of competitive high-end digital radiography // Control. Diagnostics. - 2011 - Special issue. - Pp. 25– 29.

DIFFERENT APPROACHES FOR ULTRASONIC TIME-OF-FLIGHT TO MEASURE DISTANCE

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There are various techniques to measure the distance using ultrasonic testing. Ultrasonic testing method is based on the capture and quantification of either the reflected waves or the transmitted waves and is also based on the vibration in materials which is usually mentioned as acoustics. The ultrasonic time-of-flight (TOF) to measure the distance includes different techniques like pulse echo method [1], threshold detection, cross-correlation estimator [3] etc. The measuring distance products can contain infrared light emitters and receivers. The ultrasonic testing is based on the reflection of sound waves which are travelling in a medium.

The measuring device mainly consists of the transmitter unit and the receiver unit. The sound waves travelling from the transmitter unit is received in the receiver unit as reflected waves which are called as echo signal. To measure the distance the time taken for the sound waves to travel the distance from the source to the subject and back to the source and speed of sound in the medium is required. The ultrasonic measuring devices are used in industrial applications to measure the distance in different mediums.

The pulse echo method or the TOF method [1]consists of a transmitter unit containing a switch which helps allowing the sine wave from the function generator to the gain amplifier. The transmitter excitation is controlled digitally which is given from the function generator through the switch. The microcontroller is used for switching signal, and to calculate the distance. The receiver unit contains the amplifier which is required when higher frequency pulse is received and the comparator which compares the output signal with reference threshold level to clear out the noises and false triggering. Then it passes through the voltage limiter to which sends to microcontroller to count pulses. The transmitter passes the pulses which are received at the receiver as echo pulses. The time-of-flight (TOF) is calculated by microcontroller using the time delay between the received pulses and the transmitted edges. The Fig.1.shows the echo signal reflected at the receiver.

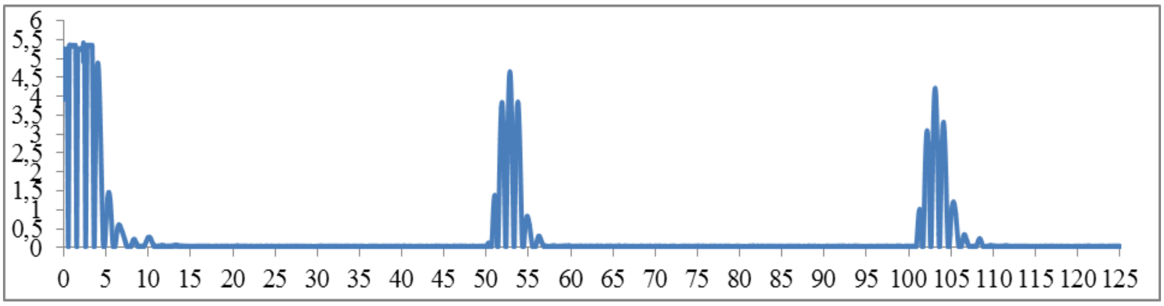

Fig.1.Echo Signal

The other different approaches for ultrasonic time-of-flight (TOF) to measure the distance are such as the measuring method based on threshold detection, cross-correlation estimator and discrete extended Kalman filter [3]. The two consecutive steps for TOF-based measurements are the first step is for the digitization of the received ultrasonic signal through a data acquisition system, and the second step includes a suitable digital signal-processing algorithm is applied to the acquired samples for the preferred TOF. Major sources of inaccuracy can be found in additive noise affecting the acquired ultrasonic signal, shape distortion of the received echo, and dependence on temperature of the propagation velocity.

The threshold method is used in realizing on actual sensor in a simple but the drawback is the echo signal undergoes from noise sensitivity and in the signal shape distortion.. The cross-correlation estimator method is used to detect the maximum value of the cross-correlation between the return signal and a reference signal and the drawback is echo shape distortions. The Kalman filter method is for a linear process which uses a kind of feedback control based on measurement results of measures that are linear functions. The TOF approximation inherently accounts for distortions the ultrasonic echo in the end experiences; with a consequent positive effect on bias reduction is the main advantage of the Kalman filter approach. This has been helped to improve the accuracy of ultrasonic-based location systems of robots [4].

The unscented Kalman filter [7] is a new addition of the Kalman filter method to calculate the reflected echo signal and to trace its onset accurately using digital signal processing method. This method has helped to improve the issues related to presence of noise and other interfering signals, amplitude attenuation and shape distortion of ultrasonic echo, temperature and humidity and TOF evaluations not greater than 0.3%. The experiment observed in free-space has distances varying inside the interval 400–1000 mm whereas while experiment observed in closed tank has distances varying inside the interval 350–510 mm. The values of bias (δ) percentage and experimental standard deviation (σ) percentage are marginally greater in closed tank than those observed in free-space.

The distance measurement using cross-correlation by single-bit signal processing [5] is calculated by comparison with cross-correlation of multi-bit digital signals and interpolation of cross-correlation function with the linear approximation of the phase created using computer simulations and the experimental results. The amount of noise in the received signal is reduced by the using the triangular weighted moving average filter. The high-time-resolution cross-correlation function can achieve higher peak amplitude than the cross-correlation function of 8-bit digital signals. The distance measurement with cross-correlation by single-bit signal processing result has improved accuracy of distance in a noisy atmosphere.

In the above method, the time resolution of the received linear frequency modulated signal's TOF is characteristically better by introducing the cross-correlation function with its phase or refining the sampling frequency of digital signal processing. The previous needs a large lookup table of arctangent and complex cross-correlation operation, while the latter significantly increases the calculation costs of cross correlation and the time resolution of the cross-correlation function. The design costs of cross correlation by single-bit signal processing are constant and self-determining of the sampling frequency of digital signal processing. And so, cross correlation by single-bit signal processing is an effective method for improving the time resolution of the TOF.

The binary frequency shift-keyed (BFSK) [6] ultrasonic distance measurement system is based on combining both TOF method and the phase shift method in view of change in temperature and humidity to increase the accuracy of the result. The problems are reduced with the no-ideal behavior of the ultrasound transducers. The received signal has two steps to process one is TOF calculation using the elapsed time, which is the travel time of the signal from the transmitter to the receiver and the phase shift calculation using phase shifts detected by the received signals with respect to the transmit signals. The accuracy of the phase shift is limited by the amplitude accuracy of the samples and the resolution of the analog to digital converter and the refined range does not exceed a wavelength of the transmitted signals.

The pulse echo method is the easiest method to measure the distance when compared with the analyses of different approaches. The echo signal reflected at the receiver makes the microcontroller with LCD which is user friendly. The echo signal provides the accurate measurement of distance with reduced noise in the signal under the different temperature range. The different approaches of ultrasonic time-of-flight (TOF) to measure the distance have a result of improved accuracy in noise, amplitude attenuation, and shape distortion of ultrasonic echo, temperature and humidity.

References

1.Vidyadhar Kamble, Dipesh Makwana, C.Chandramouli, Prof. P.C. Pandey, Ultrasonic Based Distance Measurement System - EE616 Electronic Design Lab Project Report, EE Dept, IIT Bombay, November 2007.

2.Pawan Kumar and Meenu Bhardwaj, Accurate Measurement of Distance and Velocity Using Technological Application Of Echolocation - International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11 (2012).

3.Leopoldo Angrisani, Aldo Baccigalupi and Rosario Schiano Lo Moriello, Università degli Studi di Napoli, Italy - Ultrasonic-Based Distance Measurement Through Discrete Extended Kalman Filter.

4.F.E. Gueuning, M. Varlan, C.E. Eugene, P. Dupuis, Accurate Distance Measurement by an Autonomous Ultrasonic System Combining Time-of-Flight and Phase-Shift Methods, IEEE Trans. on Instr. and Meas., Vol.46, N.6, December 1997, pp.1236-1241.

5.Shinnosuke Hirata1, Minoru Kuribayashi Kurosawa1 and Takashi Katagiri (publication 3 June 2009 - The Acoustical Society of Japan) - Accuracy and resolution of ultrasonic distance measurement with high-time-resolution cross-correlation function obtained by single-bit signal processing.

6.Aldawi, Fouad, Longstaff, Andrew P., Fletcher, Simon, Mather, Peter and Myers, Alan A high accuracy ultrasound distance measurement system using binary frequency shift-keyed signal and phase detection. In: Proceedings of Computing and Engineering Annual Researchers' Conference 2007: CEARC’07. University of Huddersfield, Huddersfield, pp. 1-7.

7.Leopoldo Angrisani, Aldo Baccigalupi, and Rosario Schiano Lo Moriell - Ultrasonic Time-of-Flight Estimation Through Unscented Kalman Filter (IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 55, NO. 4, AUGUST 2006).