AN ACCURATE TECHNIQUE FOR ULTRASONIC RANGE MEASUREMENT IN A NOISY ENVIRONMENT

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Abstract - Successful operation of most ultrasonic ranging systems relies on accurate time of flight T_f measurements. Usually ultrasonic rangefinders for robotic applications employ a pulse- echo technique based on threshold detection to perform range measurements. The low-bandwidth ultrasonic transducers used for operation in air yield relatively long rise-time echoes; hence the range information obtained by threshold method is biased. Digital signal processing techniques using correlation methods can provide more accurate measurements. Correlation based detection methods provide better performance for their outstanding capability of detecting and recovering weak signals buried in noise. In this paper, we describe a pulse-echo ranging system whose receiver signal processing is completely digital; the proposed system employs a suitable digital signal processing technique (Hilbert transform) to extract the envelope of the reflected pulse echo together with a suitable pulse detection technique (threshold or correlation) for time of flight estimation. The experimental results obtained show the superior performance of the correlation technique compared with threshold technique especially at low signal to noise ratio.

Keywords: *robotic –time of flight – Hilbert transform – correlation*

1-Introduction

A number of industrial applications [1] involve the problem of performing non-contact distance measurements. Many techniques are available for the measurement of distance [2]; these include triangulation, return signal intensity, multi-frequency continuous wave and time of flight based technique Ultrasonic sensors are a powerful tool to effectively address this kind of problems from the viewpoint of performance and cost. Many examples can be found in different remote sensing applications including sonar mapping, robotic ranging and positioning, ultrasonic based navigation, medical imaging, non-destructive testing of materials, flow velocity, fluid level measurement and so on. The operating principle of time of flight based technique is based on the measurement of T_f of the ultrasonic pulse of energy to travel from its transmitter to the reflecting surface and then back to the receiver, the sensor transmits an ultrasonic pulse which propagates through the transmission medium and is echoed by a reflecting surface, so that the range R can be estimated indirectly by the formula

$$R = C\,T_f\,/2 \qquad (1)$$

Where C represents the propagation speed of the ultrasonic waves in the medium [3].

Correct localization of targets using ultrasonics depends on how accurately T_f can be measured and how to know the speed of sound in the medium. The dependence of sound speed on temperature is shown by the following equation

$$C = 331.4\sqrt{T\,/\,273} \quad \text{m/s} \qquad (2)$$

Where T is the absolute temperature in Kelvin. This expression neglects effects such as those due to humidity and pressure which has very minor effects in the normal applications. The critical point of the whole measurement procedure is the time of flight estimation.

Threshold detection is the most widely used method for T_f estimation, and applies to any type of short duration signal. By this method, the received signal amplitude or its envelope is compared with a threshold level, such that the arrival of the wave is acknowledged when the signal reaches this level. This is done to eliminate a false detection due to background level noise. The resulting ranging system is simple but the main disadvantage is that any disturbance in the environment which affects the received signal can easily induce range errors. More robust detection methods exist, which has the capability of detecting and receiving low energy signals buried in noise. Correlation methods are particularly suited to permit ranging at longer distances or the distance being the same, at higher frequencies where attenuation is increased [4], with simultaneous improvements in spatial resolution.

The aim of this paper is to introduce an accurate pulse-echo ranging technique based on the measurement of T_f using correlation detection for ultrasonic range measurements in a noisy environment, compared with the commonly used threshold technique.

2- Theoretical Background

2-1 Signal observation model:

To examine this problem, If the transmitter is excited at t = 0 a suitable mathematical model of the transmitted ultrasonic signal must be considered, as reported in [5]

$$s_T(t) = A_s t^m e^{-t/h} \cos(2\pi f_o t + \phi_s) \qquad (3)$$