Pit Searching System Using Iot Technology For Smartcity

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***Abstract*— This work is devoted to the problem of automatic road quality control, which can be used by both road repair services and common drivers. In this paper will be described our device for detecting potholes on the road, which can be used, as a part of the IoT system of SmartCity. It uses data from an accelerometer for finding road bumps.**

Keywords— Internet of Things, SmartCity, Potholes detection, Accelerometer, SPI, STM32, Road surface analysis.

I. INTRODUCTION

All countries around the world suffer enormous losses due to road damage every day. Firstly, millions are spent on repairing and "patching" damaged sections of roads. Secondly, driving on uneven surfaces increases the amount of fuel consumed and more often leads to the need for maintenance. We should also not to forget that potholes on the roads are often one of the causes of accidents and lead to injuries and sometimes even death.

Every year the concept of the Internet of Things is gaining popularity. Especially popular is the concept of "SmartCity", in which the elements of the infrastructure communicate with each other [1]. As a result, it has been suggested that the ability to control the quality of the road surface as an element of such a system would be an extremely useful addition [2].

Given all the above, it is safe to say that the solution to this problem is the ability of vehicles to find the problem areas while driving. To implement such a system, it is only necessary to obtain the values of linear acceleration, location, and the ability to transmit this data for display in a convenient form.

In this paper we offer our way for solving the problem of finding road defects with the help of modern linear acceleration sensors for monitoring the quality of road sections. To solve this problem, we considered and analyzed the algorithms for assessing the quality of the road surface and marking road sections by quality and create own algorithm based on known systems. We offer a hardware that allows real-time detection of defects on the road surface and in a special way to mark such road sections.

II. RELATED WORKS

Due to survey [2] interest to giving intelligence to vehicles increase rapidly in area of smart applications and algorithms of indication environment around them. Especially, technologies of communication of cars among themselves and with elements of infrastructure extends. So it will be grate, if one car can provide information about quality of road surface to another.

To choose the best way to identify problem areas of the road, we considered the existing analogs of the systems, which also dealt with this issue, namely, what characteristics they relied on to decide on the quality of the road surface.

The costliest way to determine the quality of roads is to use road labs, mobile data, and roadside data collection centers. Depending on the set purposes, such cars equipped by a large number of sensors (several video cameras, GPS receiver, three-dimensional laser scanner, soil analysis system, positioning unit). The main part of the analysis is non-autonomous and proceed after driving. Such a method is more scientific but requires a special person to process data.

Another option presented in [3] is determining potholes and cracks on the roads by finding them using data in video format. The basis of the search for potholes and patches in this method is the use of the method of active circuits. The essence of the method is to select the contour of the object at a given point, which exactly belongs to the object. The intensity dispersion in its inner region is considered as the initiator for determining the damage. This method has some critical shortcomings. Firstly, already repaired areas that differ in color or covered with a shadow are also can be detected as potholes. Also, the original video gives a high error due to problems with perspective distortion of shooting.

The next option for solving this problem described in [4] - a mobile service to assess the road surface. To join this program, just install the application on your mobile phone, register, allow access to GPS and the accelerometer built into each phone and place the phone on the desk of your car. All modern smartphones can measure the force of "shaking" the phone with an accelerometer. This allows you to turn the machine into a mobile laboratory without any additional spending. Collected information is processed using mathematical algorithms. Also, as an option, the possibility of using artificial intelligence for search is considered [5]. The GPS sensor finds the current location and displays the quality on the map. Such a method is available to all car owners, but this option of data collection will quickly discharge your mobile phone because the long use of the GPS sensor is very resource-intensive. It is also worth noting that moving the phone will give false results, so you can't use your phone while traveling, for example, as a navigator or for other purposes.

The closest technology was used in BusNet [6] system developed at the University of Colombo and in Pothole Patrol system [7] developed at Massachusetts Institute of Technology. They create their own environment using a 3-axes accelerator and GPS module to store data and predict potholes in the traffic system of their hometown using social transport (buses/taxi). Unlike others, the system in [6] doesn't work in real-time. The data is stored on local memory and transmitted to the database at the bus station for later processing. The main difference of Pothole Patrol [7] system is using machine learning algorithms consisting of 5 different filters for getting more truthful information and rejecting not related occasions such as railway crossings etc.

III. THE PURPOSE AND OBJECTIVES OF THE STUDY

After analysis of related works, we decided to create our own device which finds potholes on a road surface, as a part of IoT road monitoring system. The main point of our work is to make pure automatic road quality control system with high accuracy of gained result for decent price which can be built in any car. There are a few steps which we made to reach our goal.

First of all, we choose hardware and peripherals which would meets our needs to create our system and device for finding potholes in particular and developed device and system architecture.

The next step was to develop an algorithm for spotting road bumps. On this phase we implemented methods for reading data from sensors, data processing, communication between device and cloud storage, processing the result.

The final stage of the work was the implementation of the system of finding pits on the roads using a linear acceleration sensor with the following functions: removal of indicators from the sensor, filtering noise and errors, sending data to cloud storage with further processing. According to the results of the created system it was carried out testing.

IV. MATERIALS AND METHODS OF RESEARCH

A. IoT system architecture

In the book Designing the Internet of Things [8], the elements of the IoT are presented as a simple equation:

Physical Objects + Controllers, Sensors, Actuators + Internet = IoT.

This equation clearly explains the nature of the Internet of Things. Standard IoT system consists of a collection of physical objects, each of which:

- contains a microcontroller that provides intelligence;
- contains a sensor that measures some physical parameter and/or an actuator that acts on some physical parameter;
- provides a means of communicating via the Internet or some other network.

The role of the object in our system is played by the car. It houses our device, which is a microcontroller with an accelerometer attached to it. The microcontroller exchanges information with server using Ethernet technology. The general architecture of our system consists of hardware and server parts, as shown in Figure 1.

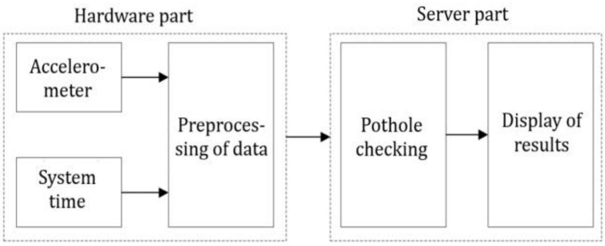

Fig. 1. System architecture

The general hardware diagram of the device is presented in figure 2. The reason for this choice is the rapid popularization of the development of SmartCity systems. Dozens of different sensors work in such systems at once, so it is extremely valuable to implement the system so that the developed device can be used as part of a larger project.

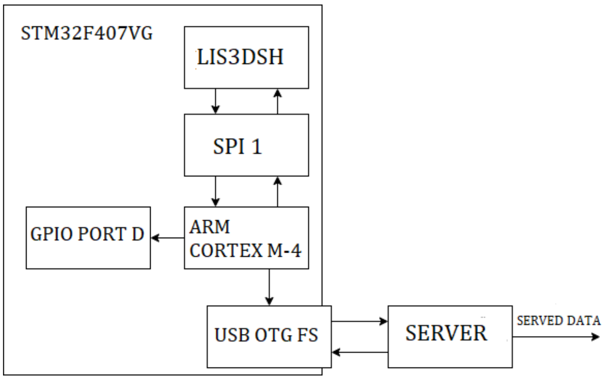

Fig. 2. Hardware architecture

First of all, the developed device is implemented on the STM32F4 Discovery microcontroller. STM boards have developed most of the projects related to IoT and work with peripherals in general. The choice of the STM32F4 Discovery board is explained by the fact that it has all the necessary elements to solve the problem. It has low power consumption, high performance, has several interfaces for information exchange, has a large number of free I / O ports. However, there is no hard link to work with this particular board. Project transfer is possible by reconfiguring the I / O

ports, clocking, and using the built-in libraries for another microcontroller.
The LIS3DSH linear acceleration sensor is used in the work. First of all, the choice was based on it because this sensor is built into the selected board, but this is not its only advantage. It is highly specialized and therefore does not spend extra energy in its work, which is very important for microprocessor systems. It has high sensitivity and adjusts well to different measurement ranges depending on the tasks.
To receive data from the sensor was selected using bus SPI, as one of the most convenient for receiving data. This choice is due to the simplification of data processing, as this method organizes fast synchronous communication, and can simultaneously implement serial communication between many peripherals and a single microcontroller. Transition of data between device and server occurs using Ethernet. After receiving information server performs bump detection algorithm and displays the result of road testing.

B. Bump detection algorithm

The algorithm we offer performs a two-level test. First of all, when the car hits a pothole, the car significantly changes its acceleration along the vertical axis. With this in mind, the first method in testing which we named Threshold method is to compare the acceleration value with the threshold value. Since entering the pit of acceleration takes the form of a sinusoid - sharply accelerating, and then just as sharply slowing down like it's shown on figure 3, it is necessary to set both the upper and lower thresholds of acceleration.

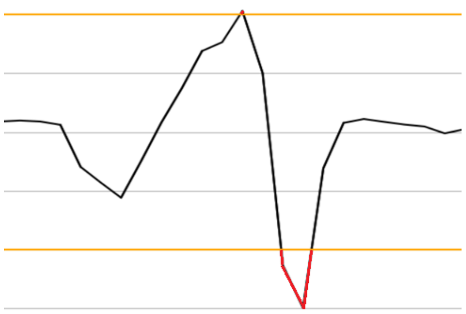

Fig. 3. Threshold method

Secondly, the acceleration when entering the pit increases very sharply, so it is possible to detect cracks that may not lead to high performance, but the change between successive measurements will be significant to assume the presence of a defect on the road. Therefore, the second method to check the indicators, which we named difference method, will be to compare neighboring values in the indicator buffer, like in figure 4.

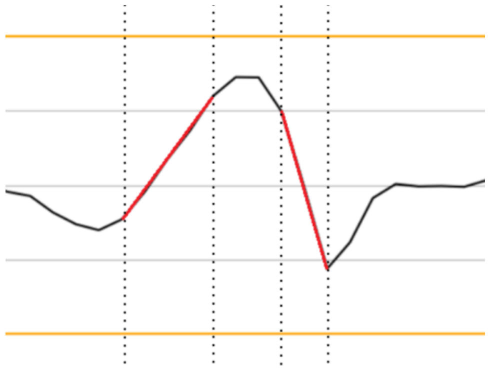

Fig. 4. Difference method

V. Research Results

Detailed information about testing described at table 1. All tests were performed at a speed of 60 km per hour. At different speeds the accuracy of operation may vary. For further usage of the system it is necessary to add elements of machine learning to analyze the obtained indicators in the presence of a large sample of results on the same section of the road. Both methods were tested with different comparative values (threshold method – 0.1-1g; difference method - 0.1-0.5g). Threshold method shows the best results using 0.4g as indicator. The best score for difference method was when indicator is equal to 0.2g.

TABLE I. Percentage of true founded road roughness

Method	**Threshold method**	**Difference method**
Large potholes	100%	100%
Small potholes	82%	91%
Pothole clusters	80%	90%
Gaps	42%	88%
Total	**76%**	**92%**

TABLE II. Percentage of false founded road roughness on "fake gaps"

Method	**Threshold method**	**Difference method**
Pavements	22%	81%
Rail crossings	25%	75%

Given this, it can be assumed that double-checking helps to eliminate possible errors. At the same time, applying multiple inspections of one section of the road each time will improve the accuracy of testing.
The sample of checking is the graph shown in figure 5. The blue curve shows the processed acceleration indicators along the Z-axis. In the case of finding a sharp acceleration, the algorithm considers such a section as a potential and the graph of the third curve on this segment becomes red.

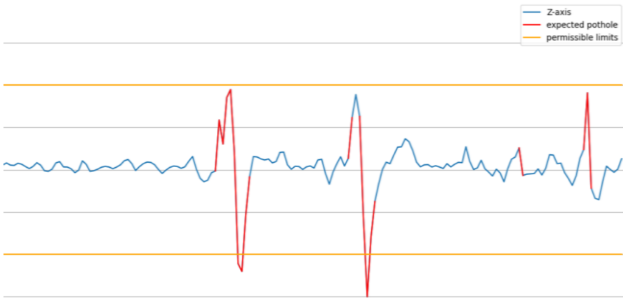

Fig. 5. Pothole detection

VI. Conclusion

This paper describes a system for identifying potholes on roads using developed device as part of the IoT system. The hole search algorithm is a combination of several algorithms to obtain a more accurate result. The essence of the device is the processing of data read from the linear acceleration sensor to identify potholes on the roads and present this information in a convenient form. At this stage, the basic part of the system is developed, which correctly responds to changes in the position and movement of the device. Such hardware in the future may become part of a larger project, and increase its functionality.

Based on the obtained result, we can clearly say that the system has certain advantages over analogues that exist in the world. First of all, the created model has a low level of energy consumption, competitive for similar microcontroller systems and much more prevalent in comparison with the systems as used by mobile devices. Disadvantages include the attachment to the correct position of the sensor, but this problem is solved by rigid fixation, or by adding a method to recalculate the acceleration relative to the static coordinate system.

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