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Non-contact Real Time Digital Distance Measurement System for Vehicle Applications

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Abstract

An Arduino-powered Digital Distance Measurement System with LCD Display a compact and precise solution presents a practical and portable digital distance measurement system utilizing the versatility of Arduino microcontrollers and the accuracy of ultrasonic sensors. This system can be utilised for airplane docking system which measures the distance exactly. Leveraging Arduino's programming capabilities and readily available libraries, the system transmits ultrasonic pulses and analyses the reflected echoes to calculate real-time distances displayed on a user-friendly LCD screen. This non-contact approach eliminates physical barriers and minimizes potential errors, making it suitable for various applications including robotics, obstacle detection, and industrial automation especially it can be also be utilised for applications like airplane docking system which avoids collision. The compact and cost-effective design offers high portability and accessibility for enthusiasts and professional applications like airplane docking system. Additionally, the modular nature of the system allows for further customization and integration with other sensors or actuators, expanding its potential functionalities. These concise abstract highlights the key aspects of the work, Arduino platform, ultrasonic sensor technology, LCD display integration, distance measurement principle, non-contact operation, portability, and customization potential. The proposed system is a perfect technology for placing the airplane in the exact location even without few centimetres away from the located place for aerial refuelling or other usage too. The results were accurate in measuring the distance contactless, the measurement was cross checked with manually by using a scale and is found to be matching accurately.

Keywords: Vehicle, digital distance measurement, airplane, docking system, arduino, ultrasonic sensor, non-contact sensing, aerial refuelling

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INTRODUCTION

Accurately measuring distances plays a crucial role in various fields, from robotics and automation to construction and surveying. Traditional methods like tape measures and laser rangefinders often prove cumbersome or expensive, especially for real-time applications. Non-contact distance measuring technique for vehicles naturally comprises of use of numerous technologies few of them listed and explained below

- *Ultrasonic Sensors:* These sensors are found to emit high frequency sound waves and the time taken for the sound waves to bounce back is measured. The signal reverts back after hitting the object. These are usually used in short range distance measurement.

- *Radar (Radio Detection and Ranging):* Radar utilises radio waves to measure their distance and speed to detect the objects. This technology can be effectively used for long distances measurements. These are generally used in collision avoidance systems.
- *Lidar (Light Detection and Ranging):* Lidar is a technology which utilises laser beams to scan the environment and measure distances by experimenting the reflected light. It provides 3D maps and high-resolution. It is widely used in autonomous vehicles for precise obstacle detection.
- *Infrared Sensors:* Infrared sensors work on the basis of measuring the heat emitted by the objects in the environment. This technology is used in night vision systems. In many cases it is used for detecting heat sources either pedestrian or animals near the vehicle.
- *Cameras:* Cameras are also termed as Stereo Vision. By placing few cameras positioned at various angles, this stereo vision can create a 3D view of the vehicle's surroundings. The distance is calculated by comparing the different images taken from different angles. This technology is generally used in autonomous driving systems.

Modern vehicles are safer and more automated due to these technologies, which can be used separately or combination with other technologies to let vehicles identify and compute distances to nearby objects without making any direct contact. By creating a digital distance measurement device that is accessible, lightweight, and precise, this effort aims to fill this demand. When identifying things and measuring distance without making physical contact with the environment, ultrasonic sensors are an excellent tool. It has numerous uses, including liquid level measurement, proximity detection, and perhaps most notably assistance with self-parking and anti-collision systems in automobiles. The HC-SR04 Ultrasonic Sensor and Arduino were employed in this work to calculate the distance between the sensor and an obstruction. ECHO forms the foundation of ultrasonic distance measurement. When sound waves travel throughout their surroundings, they encounter a barrier and then bounce back to the source. The only thing left to be done is figure out how long it takes both of the noises to travel that is, how long it takes for them to pass through the obstruction and how long it takes them to return. We can determine the distance after doing some calculations because we know the sound's speed.

Extreme temperatures, humidity, and air density can affect the performance of the Ultrasonic sensors but their performance tends to be comparatively unaffected by rain, fog, or dust. Sometimes extremely heavy rain or dense fog may cause a slight deviation in the in performance as a result of scattering or absorption of the sound waves generated by the Ultrasonic Sensors. The accuracy, precision rarely gets affected as the sensors are designed for short range use.

The primary aim of this paper is to design and build a reliable and accessible digital distance measurement system utilizing the versatility of Arduino and the visual clarity of LCDs. This system should provide real-time distance readings within a pre-defined range, catering to various practical applications requiring precise and convenient distance measurement. This project falls under the domain of embedded systems and electronics engineering. It combines principles of sensor technology, specifically ultrasonic sensing, with microcontroller programming and user interface design to create a functional and interactive distance measurement tool.

LITERATURE REVIEW

M.Li et al. (2020), had proposed that distance has captivated humanity since the dawn of exploration. From rudimentary sundials to sophisticated laser rangefinders, our tools have evolved alongside our need to navigate the physical world and the ubiquitous Arduino microcontroller offers a fascinating bridge between the worlds of electronics and practical measurement, opening up exciting possibilities for DIY enthusiasts and hobbyists [1].

A.Kumar et al. (2019) said that the paper focused on the development of a digital distance measurement system utilizing Arduino Nano microcontroller and Ultrasonic sensor technology. The system aimed to accurately measure distances and display them on an LCD screen in real-time. The authors discussed the hardware setup, which primarily involved Arduino Nano, an ultrasonic sensor, and other supporting components. They provided detailed information on the circuit design, sensor interfacing, and connections required for the system [2].

R.K. Patil et al. (2018), provided insights into the development and implementation of a digital distance measurement system using Arduino and an ultrasonic sensor. The study addressed the need for accurate and reliable distance measurement systems in various applications, including robotics, automation, and industrial monitoring. The authors leveraged the Arduino platform, which provided an open-source hardware and software ecosystem, making it accessible and cost-effective for developing prototypes and projects [3].

Shukla et al. (2021), contributed to the existing literature on digital distance measurement systems by presenting a practical implementation using Arduino and an ultrasonic sensor. The study additionally gave to the form of facts on Arduino based sensor systems and provided insights into the integration of LCD displays for user interaction and feedback. The authors may had provided insights into the programming aspect, explaining how the Arduino microcontroller processed the sensor data and calculated the distance. This likely involved writing code to control the ultrasonic sensor, read the sensor data, and perform necessary calculations to obtain the distance measurement [4].

J.Li et al. (2017), proposed the leverages commonly available components like Arduino microcontrollers, ultrasonic sensors, and LCD displays to build a cost effective and portable solution for distance measurement. The authors detailed the hardware setup and the algorithm used for distance calculation based on the time-of-flight principle of ultrasonic waves. The authors introduced the context of the research by emphasizing the importance of distance measurement systems in various fields such as robotics, automation, and consumer electronics. They highlighted the need for cost-effective and portable solutions that could be easily implemented in practical applications [5].

H. Zhang et al. (2020). explained in detail about the necessity for precise and effective distance measurement systems in a variety of domains, including robotics, automation, and industrial applications, they brought emphasis to the limitations of conventional approaches and underlined the importance of creating affordable and easily accessible options. This work is described the hardware components used in the system, including ultrasonic sensors for distance measurement and Arduino microcontrollers for data processing and control. The authors discussed the design considerations, challenges, and potential applications of the digital distance measurement system [6].

S. Saha et al. (2019) presented the development and implementation of a digital distance measurement system utilizing Arduino and an LCD display. The digital distance measurement system described in the paper offered a cost-effective and efficient solution for measuring distances in various applications. By employing Arduino microcontrollers and LCD displays, the system provided real-time distance readings with high accuracy and reliability [7].

Yiheng Liu et al. (2020) proposed a technique to increase the AAR docking safety and success percentage, a data-driven approach for docking safety assessment and optimization is presented in this study. In order to provide the data-driven framework with an abundance of realistic simulation data, a thorough AAR docking system must first be created. After that, the docking data is handled by a deep learning technique to extract pertinent data [8].

Dandan Hu et al. (2008) has given an idea that when measure values differ the Fuzzy Inference System (FIS) is used to adjust the weight of each fusion information online in the primary filtering, which reduces the disruption of the fluctuating data. This changes the state vector covariance of each local filtering [9].

R.K.Roy et al. (2023) has developed a weight measurement technique based on ultrasonic sensors that performs well to determine weight in tiny amounts. The technique involves placing an ultrasonic sensor on top of the vertically hanging extension spring and attaching a circular metal reflecting plate to the bottom of it. The distance between the ultrasonic sensor and the reflective plate rises linearly with an increase in weight in a pan that is fastened to the bottom of the spring. The advantages of the suggested approach include being easy in design, great consistency, linear responses, and lack of hysteresis effect [10].

T. F. Astarani et al. (2023) has given an idea regarding the Ultrasonic sensors that are often used in advances in technology to figure out the distance of an object. Studying whether ultrasonic waves reflect through metal objects is the particular objective of this research. Matlab software as well as an Arduino Uno are used for controlling the device. According to oscilloscope metrics, the ultrasonic wave's coefficient of reflection ranges from 0.81 to 0.93. Metal distances can be measured with the HCSR04 ultrasonic sensor. The sensor's accuracy was less than 95%, indicating it read values which were less than 2 cm from the genuine distance [11].

DESCRIPTIONS

Existing System

Traditional distance measurement relies on manual tools like tape measures or rulers, which can be cumbersome, inaccurate, and inefficient. They require physical contact with the object and offer limited precision, especially for larger distances. Addition ally, recording and storing measurements can be tedious and prone to errors.

Proposed System

This project proposes a digital distance measurement system using an Arduino microcontroller and an LCD display. The system emits inaudible sound waves using ultrasonic sensors, then timed the return of the waves that are reflected. The technology determines the target object's distance with accuracy by computing the sound's speed and travel time. The LCD panel then displays this data for convenient reading and recording.

Methodology - General Architecture

The Arduino microcontroller, LCD display, buzzer, LED, and ultrasonic sensor are the main elements of the project, as seen in Figure 1 above. A device that measures distance by producing and receiving sound waves is called an ultrasonic sensor. The ultra sonic sensor is a distance measurement device which is measure distance by generating and receiving sound wave. Here it is used to measure distance. The Arduino microcontroller controls the whole system. The LCD display is used to print the measuring distance. The LED and buzzer act as indicators. The Arduino prints the value for the distance on the screen after reading the sensor's data. The buzzer and LED turn on if there is an object outside the ultrasonic sensor's detection range.

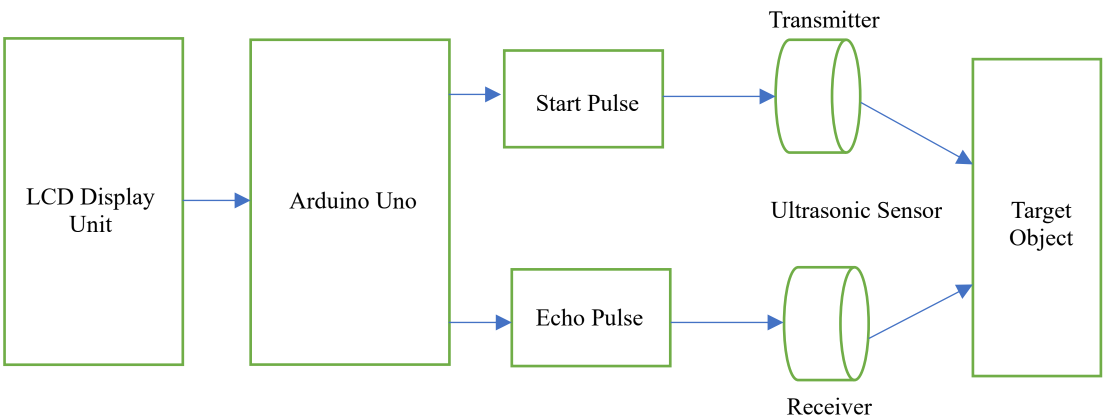

Figure 1. General architecture.

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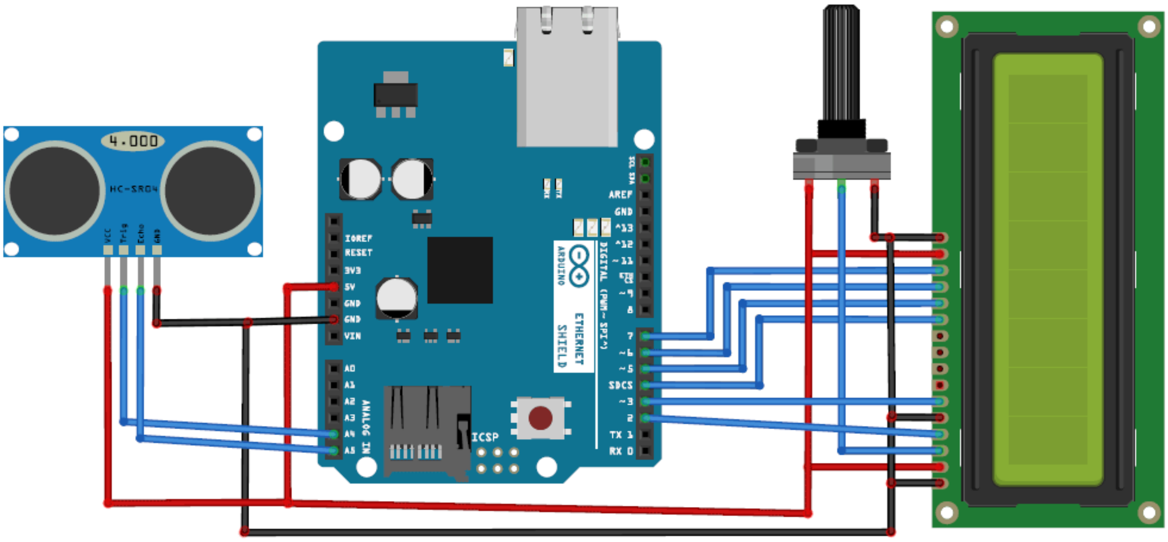

Figure 2. Circuit diagram.

The circuit diagram for the working model of non-contact measuring of distance is shown in the above Figure 2. The Arduino Board and its peripheral connection is shown in the below figure.

Algorithm

- *Step 1:* Set up the Arduino IDE and connect your Arduino board
- *Step 2:* Import the necessary libraries (e.g., Liquid Crystal) for LCD communication.
- *Step 3:* Define pin connections for trigger, echo, and LCD data/control pins.
- *Step 4:* Set up the LCD display
- *Step 5:* Send a HIGH pulse for a specific duration (e.g., ultrasonic sensor has the trigger to get activated in few microseconds).
- *Step 6:* Read the echo pin and wait for a HIGH pulse indicating the reflected sound wave return.
- *Step 7:* Determine the time difference between providing the trigger signal and receiving the echo signal.
- *Step 8:* Distance calculation: Convert the travel time to distance using the formula: Distance = (Travel Time * Speed of Sound in Air) / 2 (Speed of sound in air is approximately 343 m/s)
- *Step 9:* Display output: Format the calculated distance value and display it on the LCD screen.
- *Step 10:* Data logging: Implement external storage (e.g., SD card) to record distance measurements over time.
- *Step 11:* Test the system with objects at known distances to verify accuracy.
- *Step 12:* Fine-tune the distance calculation formula based on your specific sensor and environment.

Pseudo Code

1. Declare variables to store the pin numbers aimed at the ultrasonic sensor and for storing the pulse duration and calculated distance
2. Initialize serial communication and set pin modes.
3. Initialize LCD and adjust it as per requirement
4. Pulse the trigger pin for 10 microseconds.
5. Examine the signal from the echo and calculate the duration length of the echo pulse lasts.
6. Use the speed of sound (343 m/s) and the duration to calculate the distance.
7. Display the distance on the LCD and Clear the LCD, Print the distance value, Print the calculated distance,

Description of the Model

The Arduino Module the primary component of the system that is in charge of managing every other element. processes the echo signal which gets generated after delivering trigger impulses to the ultrasonic sensor.

Performs calculations to determine the distance depends and rely on travel speed and time of sound. It controls the LCD display to show the calculated distance value.

LCD Display Module Visual interface for the system, displaying the measured distance value. Provides user feedback on the current measurement and system status. The system status can either be text display on the screen sometimes rarely it can be graphics based on the type of LCD display. May offer backlight options for visibility in different lighting conditions.

There exists a power supply chamber which is the one responsible for giving voltage and current. Choosing the appropriate power source depends on portability and desired operating time.

Hardware Setup

- Gather your components: Arduino UNO, ultrasonic sensor (HC-SR04), LCD screen (16x2), breadboard, jumper wires, power supply.
- Connect the Voltage supply VCC and Ground GND pins of the sensor and LCD to the corresponding Arduino pins (5V and GND).
- Link the sensor’s Trigger connection with the Arduino board and the connection meant for Echo.
- Connect the LCD’s RS, E, D4-D7pinstodesignated Arduino pins based on your chosen library (consult LCD library documentation).
- For the library files Arduino IDE is utilised.
- Install the necessary libraries: LiquidCrystal (for LCD) and NewPing (for ultrasonic sensor).
- Upload the sample code for NewPing library to familiarize with sensor communication.

RESULTS AND DISCUSSIONS

Hardware Design

The above Figure 3 shows the actual working will be done. After the connections are made the collection of necessary hardware the data is shared with respectively. The above hardware setup depicts a brief demonstration that describes the operation and illustrates how the measuring process is carried out. The device model and the airplane or any vehicle are measured for distance, and the measurement obtained was confirmed to be accurate using a scale. It precisely calculates the distance between the aircraft and the measuring distance, even in the event that another little obstruction is discovered along the route.

When evaluating a digital distance measurement system, several key performance metrics are used to assess the system's accuracy, reliability, and suitability for various applications. In general, to evaluate a digital distance measurement system, the key performance metrics includes firstly accuracy and precision, the range of the signal (minimum and maximum it can measure with accuracy), latency. Since it deals with hardware environmental robustness, power consumption and finally falls the cost and the maintenance. The accuracy in the non-contact distance is measured with a scale and is found to be accurate. The second main parameter to be considered is precision, the tests were performed repeatedly several times and the results were found to be the same, thus the system’s precision is good. The signal range for the test performed were with good signal strength.

Efficiency of the Proposed System

Sensors provide continuous feedback by calculating the distance between the vehicle and surrounding objects, allowing the system to guiding the driver in real-time. With the help of cameras or ultrasonic sensors it can be made to display the real-time images or proximity maps on the vehicle’s screen.

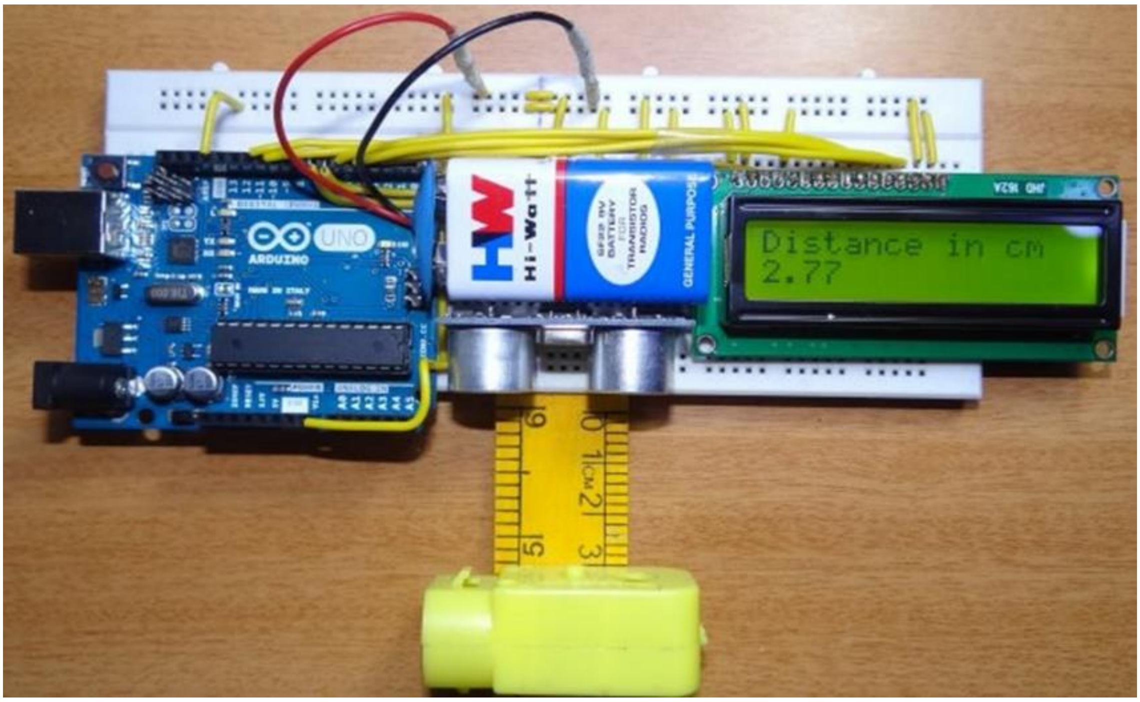

Figure 3. Hardware Setup.

This guides the driver exactly where they are situated relative to other objects. This makes it easier for the car user to park in tight spaces precisely, enhancing overall parking accuracy. In addition, not only Ultrasonic sensors, cameras but also radars can be used to scan the surroundings to identify the open spots for parking the vehicle quickly in crowded areas.

There exist blind spots that the vehicle operator will not be able to see, these areas can be monitored with the help of sensors like radar and cameras. The combination of radar and camera can be used effectively to detect the blind spots thus leading to detect the obstacles. This makes the system to be collision free and smart enough to detect the obstacles.

The proposed digital distance measurement system utilizing Arduino, LCD, and ultrasonic technology promises significant efficiency improvements over traditional measurement methods. By leveraging the capabilities of these components, the system offers several key advantages that enhance its overall efficiency and effectiveness in airplane docking system. Firstly, Arduino's robust processing capabilities allow for real-time data acquisition and analysis, ensuring precise distance measurements with minimal latency. This efficiency is critical in applications where rapid and accurate measurements are essential, such as in industrial automation, robotics, and environmental monitoring. Secondly, the integration of an LCD (Liquid Crystal Display) screen provides a user-friendly interface for displaying distance measurements. The LCD screen allows users to view distance readings conveniently and intuitively, facilitating ease of use and reducing the need for additional equipment or complex setup procedures. This simplicity enhances the overall efficiency of the system by streamlining the user experience and minimizing the time required for operation and interpretation of results. Furthermore, the utilization of ultrasonic sensors enables non-contact distance measurement, offering several advantages over traditional contact-based methods. High-frequency sound waves are emitted by ultrasonic sensors, which track how long it takes for the waves to bounce off an object and return to the sensor. The best advantage of using this application in airplane docking system is listed below. This non-contact approach eliminates the need for physical contact with the target object, reducing wear and tear on equipment and eliminating the risk of damage or contamination. Addition ally, ultrasonic sensors are capable of measuring distances accurately across a wide range of surfaces and materials, further enhancing the versatility and efficiency of the system.

CONCLUSION AND FUTURE ENHANCEMENTS

Conclusion

In conclusion, the development of a digital distance measurement system using Arduino and LCD has proven to be a valuable addition to the field of distance measurement and automation for an airplane docking system. Throughout this work, it has been successfully implemented a cost-effective and efficient solution that utilizes readily available components to accurately measure distances and display the results on an LCD screen. The system leverages ultrasonic sensors to transmit and receive ultrasonic waves, Arduino microcontrollers to process the received signals, and LCD displays to present the distance measurements in a user-friendly format. Through careful calibration and programming, it has achieved reliable and accurate distance readings, making the system suitable for various applications. It is best suited for airport docking system in spite of its usage been utilised for robotics, home automation, and industrial monitoring.

Future Enhancements

While the current implementation of the digital distance measurement system using Arduino and LCD has met our initial objectives, there are several avenues for future enhancements and improvements: Increased Implementing advanced signal processing techniques or integrating additional sensors such as infrared or laser rangefinders can improve the accuracy of distance measurements, especially in challenging environments with obstacles or noise. Expanding the user interface capabilities by incorporating touchscreens, graphical displays, or intuitive controls can enhance the user experience and make the system more user-friendly. By including wireless connection modules like Bluetooth or Wi-Fi, the measurement of distance system may be remotely observed and controlled, offering increased convenience and flexibility. By including features for data tracking and analysis, users can track distance measurements over time, spot patterns, and utilize the information to influence decisions. Integration with IoT Platforms: Remote access, real-time monitoring, and integration with other smart devices and systems can be made possible by integrating the system with cloud services or Internet of Things (IoT) platforms. This can be implemented further in the other applications in airplane.

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