An internet of things system for monitoring and control of mobile Diesel tanks

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Abstract

This contribution presents a sensor system solution aimed at retrofitting mobile Diesel tanks to enable owners to control access, make usage data available, and provide additional services such as geolocalization and environmental monitoring. The system is set-up as an end-to-end digitized system combing information from numerous sensors in order to facilitate holistic information about mobile tanks. In particular, one-size-fits-all level and flow sensors enable the system's installation at arbitrary tanks without the need for calibration.

1 Introduction

Mobile Diesel tanks are long-lived, low tech industrial assets used to distribute the majority of Europe's total off-road Diesel consumption [1]. These are used in numerous fields, including agriculture and construction sites [2]. The digitization of this distribution route would help to prevent theft, automatically detect leakages, and allow stakeholders to acquire important usage data for optimized refilling and localization of tanks in the field [3]. However, retrofitting Internet of Things (IoT) technology is hindered by high costs associated with installation and calibration due to the vast variety of tank sizes and shapes. Previous designs of IoT-enabled fuel tanks have been carried out in the past, but so far none have implemented a system for the calculation of volumes that allows for retrofitting to existent tanks using a universal firmware that doesn't require tank-specific preconfiguration [4,5].

To overcome these obstacles an IoT system has been devised and developed that allows for access control to mobile tanks via a mobile smart device. An algorithm based on the data of fuel level and flow rate sensors provides an automated classification of tank size and shape. Additional sensors enable geolocalization and recording of environmental conditions.

2 System Concept

Since mobile Diesel tanks are oftentimes located at remote locations without any network coverage, the Bluetooth Low Energy (BLE) protocol in combination with a dedicated smart device app has been chosen to access the internet indirectly. This way user authentification and access control to the Diesel tank is independent on network coverage at the respective location of the tank. All data is stored in the app and transmitted to a web-based server as soon as internet connectivity of the user is available again. A double authentification process is established such that only users authorized to access a certrain tank using vehicles can access it. This is implemented using a fixed BLE beacon in the user's vehicle to perform a double proximity check: Only if an authenticated user and his/her vehicle are close enough to the tank may they access it. This is implemented using a relay that controls the tank's pump. The tank user's status is stored in the app and updated continuously whenever internet access is available. The Diesel tank sensor system includes a novel, one-size-fits-all capacitive sensor as well as a low-cost flow sensor to gather tank usage data. A PSoC6® microcontroller manages digitization of all sensor data, and BLE communication. An algorithm to automatically determine tank size and shape is implemented in the microcontroller and once tank classification is complete, this information is transmitted to the internet platform via the app. An overview of the system is provided in Figure 1, and a picture of the system is given in Figure 4.

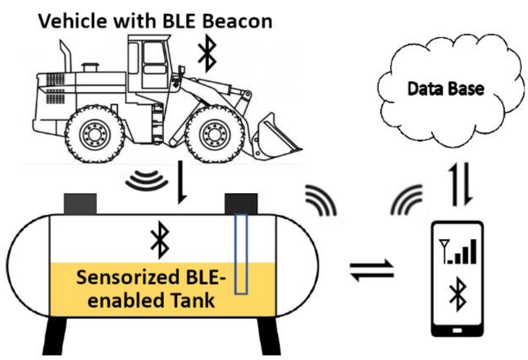

Figure 1: Schematic depiction of the system's components.

Using the data from the flow sensor, it is possible to know the volume of fuel that has been extracted during a refueling process. Additionally, the capacitive sensor allows for a measurement of the level change of the tank simultaneously. Combining both sensors, the novel algorithm is capable of calculating and storing the cross-section of the chamber for each given fuel height. This enables the system to calculate the remaining fuel volume in liters for a given height of fuel, which traditional systems for measurement of fuel level can only do with a previous calibration for the specific tank. Initially, the algorithm mathematically slices the tank into several disks perpendicularly to the level sensor. Upon refueling, the flow sensor measures the total volume of fuel flowing out of the tank for each of the disks. This way, it can assign a volume to each disk

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independently of the shape of the tank, which allows it to self-calibrate upon performing a complete emptying of the tank. Further information on the volume of the disks obtained from later refueling processes is added using an Infinite Impulse Response (IIR) filter, which enables higher precision in the volume calculations by means of averaging.

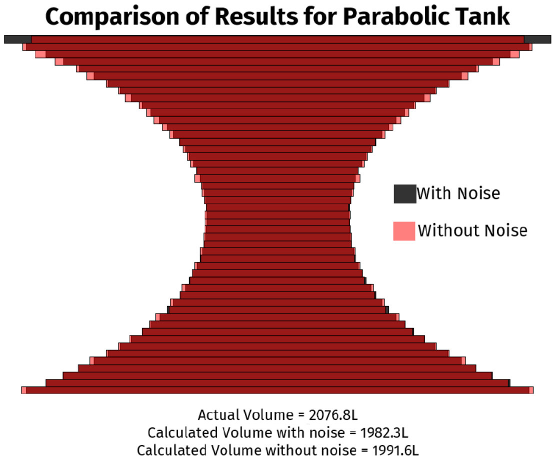

Figure 2: Results of the volume calculated by the algorithm in the simulation with a tank with a paraboloid shape.

Since the microcontroller is constantly measuring the level and not only during refueling, it automatically detects when a refill of the tank takes place, i.e. any increase in fuel level, and also when an unauthorized extraction of fuel or leak takes place. In the latter case, once it has calculated the shape of the tank, it is capable of knowing how much fuel has been removed, e.g. during theft, even if the extraction takes place through a conduct different than the one with the flow sensor.

3 Results

The algorithm has been tested using simulations first and later put to test with a real tank. The simulations include a tank of spherical shape and another with the shape of a revolution paraboloid.

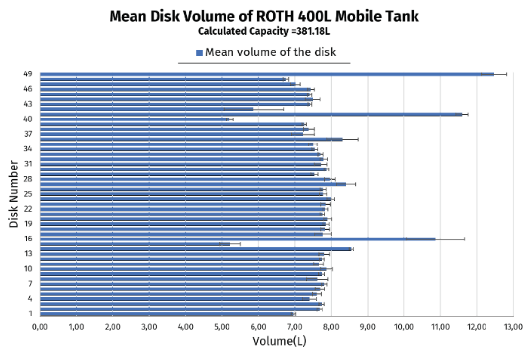

Figure 3: Data output from the algorithm for a real tank with a volume of 400L. The outliers can be explained by differences in the cross-section of the tank and by Differential Non-Linearities in the ADC of the level sensor.

The simulations consist of a set of Analog to Digital Converter (ADC) values corresponding to the height of the level sensor during a refueling process, together with the output of the flow sensor, correspondingly. For each tank shape, two simulations were carried out: one including white noise on top of the ADC measurements, and another without noise. In both cases, the algorithm discerns the shape of the tank accurately. Since the emptying of the tank is an accumulative process, the error in the calculation of the volume of any particular disk coming from the level sensor will be compensated with the calculation of the one directly above or below, and in any case, refined with further refueling processes through the IIR filter. The results for one of the simulations can be found on Figure 2, and the results for the real measurement can be found on Figure 3. In the latter figure, the outlier values serve as proof that the algorithm automatically calculates the correct cross section taking into account the shape of the tank and, if present, the Differential Non-Linearity (DNL) of the level measurements.

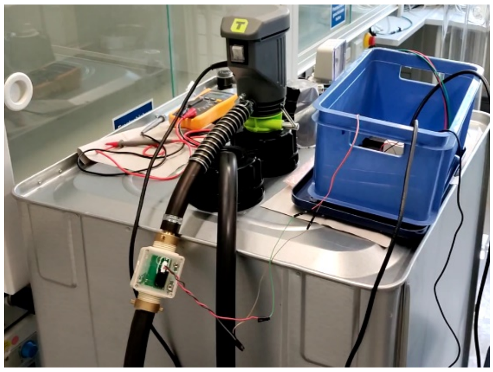

Figure 4: Experimental setup for the measurement in the laboratory. The prototype electronic circuit is placed the blue box to the right, the flow sensor can be seen connected to the pump's output, and the level sensor is hidden behind the pump.

4 Literature

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