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Motion Monitoring of Coupled Structures Using Ultrasonic Distance Sensing System and Wire Draw Distance Encoder

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ABSTRACT

This paper develops two distance sensing systems for coupled structures. The first system measures distance with ultrasonic sensor. It consists of an ultrasonic sensing module, an Arduino interface board and a control computer. The system is then further upgraded to a three-sensor version, which can measure three sets of distance data at the same time. The three modules are synchronized by the Arduino board as well as self-developed software. The second distance sensing system consists of a wire draw encoder, a data collection board and a control computer. Wire draw encoder is an electromechanical device to monitor linear motion by converting a central shaft rotation into electronic pulses of the encoder. Encoder can measure displacement, velocity and acceleration simultaneously and send the measured data to the control computer via the data acquisition board. From experimental results, it is concluded that both the ultrasonic and the wire draw encoder systems can obtain the linear motion of structures in real-time.

1. BACKGROUND

Ultrasonic-based distance measurement is now recognized as a simple and inexpensive answer to many demands of industrial manufacturing (Carullo *et al.* 1996, Marioli *et al.* 1988). For instance, ultrasonic distance sensor is used to monitor the pedestrian traffic by measuring distance based on the round trip time of the ultrasonic waves (Marioli et al. 1988). The use of such a technique in an industrial environment is sometimes prevented by its drawbacks, such as poor sensitivity to temperature

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(Găşpăresc *et al.* 2014). Recently, the temperature effect can be satisfactorily compensated by adding a small circuit to the sensor (Mariani *et al.* 2016, Minomi *et al.* 2013).

Encoder is another commonly used device to monitor position (Lee *et al.* 2016). Incremental encoder plays an important role in automation, drilling excavator system, machinery construction, medical technology and many other industries. For instance, Ogitsu *et al.* developed a vehicle following device that uses a wire draw encoder for guiding elderly people in urban areas (Ogitsu *et al.* 2014). The encoder measures the vehicle-to-vehicle distance when attached to the metallic parts on the rear of the preceding vehicle.

A wire draw encoder has a rotary encoder in its rewind mechanism and can measure the length of the drawn wire. It provides the number of pulses in proportion to the amount of movement, and its pulses are accumulated by a counter to determine the position. This facilitates positioning on linear measuring paths (Lee *et al.* 2016).

2. ULTRASONIC SENSING SYSTEM

Ultrasonic sensor transmits ultrasonic waves from its transmitting unit and again receives the ultrasonic waves reflected from an object via its receiving unit. From the measured time interval between sending the signal and receiving the echo, the distance to an object is determined. For distance sensing, first a high level electrical signal is supplied as IO trigger for at least 10us. After receiving the IO trigger, the ultrasonic module automatically sends eight 40 kHz square waves and detect whether there are returning pulse signals. If there are signals returning, the time of the high output IO duration is recorded to calculate distance as:

$$d = t * v_s / 2$$

where d is the distance, t is the measured time and V_s is the velocity of sound.

As sound velocity increases by 0.607 m/s when the temperature rises for 1°C, the velocity of sound is temperature dependent:

$$v_s = / 2331.45 + 0.607 * T$$

where T is the temperature.

First an ultrasonic sensing system with US-100 module is set up and tested (Figure 1). US-100 module have a measurement range of 300mm and a resolution of

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