Exploration of Autonomous Vehicles in Smart City Environment

Prakash Shubham and Vyacheslav Begishev

June 28, 2023

Exploration of Autonomous Vehicles in Smart City Environment

Shubham Prakash[1] and Vyacheslav Begishev[1]

[1]Department of Applied Probability and Informatics, Peoples' Friendship University of Russia (RUDN University), Miklukho-Maklaya str. 6, Moscow, 117198, Russian Federation

1042225181@pfur.ru, begishev-vo@rudn.ru

Abstract

The main component of this article is the Arduino board, which is used to model the system for collecting data from the ultrasonic sensor and transmitting it to the processor that implements a graphical application to simulate the radar screen. A technical system has been assembled for the practical use of the sensor by detecting objects and obstacles that appear in front of the radar. Further in this study we are working on network model in NB-IoT. NB-IoT technology uses much narrower channels at 200 kHz, allowing devices to have approximately 10% complexity compared to LTE-M. NB-IoT and LTE-M technologies have the ability to cover up to 30 km and connect with more than $50,000$ devices per cell and it is also battery efficient. LTE-M, NB-IoT are being deployed on the LTE infrastructure, which enables the provision of advanced security features.

Keywords: Arduino platform, radar, autonomous transportation, ultrasonic sensor, NB-IoT, LTE-M, IoT.

1. Introduction

The study is based on sensors can be mounted on the roads. As you know, in most developed cities, road side divider, pillars, reflectors are installed on the roads. Most developed cities are connected by high speed networks. In recent years, complex radar sensors and network systems with advanced mobility support capabilities have been actively equipped with NB-IoT technologies. These technologies can become the future of the world. This study proposes a model for the behavior of advanced sensors and networking between NB-IoT technology coverage areas and LTE-M [1].

Moreover we are also using "Arduino Radar" which is based on the Internet of Things (IoT). In this article, we also create simple radar that detects objects within its range using an ultrasonic sensor. The main component are Arduino board, which is used to model the system for collecting data from the ultrasonic sensor and

The research was funded by the Russian Science Foundation, project No. 21-79-10139.

transmitting it to the processor that implements a graphical application to simulate the radar screen. A technical system has been assembled for the practical use of the sensor by detecting objects and obstacles that appear in front of the radar [2].

2. Research Procedure

IoT is basically an ecosystem of physical devices, vehicles, household appliances, etc., with the ability to connect, collect, and exchange data over wired and wireless networks. In this context, there is minimal or no interaction between people. This new wave of technologies combines the transmission and exchange of data between physical devices and computers, aiming to make people's lives easier and more comfortable through the right combination of efficiency and productivity. In particular, through the use of advanced technologies such as machine learning, machine-to-machine communication (M2M), and artificial intelligence (AI), the Internet of Things enables the use of standard physical devices with internet access (smartphones, tablets, desktop computers, etc.). There are scenarios for connecting various physical devices to household items such as coffee makers, washing machines, thermostats, door locks, etc., allowing remote control and monitoring using mobile or tablet devices.

Due to the highly technical nature of IoT devices, many people do not understand how IoT systems actually work. Well, just like any other system, the IoT has its own set of instructions. A complete IoT system consists of four different components that work together to provide the desired result.

At first, sensors and devices collect highly precise data from their surrounding environment. The collected data can range from simple geographic positions to complex health information about a patient. To capture the most sensitive changes in data, multiple sensors can be combined to form a device that does more than just sensing. For example, a cellphone is a device that includes multiple sensors such as GPS, cameras, and accelerometers, without which the phone cannot detect anything. So, whether it's a standalone data chip or a device with multiple sensors, the first step is to collect all the details from the environment [3].

The first step in an IoT system is to collect data from the environment. The collected data is then sent to the cloud infrastructure or IoT platform through various connectivity options. Once in the cloud, the data is securely stored, analyzed, and processed using Big Data Analytics for decision making. The processed data enables smart actions and the user is notified through various means. The user can choose to leave the automatic actions or manually intervene through the IoT application installed on their phone.

To calculate the distance between a sensor and an object, the sensor measures the time it takes for the transmitter to make a sound and communicate with the receiver. The formula for this calculation is:

$$E = \frac{1}{2}tc \quad (1)$$

can be referred as (1), where E is distance, t is time, and c is the speed of sound, which is 343 meters per second. For example, if a scientist places an ultrasonic sensor on a box and it takes 0.025 seconds for the sound to reflect, the distance between the ultrasonic sensor and the box is: $E = 0.5 \times 0.025 \times 343$ or about 4.2875 meters.

Ultrasonic sensors are commonly used as proximity sensors, in car parking systems, collision safety systems, obstacle detection systems, and robotics. They have advantages over infrared sensors as they are unaffected by smoke, gas, and airborne particles. Ultrasonic sensors are also used as level sensors in closed vessels and have enabled advancements in medical imaging. NB-IoT, known as Narrowband IoT, is a wireless technology designed for IoT devices that require low data amounts, low bandwidth, and long battery life. It provides long-distance connectivity at a low cost and low power consumption.

NB-IoT is a data transmission standard that allows devices to work in the networks of mobile operators. NB-IoT technology uses low bandwidth signals to communicate within existing GSM and LTE technologies. Custom designed devices and sensors are the main components of NB-IoT systems. These devices collect information from their surroundings and transmit it to NB-IoT base stations or transmitting nodes. Individual base stations are connected to the IoT gateway and cloud IoT application servers for centralized monitoring and data analysis. NB-IoT uses a new physical layer with signals and channels to meet extended coverage requirements in rural areas and deep indoors while providing very low device complexity. The underlying technology is much simpler than the GSM/GPRS modules. Supported by all major manufacturers of mobile equipment, chipsets and modules, NB-IoT can exist alongside 2G, 3G and 4G mobile networks.

Further our study is not very complex. In our visual project, we utilize equipment such as the Arduino UNO, HC-SR04 ultrasonic sensors, and servo motors, which we will discuss further in the project development. The main aspect is the visual representation of the object processing application in front of the radar [4].

The servo motor control center is connected to the Arduino board, and the trigger (TRIG) and echo (ECHO) terminals of the ultrasonic sensor are connected to the Arduino accordingly (Fig.1a). The servo motor and ultrasonic sensor are powered by a separate 5V power source. Since the ultrasonic sensor needs to perform a 180-degree sweep using the servo motor, we used a mounting bracket to attach the ultrasonic sensor. After fixing the sensor, the mounting bracket is attached to the servo motor. This step is not mandatory, and you can use cardboard to create a simple structure that attaches the ultrasonic sensor to the servo motor.

Next, we connect the Arduino to a computer device where we will code and run a Java application to obtain graphical results of the object detected by the radar (Fig.1b). Arduino is easily used in operating systems such as macOS, Windows, and Linux, and it operates on the Java platform. It comes with built-in functions and commands and plays an important role in debugging, editing, and compiling code in your environment. Various Arduino modules are available, each containing a built-in microcontroller that is programmed and receives information in the form of code. The main code created in the IDE platform ultimately generates a Hex file. This Hex file is then transferred and uploaded to the controller. The IDE consists of two main parts: one is used to write the necessary code, and the other is used for its compilation and uploading to the specific Arduino module.

Furthermore, we load a new processing sketch that allows us to enter the desired resolution (e.g., 1920 × 1080), and all calculations are automatically adapted to this resolution. The graphical representation of the ultrasonic sensor data (Fig.1c) is displayed on a radar-like display. If the ultrasonic sensor detects an object within its range, a red symbol is displayed, and an audible signal is triggered. When there is no threat, the symbol turns green [5].

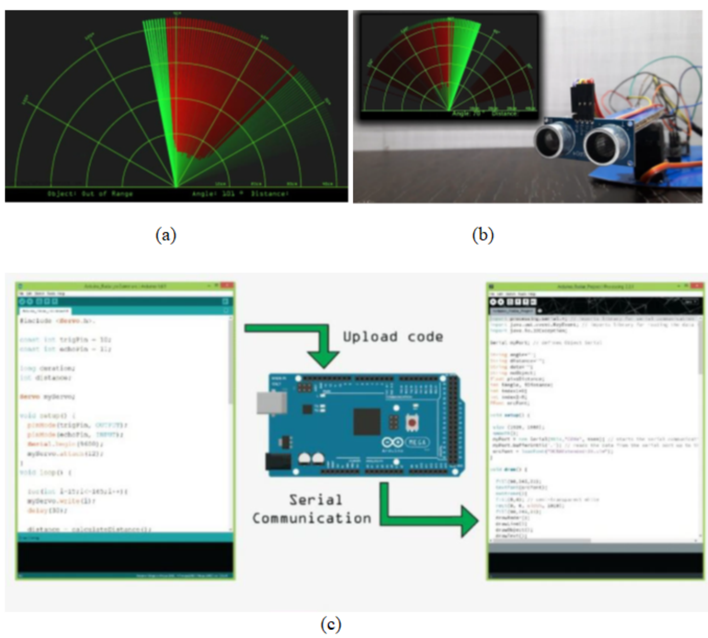

Fig. 1. Research scheme: a) scanning and object detection on the graph (radar), b) Arduino radar, c) code for establishing communication on Arduino.

3. Conclusion

In conclusion, our aim is to promote the cost-effective utilization of radar sensors, enabling the realization of economically viable smart cities and smart transportation systems accessible to all. With a significant shift towards automated transportation, there is a pressing need to advance radar sensor technology through software and hardware solutions for autonomous vehicles.

However, in the context of widespread mobile IoT usage, intermittent communication can result in undesired effects such as data synchronization issues when entering and exiting the service area of mMTC (massive Machine-Type Communications) technology. To address this, we have proposed an analytical model based on Markov chains specifically designed for NB-IoT (Narrowband Internet of Things) technology which is still under progress. This model considers realistic downtime and failure periods, as well as the intensity of received messages. It is particularly suitable for systems equipped with numerous sensors, such as ships or vehicles operating within the coverage areas of NB-IoT base stations.

By leveraging this analytical model, we can better understand and optimize the performance of NB-IoT technology in scenarios involving a large number of sensors. This research contributes to the development of reliable and efficient communication protocols, ensuring seamless connectivity and enhancing the overall effectiveness of IoT applications.

REFERENCES

1. P. Masek, M. Stusek, K. Zeman, R. Drapela, A. Ometov, J. Hosek, Implementation of 3gpp lte cat-m1 technology in ns-3: System simulation and performance, in: 2019 11th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2019, pp. 1–7. doi:10.1109/ICUMT48472.2019.8970869.
2. A. E. Onoja, A. M. Oluwadamilola, L. A. Ajao, Embedded system based radio detection and ranging (radar) system using arduino and ultra-sonic sensor, American Journal of Embedded Systems and Applications 5 (1) (2017) 7–12.
3. M. Lauridsen, I. Z. Kovács, P. Mogensen, M. Sorensen, S. Holst, Coverage and capacity analysis of lte-m and nb-iot in a rural area, in: 2016 IEEE 84th Vehicular Technology Conference (VTC-Fall), IEEE, 2016, pp. 1–5.
4. A. Dutt, Arduino Based RADAR System, GRIN Verlag, 2014.
5. A. Biswas, S. Abedin, M. A. Kabir, Moving object detection using ultrasonic radar with proper distance, direction, and object shape analysis, Journal of Information Systems Engineering and Business Intelligence 6 (2) (2020) 99–111.