the Application of Correlation Function in Acoustic Source Localization

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Abstract: In order to obtain the acoustic source localization accurately, correlation function was used to estimate time delay. It was caused by the acoustic signal arriving at different microphones. And localization software platform was provided based on many merits of LabVIEW. The emulation program tests that the correlation function could estimate time delay accurately. And the acoustic source localization is calculated exactly. Interactive operation is also satisfied. Some factors are analyzed that influent localization accuracy based on simulation result.

Key words: acoustic source localization; correlation function; time delay estimation; LabVIEW

1 Introduction

Based on the principle of passive acoustic detection, acoustic source localization is to obtain the target coordinates in world coordinate system by analyzing the acoustic signals, which are received by microphone array. The time delay localization is high precision and easy to realize real-time system during all acoustic source localization methods based on microphone array. But generalized cross-correlation function is widespread used among many methods estimating the time delay. LabVIEW provided by American NI Corporation has formidable function of data acquisition and the instrument control. Graphic program is designed by LabVIEW based on the principles of correlation function and localization. And it enhances the interactive operation for users.

2 Acoustic source localization principles

Acoustic passive localization [1] is passive detection technology and realizes acoustic source localization by analyzing aural signal. It has the remarkable superiority in practice and owns many merits. For example, its operate mode is passive way. And no electromagnetic wave and strong confidentiality are its merits. It also isn't influenced by smog impediment and has good visibility condition and. These make it cover insufficiency of radar detection and apply widely in the military field.

The method of time delay localization holds very great proportion among numerous passive localization methods. Its calculation process is little and it is convenient for real-time processing.

2.1 Time delay localization principle

The principle of time delay localization refers to collect acoustic signal using microphone array.[2] Two or more time delays are obtained by analyzing and processing the multi-channel signals which the acoustic signal arrives at different microphones. Then acoustic source position is judged by using space geometry knowledge. In the two-dimensional surface, the acoustic signal arrives at two microphones time delay determine acoustic traverse line. The acoustic source the position could be determined combining the other traverse line defined by other two microphones. Its principle is shown in **Figure 1**.

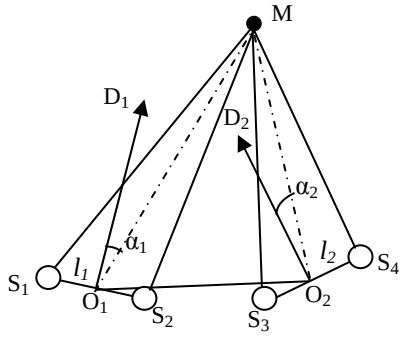

Figure 1 The model of acoustic source localization system principle

M expression is the acoustic target and what $S_1 \ldots S_4$ expressed is the microphone array. O_1D_1, O_2D_2 respectively is S1S2, the *S3S4* vertical bisector and O_1M, O_2M

are target traverse line which are defined by microphone array. The traverse lines intersection is the target position.

The distance between acoustic source and microphone array is far further than the distance between two microphones in acoustic source localization system usually. Therefore, the wave surface is supposed plane wave. And the microphone array coordinates are known usually. Based on geometry theoretical derivation, formula 1 expresses the angle between the target traverse line and vertical bisector.

$$\sin\alpha = \frac{\tau}{T} \tag{1}$$

And α is the angle between the target traverse line and midnormal. τ expresses the time delay of the acoustic source collected by the two microphones. *T* shows the acoustic transmission time between the two microphones under the same condition

2.2 correlation function algorithms

The correlation function analysis is important component in signal analysis domain. It is applied widely in examination system, control system, communication system and so on. This function mainly solves the problems of signal internal relation or signals similarity. And it is an important method for analyzing the two signals relation, the signal after certain time delay and two random signals relations. The correlation function could discover the signals functional relations from the noise and other irrelevant signals. Then the signals are detected and extracted according to the correlation function relevance and so on. This is widespread application for speed measurement or filter. [3]

It is supposed that two microphones compose a sensor array. And *S(n)* expresses the acoustic source. $X_1(n)$ and $X_2(n)$ show signals collected by microphone 1 and microphone 2 respectively. $b_1(n)$ and $b_2(n)$ indicate additional noise signal except acoustic source signal. Therefore, the signals which the microphone 1and 2 obtained under ideal environment could express as formula 2.

$$\begin{cases} X_1(n) = a_1 S(n) + b_1(n) \\ X_2(n) = a_2 S(n-\tau) + b_2(n) \end{cases} \tag{2}$$

a_1 and a_2 show attenuation coefficients as the acoustic source signals arriving at microphones. And τ is time delay between the collected acoustic source signals. It could be calculated by traditional correlation function. The equation is shown in formula 3.

$$R_{X_1X_2}(\tau) = \int_{-\infty}^{+\infty} \Phi(f) S_{X_1X_2}(f) e^{j2\pi f\tau} df = \int_{-\infty}^{+\infty} \Psi_{X_1X_2}(f) e^{j2\pi f\tau} df \tag{3}$$

$S_{X_1X_2}(f) = E\{X_1(f)X_1^*(f)\}$ shows the signals correlation function spectrum. $\Phi(f)$ is the weight function and $\Psi_{X_1X_2}(f) = \Phi(f) S_{X_1X_2}(f)$ is generalized correlation function spectrum. The time delay could be expressed in formula 4.

$$\tau_\varphi = \arg\max_\tau R_{X_1X_2}(\tau) \tag{4}$$

In order to suppress the effect of noise and reverberation, the signals amplitude information is usually eliminated and the phase characteristic is only retained. Base on this requirement, formula 5 is needed.

$$\Phi(f) = \frac{1}{S_{X_1X_2}(f)} \tag{5}$$

3 Programs

3.1 LabVIEW summary

LabVIEW is graphic programming language for object-oriented. It could be used in surveying computation, the test and the control because its formidable data acquisition and the instrument control function in the modern test domain. The interactive control front panel could be built conveniently. Its panel and the operation may simulate the actual instrument. This is user-friendlier for signal gathering and processing development. And many functions have been built for analyzing the metrical data. These could be competent the majority survey duties. It could be connected with the survey hardware because all interface buses and commonly used instruments drivers are provided. It is convenient for completing signal data acquisition, analysis processing and data storage and so on.

3.2 Graphic program designs

The program for acoustic source localization could be divided into two parts based on LabVIEW. The first part is used to estimate the time delay base on correlation function. Then the acoustic source coordinates is calculated according to the time delay estimation and geometrical model. The acoustic source localization program is shown in **Figure 2**. The simulation signal is chosen to test the designs. This includes the time delay estimation and coordinates calculation.

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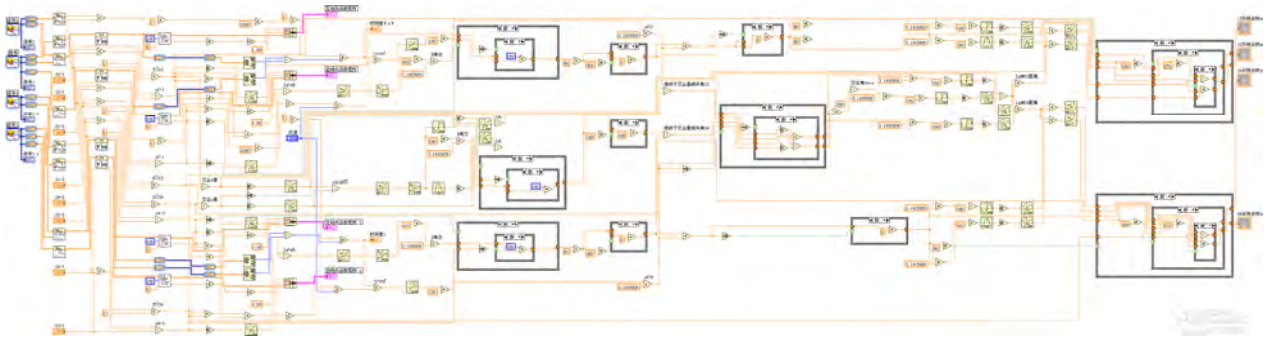

Figure 2 Graphic program acoustic source localization

3.3 Front panel designs

The LabVIEW front panel is the interface for correspondence between user and instrument, the input parameter establishment and the output result display. The front panel is shown in **Figure 3** based on the correlation function to realize the acoustic source localization. Interactive operation surface is established using LabVIEW. It could establish attribute of the controls, the displays and the appearance. This would observe the waveform or the buttons operation.

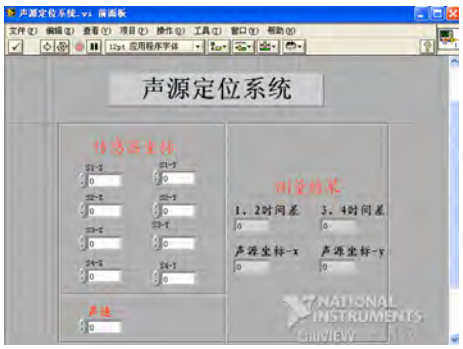

Figure 3. Front panel for acoustic source localization

In the front panel, the controlling parameter includes microphones coordinates and real-time wind speed which are needed input. The target coordinates and time delay are display by executing program. The time delay is obtained according to correlation function algorithm and the coordinates are gained based on the schematic diagram shown in Figure 1.

4 Error analyses

Through analyzing the localization model and simulation result, the errors are concluded as followings which would influence localization accuracy.

①Time delay error

Time delay error would exist in all the algorithms and is named algorithm error. The time delay obtained by correlation function is also inevitable.

②Acoustic source localization model error

There are some suppositions in building model. Microphones positions are assumed on the flat and the depth displacement differences are ignored. The wave front is assumed plane wave because the acoustic source-detector is longer than microphones distance. These would cause the error.

③Microphone error

The phases between the signals are different because each microphone's electrical specification is inconsistent. In addition, microphones arrangement should observe the coordinates strictly which are precision measurement previously. But the microphones physical location would influence measurement result because arrangement error.

5 Conclusion

Based on the acoustic source localization principle and correlation function algorithm, interactive program has been established using LabVIEW. And the factors are analyzed which influence the measuring accuracy. The result indicates that the acoustic source localization coordinates could satisfy certain specification based on correlation function. This will supply certain reference value to the application.

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