Development of Range Sensing System Using Spread Spectrum Sound Waves

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Abstract

A new ultrasonic sensing system using spread spectrum sound waves which is modulated with Pseudo Random Noise Code (e.g.,M-sequence) by phase shift keying, has been proposed and investigated. The system permits a mobile object to recognize its own position in local environments, in which it is impossible to use electromagnetic waves. To achieve this system, we have examined whether the spread spectrum technique, which have been used on electromagnetic waves for Global Positioning System (GPS), can be applied to sound waves, which have longitudinal and elastic characteristics. This experiment was performed with a special emphasis on detection of the objective signal in the mixed sound waves, which contain two kinds of transmitted signal. And we evaluated the accuracy of the measured distance between two sound sources by the received time difference of the transmitted signals. From experimental results using carrier frequency 3kHz, we obtained the high distance accuracy, which is no more than just only 0.035m. This can be expected as the high resolution sensing system and also means that spread spectrum technique can be applied to the sound waves.

1. Introduction

As for an autonomous mobile object, it is one of indispensable work to recognize its own location for the safe navigation. In recent days, a sensing system being used for recognizing the current location of mobile objects such as cars, ships and airplanes is the current GPS, global positioning system. The object's location on this system is calculated with distance data by the received electromagnetic waves from some satelites going round the earth, and it is also known that the measurement accuracy is within a range from several to hundreds of meter. However, this sensor can't be employed in the indoor environments such as buildings and tunnels due to the impedimenta in the electric wave propagation. Assuming that it is used in indoor environments, we may also consider the environments where can't use the electromagnetic wave s such as medical institutions. Some these limitations concerning the electromagnetic wave used on GPS caused to develop the range sensing system, LPS (Local Positioning System), and to select the ultrasonic waves as the medium that can overcome these limitations and ensure the measurement accuracy of sensor in indoor environments.

In the popular applications of the existing many range system using the ultrasonic pulse. We have generally identified some problems about misreading with cause such as either ultrasonic noise from external sources or interferences from neighboring sensors. In addition, among some applications using the modulated ultrasonic waves, there were ways measuring the distance to apply real orthogonal pseudo noise sequence to a carrier of square waves [2] and to directly arise pulses of M-sequence [3]. These are proposed to avoid interferences from only external noise, but were not considered interference and the detection of objective signals in several kinds of transmitting signals defined with pseudo random noise code.

As a way to achieve our LPS and to negotiate these problems reviewed above, we attempted to apply the spread spectrum technique to sound waves. This method, which has been used on electromagnetic waves can be applied to sound waves, should also be examined whether it can be applied to the sound waves, which are longitudinal elastic waves. In this paper, we introduce the following two fundamental experiments carried out in order to identify the spread spectrum technique on sound waves. The first is to make sure that it is to possible to select out the objective signal in the received waves, which contain two transmitted spread spectrum sound waves. The second is to check whether the measurement accuracy of a distance can be obtained with the time difference of the given objective signals in the received waves.

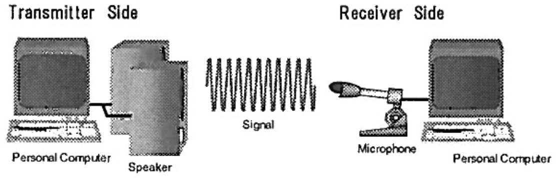

Fig.1 The experimental equipments

2. Experimental environments and the data

This chapter summarizes experimental equipments and the data, which are modulated with pseudo random noise code in order to spread the spectrum necessary to the implementation of our experiments.

2.1 Equipments and experimentation

Two different types of sound waves which are modulated with two kinds of M-sequence to spread spectrum ones respectively, are simultaneously emitted as transmitting signal from two speakers A and B, spaced out some distance, which are connected with the personal computer (PC) in the transmitter side, as shown in Fig.1. The signal to be received by a microphone of PC in receiver side is the mixed signal that contains the transmitted signals from speaker A and B. If we can detect each transmitted signal and starting point of objective signals contained in the mixed sound waves, then we can measure the distance between two speakers from time difference of the capturing points for each objective signal.

On the popular ultrasonic range finder, it's general to measure the propagation time from a transmitter to a receiver. However, with a generally software on a pc it's difficult to synchronize the timing for transmitting and receiving, so we use two speakers in this experiment. And it enable that we make sure whether an objective signal can be distinguished from the mixed ones and whether the spread spectrum ways on sound waves enable a robustness against interferences and a identifiable characteristics to detect each other for several kinds of transmitting signals.

With these equipments, we measure the distance of two speakers by the time difference between the first arrived sound waves as a starting point and the later ones, and then also evaluate the accuracy of the measured distance by using sound waves to spread the spectrum. To perform our experiments, we put a speaker A at the position spaced 0.5m from a microphone and B at any nine locations spaced away from the speaker A, as can be seen in Fig.2. And then we implemented the experiment of distance measurement. The experimental results will be described in the chapter 3.

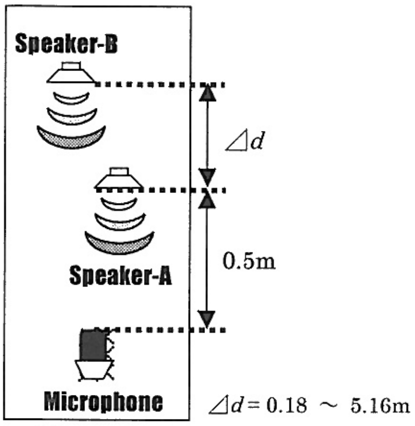

Fig.2 The experiment environment

2.2 The used data on the experiment

On the PC of transmitter side, carrier waves are modulated to spread spectrum ones with M-sequence of pseudo random noise code (PRN) by phase shift keying. In this experiment, we used 690Hz and 3kHz for carrier frequency, and one period of the carrier waves is expressed with 16 points and also employed the M-sequence with period of 127 bits obtained with 7 bits shift register. And, as we assume that the time corresponding to 1 bit of M-sequence as a length of chip Tc, which is defined as three times of a carrier wave period T. In other words, as we set a modulated period for carrier at Tc = 3T, the transmitting signal is modulated with 1 bit of M-sequence to 3 periods of carrier waves. Then, the amplitude for output data is expressed with 8 bits (256 steps) and a part of the transmitting signal is shown in Fig.3.

On the PC of receiver side, a synchronized capture to detect the transmitting data in the received waves are done nicely, by demodulating with the same exact M-sequence code as transmitting signal.

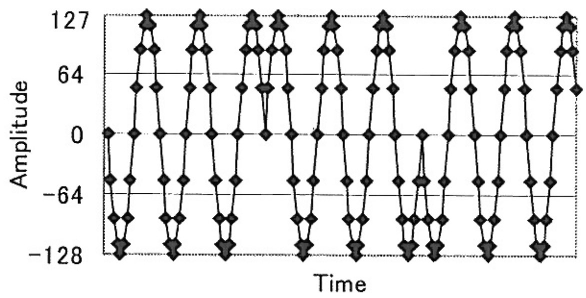

Fig.3 A part of transmitting signal

3. Experimental results and discussion

In this chapter, we present the experimental results on detection of the objective signal in the mixed received wave, and the distance measurement between two speakers using the frequency of audio area.

3.1 Identification of the objective signals

The mixed sound wave from the speaker A and B is demodulated with the same M-sequence as the objective transmitted signal. And then by using a correlation method we obtain a waveform, which has a peak to detect a starting point of the transmitted signal.

Fig.4 and 5 show the waveforms measured at distance 0.18m and 0.72m between the speaker A and B, respectively. The vertical and horizontal axis of these graphs expresses the correlation values and the detection time of each detected objective signal. The a and b arrows in these figures indicate the high peak, which is the starting point of the objective signal in the mixed wave transmitted from the speaker A and B, respectively.

From these experimental results, we can know that is able to detect an objective signal in the mixed sound waves, by choosing M-sequence to demodulate the objective signals in the receiver side. Based on the time difference detected by this technique, the distance measurement results will be presented in the following section.

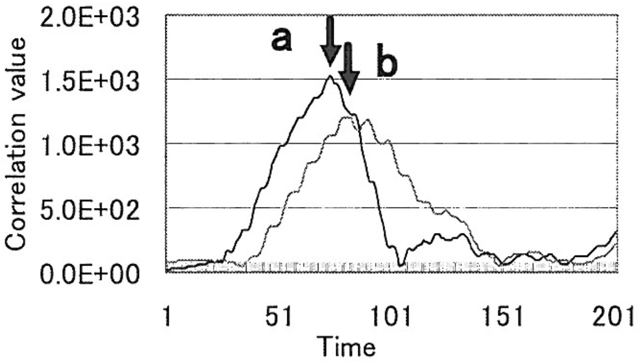

Fig.4 synchronous capture for the detection of objective signal at interval 0.18m of two speakers

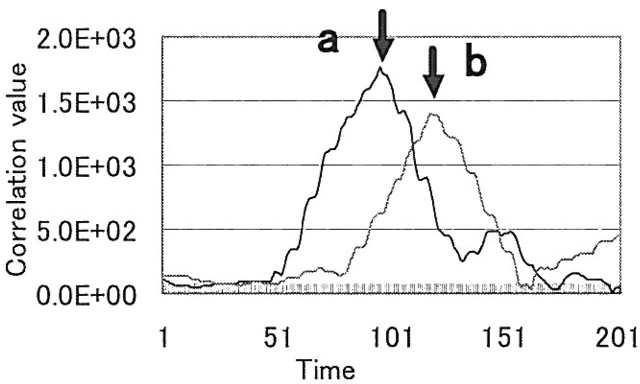

Fig.5 synchronous capture for the detection of objective signal at interval 0.57m of two speakers

3.2 Distance measurements

In two cases of carrier frequency 690Hz and 3kHz, we performed the experiments of measuring the distance between the speaker A and B. We had the measurement experiment 5 times at any nine locations in the distance between two speakers, 0.18～5.76m. Fig.6 and 7 show the measurement results for 690Hz and 3kHz. And also, the vertical and horizontal axes express the measured distance and the interval of two speakers, respectively. The average error is 0.098m, as shown in Fig.6. In the measurement using 3kHz of Fig.7, the average error is 0.012m. By using the frequency 3kHz about 3 times of 690Hz, we could obtain the smaller average error about 1/8 times than one of the 690Hz.

From these experimental results obtained on the audio frequency 690Hz and 3kHz, we can expect that it is possible to measure with the higher distance accuracy by using the popular ultrasonic frequency.

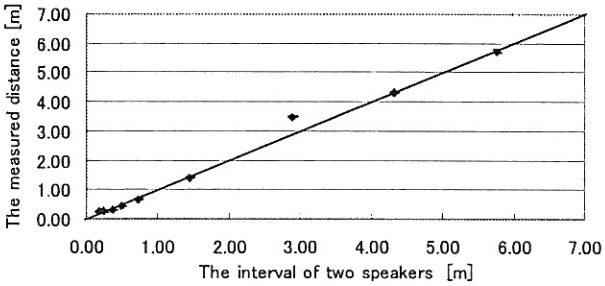

Fig.6 The measurement distance using 690Hz

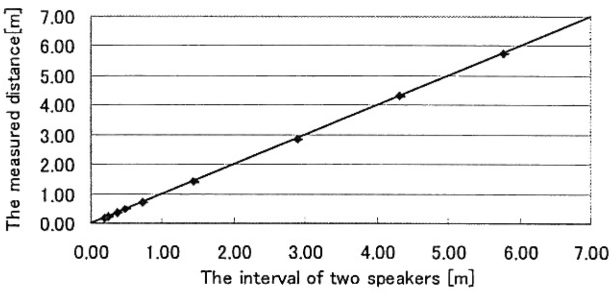

Fig.7 The measurement distance using 3kHz

4. Conclusions

This paper proposed a new ultrasonic sensing system using spread spectrum sound waves to recognize a mobile object's own position in local environments.

In popular applications of the existing many range systems using the ultrasonic pulse waves, we have identified some general problems with the caused such as misreading effected such as either ultrasonic noise from external sources or interferences from neighboring sensors.

But this spread spectrum technique enables the system to eliminate above interferences by modulating a signal with pseudo random noise code. To achieve this system, we had to examine whether the technique, which have been used on electromagnetic waves for Global Positioning system (GPS), can be applied to sound waves, which have longitudinal and elastic characteristics. And so we have experimented to measure distance difference between two sound sources with emphasis on detection of the objective signal in the mixed sound waves, which contain two kinds of transmitted signal.

From experimental results of the measurement distance using carrier frequency 3kHz, we could obtain the higher distance accuracy more than one using 690Hz. By using 3kHz, the distance error is 0.012m on average. These mean that we can obtain the higher distance accuracy by using the high frequency such as ultrasonic wave.

In the future research, we are going to use ultrasonic and measure distances from more than 3 sources to recognize own position in 3 dimensions. Finally we should evaluate whether this system has effectual position accuracy.

References

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