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THE USE OF LIDAR TECHNOLOGY IN THE MANAGEMENT OF CAR TRAFFIC IN URBAN AREAS

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Abstract: In this paper we propose a solution to realize a mobile system for traffic management by counting the vehicles on a road with one or two lanes. The traffic intensity is measured using the transducers based on lidar principle. The acquired data are local stored into a local data logger and simultaneous are transmitted via radio communication to a dedicated server. The novelty of this system is represented by the communication facility provided by the new LoRa technology. System performance is evaluated by field tests and simulations. Based on the analyzes and evaluations, some solutions for monitoring and controlling processes are proposed using this communications infrastructure. Also, it is highlights that this system is mobile and it is not invasive on the road structure.

Keywords: LoRa, data acquisition, non-invasive technology, urban traffic management, LabView.

1. INTRODUCTION

In recent decades there has been a steady increase in the number of private cars in traffic, while public transport is steadily declining. The current road infrastructure no longer meets the demands. Accidents and congestion caused by traffic have an important impact on life, reduce productivity and reduce energy. Traffic congestion, which causes environmental problems and accidents, is becoming increasingly acute. The benefits of transport are diminished by the increasing number of negative impacts (air pollution and accidents, increased stress on road users), resulting in a vicious circle in urban transport. The spectacular increase in road traffic can’t be met in the short term by a corresponding increase in road space. For this reason, in all developed economic environments, two-directional solutions were dealt with: improving the design of road space to increase utilization and improving the parameters of the traffic through control and monitoring.

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Developing an intelligent transport system requires the collection of high-quality and real-time information about the traffic flow. Increasing pressure to improve the traffic management, the collection of traffic data methods has evolved considerably, and the access to real-time traffic information becomes usual. [11],[5]

For planning the road development or the management of traffic it is very important to collect the traffic data and use them in anticipation of traffic volume. The traffic flow can be considered as a function having a random distribution because it differs from many parameters including the time of day for measurement, season, geographical position, environmental conditions. It follows that the data collected is a methodological statistic and, despite such complexities, it follows some well-defined models that can be classified and analyzed. Thus, the collection of traffic data can be done in different ways and plays an important role in the evaluation and management of road networks.[7] Generally, the traffic flow consists of vehicle count on the road and the technologies used for this can be split into two categories: the intrusive and non-intrusive.

The intrusive methods consist of transducers which are placing on or in the road and a data recorder. The most usual transducer used in intrusive methods are: pneumatic road tubes, piezoelectric and almost inductive loops. For all of them, it is necessary to bury in the construction layers of the road, becoming fixed or permanent installation.

The non-intrusive techniques are based on the remote data recording. Eliminating the manual counting that is often used, new technologies use transducers based on passive and active infrared, microwave radar, ultrasonic and passive acoustic, or video image detection.

2. LIDAR SENSORS

To achieve the system, Lidar sensors have been selected due to their features, such as influence reduced of the dust or ambient light, the operation is not influenced by the color or optical transparency of the reflective surface.

Small dimensions and low power consumption make this sensor ideal for projects where energy sources are batteries and energy consumption should be as low as possible. The sensor can be used for drones, robotics, 3D image scanning, collision avoidance, fluid / solid level measurement, medical imaging and more. This device measures the distance by calculating the delay between transmitting an infrared laser signal and receiving it after reflecting at a target meeting. This delay translates away using the known lightning speed. The sensor transmits through the laser beam a coded signature and searches for that signature in the reflection of the signal, allowing for an extremely efficient detection. Signal processing techniques are used to achieve high sensitivity, speed and accuracy using a low power source and a low-cost system. [8]

To perform a measurement, this sensor first performs a receiver polarity correction, correcting the change of ambient light level and allowing maximum sensitivity. Then the device sends a reference signal directly from the transmitter to the receiver. Store the transmission signature, set the delay for the "zero" distance and recalculate this delay periodically after several measurements.

Then the device initiates a measurement by making a series of data acquisitions. Each acquisition is a transmission of the main laser signal while recording the return signal to the receiver. If there is a signal match, the result is stored in memory as a correlation record. The next purchase is summed up with the previous result. When an object at a certain distance reflects the laser signal back to the device, these repeated acquisitions cause a peak of signal coming out of the "noise" area at the corresponding location of the distance from the correlation record.

The device integrates purchases until the peak of the correlation record signal reaches a maximum value. If the returned signal is not strong enough for this to occur, the device stops from making purchases.

The signal strength is calculated from the magnitude of the signal recording peak and from a valid signal, the reference threshold is calculated from the noise level. If the tip is above this threshold, the measurement is considered valid and the device will calculate the distance, otherwise it will report 1 cm. From the next measurement, the sequence is resumed.

At startup or reset, the device performs a self-test sequence and initializes all registers with the default values. Approximately 22 ms the distance can be taken with the I2C interface.

This device has a serial interface compatible with I2C. It can be connected to an I2C bus as a slave device under the control of an I2C master. The I2C circuit works internally at 3.3 V. An internal level switch allows the device to run at a maximum of 5 V. The 3k ohm pull-up internal resistances provide this functionality and allow easy use and easy connection to the I2C host. The device has a 7-bit slave address with a default value of 0x62. After initializing the system, the most significant bit of the I2C address byte is set to automatically increment the register address with successive reads or writes in a transfer data block. This is commonly used to read the two bytes of a 16-bit value in a single transfer and is used in the following example.

The hardware structure of the mobile system is represented in Fig. 1 and consists of the following:

- Arduino Uno/Nano development board;
- Lidar Lite v3 sensor connected to Arduino digital inputs;
- ESP32 a low-power system on a chip (SoC) with Wi-Fi and dual mode Bluetooth capabilities, that is connected to the Arduino between a serial communication bus;
- A simple local LCD display also connected to the Arduino between a serial communication bus;

The LiDAR sensor will be connected according to the technical specifications to the Arduino module either using an I2C connection or using a PWM connection. [6] The ESP32 will connect to Arduino using a serial connection and will allow the retrieved information to another module or to a LoRa gateway. The LCD display allows you to display information on the number of vehicles on a traffic arc, thus testing the entire system to the specified parameters. The entire system will be powered either from the power grid where it is possible or from an external battery in case of necessity. In the future, it is also desirable to create a power system using other types of renewable energy. ESP32 module allows communication using wireless communication protocol LoRa and so these modules can be integrated simply in any equipment regardless of its physical size tends to be minimized and a more reliable all components.

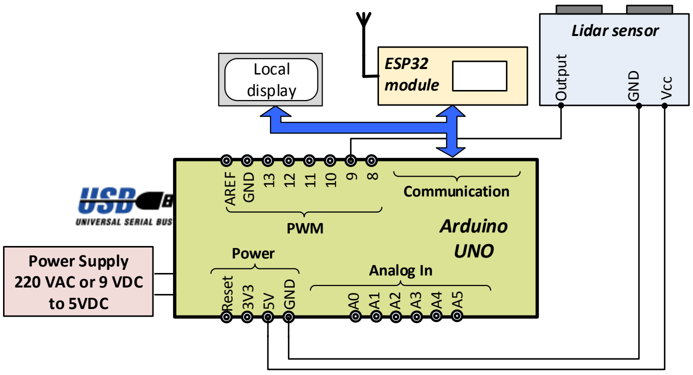

Fig. 1. Hardware structure diagram

For this system the supply voltage is provided from an alternative voltage source or from a battery through the 5 VDC controller on the Arduino board. In this way, the autonomy of the system can be assured. The monitoring system using a Lidar sensor, in addition to allowing for special portability, also ensures a fast and secure acquisition of data in traffic management (the number of machines crossing an intersection, their speed, and distance measurements). Laser scanning of the Lidar type has other applications in many areas of activity. LiDAR laser scanning provides an interactive topographic map with a height accuracy of up to 20 cm. Current data has an accuracy of up to 1.5 m. As a complement to topographic measurements, technology can be used to build roads, other construction sites, etc. It can also be used to evaluate different alternatives in the field of construction, education and research, engineering.

Since LiDAR is based on air scanning, the system is able to scan large areas of land in a relatively short time. An aircraft / helicopter mounted LiDAR system can scan a 300 km² area with a precision of 0.15 m over a 4-hour flight. Unlike photogrammetry involving manual, time-consuming work, LiDAR processing is largely automatic, with the possibility of obtaining the land model within weeks and not months after obtaining the data.

LiDAR is an automated system and does not involve a prior objective visit. Topographic maps can be obtained even in less accessible areas with reduced visibility and complexity at ground level.

Fast and automatic data collection for LiDAR allows designers to consider a multitude of options and alternatives in the design that will be performed. It also allows them to study alternative routes to suggest to the beneficiary. Normally, only 3-4 flights will be required to get a precise representation of the land and buildings, respectively alternate routes in an area with increased complexity. The optimal option will then be selected to meet the expectations of the beneficiary.

LiDAR is able to penetrate dense vegetation, which means that the team of designers can get information from hard-to-reach areas much faster and more accurately.

The experimental model setup is shown in Fig.2.

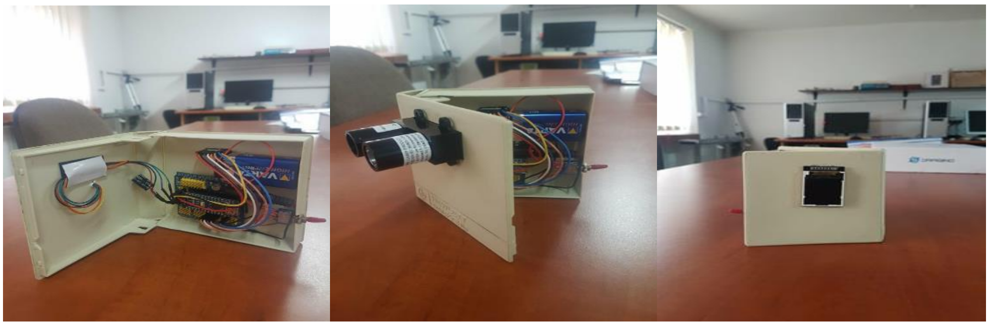

Fig. 2. Experimental model setup

The sensor is used to count vehicles on a lane at a time. Calculate the distance from the sensor to a particular reference point between it and the sidewalk, or consider the maximum distance that can be measured with this type of sensor when another value is found count a vehicle. The resulting number of counting vehicles on lane is locally displayed through a local LCD display and also are sent to the ESP32 radio module. Through this module, the information can be sent by radio transmission in 2.4 GHz band to long distance till a LoRa (Long Range Wireless Network) gateway connected to a network server from where it can be taken through internet network.

3. LoRa

The term LoRa (or LoRa technology) refers to a category of high-power low power long range radio communications. Unlike conventional digital radio transmission technologies, LoRa technologies have the capability of communicating data over tens of kilometers, with extraordinary applicability in wireless sensor networks, the Internet of Things (IoT), and networking of smart devices. [9] Behind the term LoRa is actually a multitude of proprietary or open technologies, similar to functionality but totally incompatible as implementation - the field of long distance radio communications is currently in a pioneering phase in which standardization stability and technological interconnection methods are a far-reaching goal. Other terms used to refer to high-bandwidth digital radio networks are LoRaWAN (Low Range Power Network), LPWAN (Low Power Wide Area Network), Low Power Network (LPN). Some of these terms are registered as brands belonging to certain companies or consortia being used to identify a particular LoRa technology (even the term LoRa is a registered trademark of Semtech). LoRaWAN is a radio transmission protocol capable of forms a smart grid. [1] The setup network uses a star-of-stars topology, with gateways serving as transparent bridges that transmit information between sensors and the central server. Gateways connect to the network through traditional IP connections, and sensor devices use single-pass wireless communications for one or more gateways. [3]

The structure of LoRa network is similar to one cellular network, but instead of having a single interconnected network, LoRa allows the deployment of more independent networks over the same infrastructure. [2]

LoRa can covers 15-20 kilometers. The compromise for such a distance is a reduced power and a lower bit rate, about 0.3 to 50 kbps.

The elements components of the system structure in "end-to-end" way of LoRaWAN are shown in Fig.3 and these are:

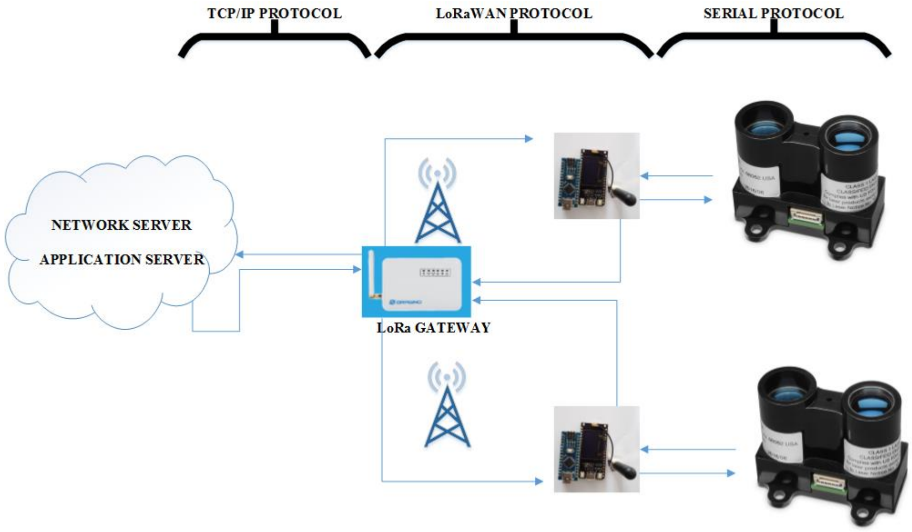

Fig. 3. The architecture of LoRa system

Nodes

Represents the elements of the LoRa network that monitors and controls the infrastructure devices which are usually located at distance, the ESP32 - LoRa – OLED which transmit the data taken from the LiDAR sensors via an Arduino Nano development board in this case. The ESP32 - LoRa - OLED has a 0.96 inch blue OLED display for displaying local information and a Lora transceiver, the SX1276 transceiver for the 868 MHz band. It has a high sensitivity over -148dBm, + 20dBm output power, high reliability and long transmission distance. The onboard Wi-Fi antenna, lithium battery charging circuit, CP2102 interface and USB serial chip, make it the perfect support for Arduino development environment. [4]

Operating voltage is from 3.3V to 7V. It have support for Sniffer software protocol analysis, Station, SoftAP, and Wi-Fi Direct modes. Data rates are comprised between: 11 Mbps and 150 Mbps and the transmit power is between 15.5 dBm and 19.5 dBm. This development board has a receiver sensitivity up to -98 dBm.

LoRa Gateway

This is the device that receives data from network nodes (ESP32) through the LoRaWAN protocol and then is transferred over the Internet to the main application server. The connection to the application server may be Ethernet, GSM data, or any other cable or wireless telecommunications connection that provides an Internet connection. In fact this base stations (LoRa Gateway) are connected to the network server using standard IP connections. In this way, the data uses a standard protocol that can be connected to any public or private telecommunications network. Given the resemblance of a LoRa network with a mobile network, the LoRa base stations can often be integrated into a cellular base station. In this way, the unused capacity of the cellular station can be used to transmit the data to the network server.[10]

Fig. 4. Dragino LoRa gateway used for system

Network server

The network server manages entire LoRa network. The network server acts to remove duplicate packets, recognition programs, and control the data transmission speed. Given the way it can be deployed and connected, the complexity of implementing a LoRa network is very low.

Application server

From the application server that is installed on the network server, we can access applications that retrieve data from network nodes through the gateway and display them to provide the most relevant information for the client. In addition, LoRa allows bidirectional communication between nodes and the network server, remote commands can be sent to the nodes, these commands can be related to node management (remote software update) and control of elements in a system (change of green time of traffic lights).

4. CONCLUSION

The realization of this mobile system of counting the vehicles crossing a road artery from an urban center is the first step in the direction of developing a traffic management system. The most important feature of this system is that it does not use invasive techniques on vehicle runways and can easily be moved from one location to another location. Through the LoRa network, real-time data can be obtained on the car traffic characteristics of the monitoring points, thus obtaining sufficient data to formulate new directions for the development of the automotive infrastructure plans. LoRa is a long-range telecommunication and low-power telecommunication system for the "Internet of Things". The physical layer of the entire system uses the LoRa module, a proprietary technology with a MAC protocol. LoRaWAN is an open standard with the specifications available for free. This paper provides an analysis of the bidirectional operation of the LoRa protocol on an experimental platform specifically designed to study the performance of the network, documented in this paper. The results obtained during the preparation of this paper show that LoRa modulation, due to modulation of spectrum dispersion and high sensitivity of the receiver, offers good interference resistance. Field trials demonstrate that LoRa can provide satisfactory network coverage of up to 3 km on a network in a suburban area with not very dense residential dwellings. LoRa is therefore suitable for low power, low speed and long range. The experimental results also show that the protocol is reliable and very simple to implement.

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