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FACULTY OF ENGINEERING-SHOUBRA

DEVELOPMENT OF ULTRASONIC RANGING SYSTEM FOR A MOBILE ROBOT

BY

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A Thesis

Submitted in Partial Fulfillment for the Requirements of the degree of Master of Science in Electrical Engineering, Communications Department

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Cairo, 2005

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ABSTRACT

The aim of this study was to develop an Ultrasonic (US) range finding system for an experimental mobile Robot, which detects and avoids obstacles by measuring the object distance using the Time of Flight (TOF) technique. This has been achieved in three stages. In the first stage, a single Transmitter/Receiver range finding system was developed. A 40 kHz square signal was experimentally generated and magnified to a level sufficient to drive the piezoelectric transducer (transmitter), which in turn converted this square signal into an ultrasonic wave. The signal was then emitted to the surrounding environment. On colliding with target, the ultrasonic signal would be reflected and detected by the receiver, which in turn converts this ultrasonic signal into an electric signal that provides the microcontroller with an external interrupt. The time elapsed from emission to detection of the reflected pulse was recorded and used along with the speed of sound in air for estimating the object distance.

Due to the poor angular resolution and the small coverage area associated with the single sonar system, a multi sonar system was developed in the second stage to overcome such limitations and improve the target resolution. An array of four transmitting transducers was used for the transmission unit; each transmitter was surrounded with two receivers. The operation of these transmitters and receivers was controlled using two different multiplexing logic circuits. An interface with the PC has been successfully implemented in the third stage. The object distance estimated by the microcontroller was verified and displayed on the PC in both numerical and graphical format.

Experimental measurements were taken on various targets with different geometry and positions by the developed single and multi sonar range finding systems. For single sonar range finding system, the object distance and time of flight were experimentally taken on flat horizontal surface, inclined surface with an angle of inclination of 60 degrees and on a corner target. The obtained results reflected the ability of the single sonar system to detect the flat object when placed in a horizontal position. While for the other two cases, the single sonar system has failed to identify the object position and geometry.

For multi sonar range finding system, the object distance and recorded time were experimentally taken on flat target placed in horizontal position and in inclined positions with inclination angles of 30, 60, 80 and 90 degrees. The obtained results reflected the high performance of the multi sonar range finding system over the single one for all the studied cases. In addition, the multi-sonar system has successfully identified the corner location and geometry. It also detected the cylindrical objects from multi viewpoints.

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B	Gas constant
C	Speed of sound in air
c	Sound velocity which is equal to 343 m/s at room temperature
D	Spot diameter in inches
d	Transducer diameter
F	Temperature in degrees Fahrenheit
f	Operating frequency in kHz
G	Gravitational constant
I	Intensity (power per unit area) at distance R
$\mathbf{I_i}$	Incident intensity
$\mathbf{I_o}$	Maximum (initial) intensity
$\mathbf{I_r}$	Reflected intensity
K	Ratio of specific heat, (for air = 1.4)
$\mathbf{K_m}$	bulk modulus of elasticity
$\mathbf{K_r}$	Coefficient of reflection
R	Range of measured distance (m)
T	Temperature of the air in °C
t	Time of flight (Sec.)
$\mathbf{Z_a}$	Acoustic impedance for air
$\mathbf{Z_o}$	Acoustic impedance for the target object
α	Attenuation coefficient for medium
θ	Total beam angles in degrees
λ	Acoustic wavelength
ρ	gas density