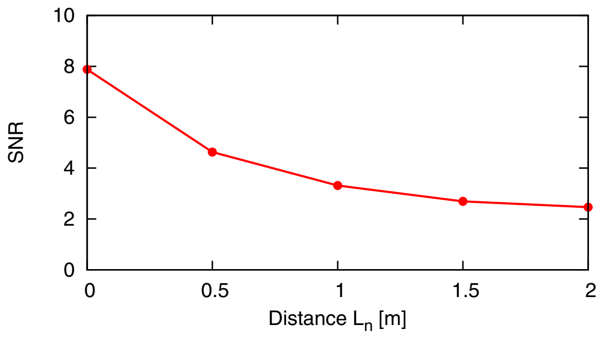

Figure 4: SNR against distance L_n ($\theta_n = 0$, $H_s = 0.33$ m)

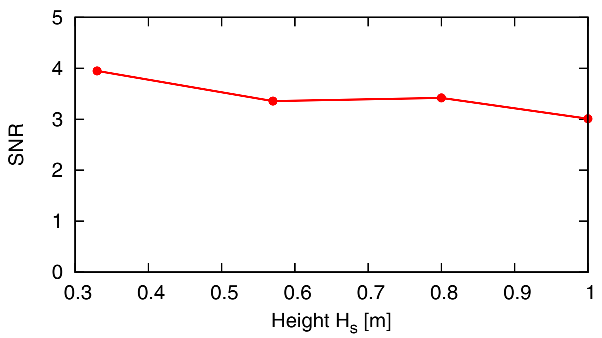

Figure 5: SNR against height H_s ($\theta_n = 0$, $L_n = 0.5$ m)

results are averaged over 10 measurement results.

Figure 4 shows the SNR against distance between nodes when the height of sink node H_s is fixed to 0.33 m and angle θ_n is set to 0. As shown in Fig. 4, SNR decreases as the increase of distance. In addition, Fig. 5 shows the SNR against the height of sink node H_s when the distance L_n is fixed to 0.5 m. Similar to Fig. 4, SNR decreases as the increase of height. Furthermore, Fig. 6 shows the SNR against angle θ_n of sensor node when the distance L_n is fixed to 0.5 m and the height of sink node H_s is fixed to 0.33 m. As shown in Fig. 6, the angle does not significantly affect to SNR. From these results, the SNR just decreases depending on the distance between nodes. In this experiments, the speaker module is attached to the fish model with some distance as shown in Fig. 2(a), therefore, the body of fish does not affect to the SNR. We plan to evaluate the performance of acoustic data communication by changing the position of speaker module as future work.

We next evaluate the performance of acoustic data communication with obstacle. Figure 6 also shows the results with obstacle and that without obstacle. As shown in Fig. 6, SNR with obstacle is lower than

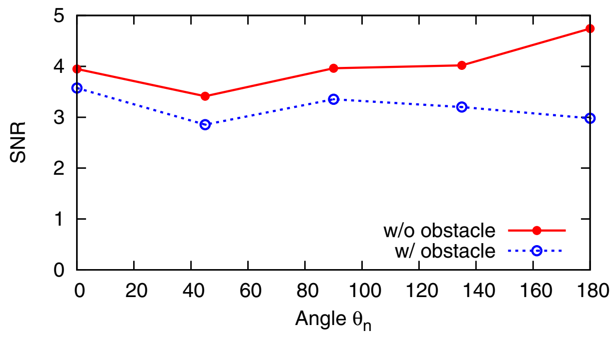

Figure 6: SNR against angle θ_n ($L_n = 0.5$ m, $H_s = 0.33$ m)

that without obstacle. Therefore, the performance of acoustic communication is affected by obstacle, i.e., body of other fish.

5 Conclusion

In this paper, we proposed a fish farm monitoring system. In the proposed monitoring system, the sensor data monitored at the fish-mounted sensor node is transmitted to a sink node by acoustic communication. In this paper, we evaluated the acoustic communication among fish-mounted sensor node and a sink node through experiments using a fish model. Through experimental evaluations, we showed that body of fish affects to performance of communication.

As future work, we plan to evaluate our experimental system in undersea environment and make an acoustic communication model of fish-mounted sensor node. In addition, we plan to evaluate the network performance when a number of sensor-mounted fish move in a preserve through simulation experiments with our acoustic data communication model.

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