Liquid Monitoring System in Industrial Tanks with Ultrasonic Sensor

Mateus Santos Rogienfisz, Laura Silva de Assis and Felipe da Rocha Henriques .

***Abstract*— Recent advances in areas such as microelectronic, digital electronic, and wireless communications enable the development of low cost sensors with energy efficiency and small scale. In this work, a prototype of a monitoring system for liquids in industrial tanks with an ultrasonic sensor is developed. A software that interpret readings from the ultrasonic sensor is also designed and the proposed system is used to monitor the liquid volume inside the tanks. An open–source platform called Arduino is considered for the hardware in order to manage and interpret data from the sensor. Experiments with a rectangular base tank filled with water showed that the proposed monitoring system is efficient, since the volume sensed closely reaches the real one.**

***Keywords*— Liquid Monitoring, Ultrasonic Sensor, Arduino.**

I. Introduction

Monitoring systems are widely used to sense an enormous sort of applications: military, medical, residential and industrial automation, among others. In a Wireless Sensor Network (WSN) [1], low cost and tiny sensors are spread in some region in order to sense physical variables, such as temperature and humidity [2], [3].

In this work, we focus in the industrial automation and we intend to remotely sense liquids inside industrial tanks. The monitoring system makes the level reading more accurate throughout the storage tank management process. Through such monitoring preventive actions can be taken, as like triggering an alarm. This approach brings up several advantages over the manual monitoring process. In a manual sensing system, a person needs to frequently check the level inside the tanks and this process could easily fail. When it is done automatically, several tanks could be simultaneously monitored and solutions for possible problems could be remotely and quickly taken.

The ultrasonic sensor is widely used to sense liquids inside tanks [4], because of its low cost and simplicity. In this work we propose a prototype of a monitoring system for liquids inside tanks by using an ultrasonic sensor. Experimental tests are done in a rectangular base tank with water. A software that reads data collected by the sensor are developed and the error rate between the real water volume and the volume estimated by the prototype is negligible.

This work is structured as follows: Section II presents the proposed monitoring system; Section III describes the experimental set–up and the obtained results are showed; finally, conclusions and future directions are discussed in Section IV.

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II. The Monitoring System with Ultrasonic Sensor

Ultrasonic sensors use sound vibrations to estimate the distance between a source (sensor) and a given target. The echo of the emission is used to calculate the desired distance. For the proposed system, the sound reflection in the water mirror is considered for the calculus.

The distance (d) between the sensor and the water mirror–eq. (1)–is used to calculate the level inside the tank.

$$d = \frac{t_e \times c}{2}, \tag{1}$$

in which t_e is the time period for the echo and c is the speed of the sound.

The monitoring procedure is done in two steps:

1) Calibration: this is the first stage for the sensing procedure, in which the system calculates the distance between the sensor and the base of the tank. For the calibration, the tank must be empty;
2) Measuring: after the calibration, the system is able to measure the liquid level of the tank.

The information about the liquid level inside the tank is used to make some decisions; if the level is too low, the system is used for the tank to be filled; on the other hand, if the level is too high, the liquid is automatically drained from inside the tank.

One of the main objectives of the design and implementation of this monitoring system is to reduce maintenance costs and waste of raw material caused by overflow.

III. Experimental Set–up and Results

A prototype for the monitoring system was developed, considering a tank with a rectangular base with 3600 cm^2. An Arduino Mega 2560 micro–controller that uses C programing language is considered. Furthermore, an HC–SR04 ultrasonic sensor is used in this project. Figure 1 shows the Arduino Mega micro–controller and the ultrasonic sensor used in this project.

The following components were used in this experiment:

- 1 Arduino Mega 2560;
- 1 LCD display;
- 1 joystick;
- 1 HC–SR04 ultrasonic sensor;
- 1 potentiometer (50k Ω);
- some jumpers for connections.

Initially, a menu is presented in the LCD display, showing two options: calibration and measuring. The calibration is the

Fig. 1. Illustrations of the micro–controller and sensor considered in this work.

first stage selected by the user and the tank must be empty. Thus, the Arduino calculates the height of the sensor relative to the base. After that, 1L of liquid is added to the tank and the sensor computes a new height. Based on these data, the micro–controller is able to calculate the area of the base of the tank, and the user can perform measurements. Figure 2 illustrates the designed system and prototype.

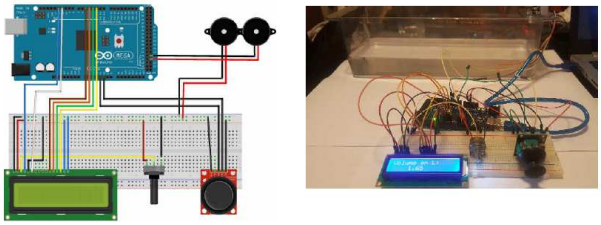

Fig. 2. Ultrasonic sensing illustrative scheme and prototype.

Table I presents the experimental results obtained with the prototype designed in this project. This table shows the absolute volume calculated by the monitoring system and the percentage error between the real and the calculated ones for each inserted volume of water.

TABLE I

EXPERIMENTAL RESULTS OBTAINED BY THE PROTOTYPE FOR SEVERAL INSERTED VOLUMES OF WATER, CONSIDERING A TANK WITH A RECTANGULAR BASE OF 3600 CM^2.

Real volume (cm^3)	Calculated volume (cm^3)	Percentage error (%)
20.00	20.66	3.30
25.00	25.60	2.40
27.00	27.36	1.35
30.00	30.27	0.93
32.00	32.01	0.05

IV. CONCLUSIONS

A monitoring system for liquids in industrial tanks with ultrasonic sensor is developed in this work. An Arduino micro–controller is used to interpret data collected by the ultrasonic sensor, and decisions are made based on the level of the liquid inside the tank. The monitoring procedure is composed by two steps: the first one is the calibration of the system, in order to verify the distance between the sensor and the target; and the measuring of the liquid level inside the tank.

Experimental tests were done in a prototype for a tank with rectangular base and results show small percentage errors between the real volume of water inserted inside the tank and the volume that was calculated by the proposed system.

For future works, we intend to use the system in a more realistic scenario with larger tanks. Finally, we plan to consider the transmission of collected data over a wireless network [5] to a central, and to compare the proposed system against other similar ones.

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