Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 4, 362-378
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i4.5982

Design of wearable social distancing card for enhancing public health safety compliance

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Abstract: During the COVID-19 pandemic, physical distancing has been essential in preventing the virus's spread. The WHO has implemented physical distancing with at least one meter between individuals. Despite widespread awareness, people often forget to maintain a safe distance in public spaces. This paper addresses this issue by proposing an innovative solution: a wearable social distance card. The objective of this paper is to design a wearable device equipped with modern sensor technology to detect and promote safe distance practices. This device integrates ultrasonics and passive infrared sensors, an Arduino UNO, a buzzer, and an LCD display. The device uses high-frequency sound waves from ultrasonic sensors to measure the distance between individuals in real-time. When individuals reach the predetermined safe distance threshold, the buzzer emits a sound to notify both people to maintain a proper distance. A microcontroller-based wearable social distancing card helps the community practice social distancing. The prototype demonstrates accuracy in distance measurements, exhibiting an average deviation of ±4 cm. This wearable card aids in encouraging social distancing practices, supporting public health efforts to mitigate the spread of infectious diseases. The design represents a significant step forward in promoting social distancing compliance.

Keywords: *Wearable Card, Social Distancing, Ultrasonic Sensor, Object Detection, Embedded System, Microcontroller.*

1. Introduction

Coronavirus disease 2019 (COVID-19) is a disease caused by the SARS-CoV-2 virus, which was first identified in Wuhan, China [1]. COVID-19 has had a catastrophic effect on the world, resulting in more than 7 million deaths worldwide [2]. A highly contagious and deadly virus, COVID-19 can spread between individuals, causing mild to moderate respiratory illness or severe pneumonia that may require medical intervention. The COVID-19 pandemic has impacted not only public health but also the daily lives of people worldwide [3]. By the end of December 2020, there were more than 650 million reported cases of the disease, leading to an estimated death toll of approximately seven million individuals [4].

COVID-19 can spread among people in several ways [5]. First, the virus can spread between individuals who are in close proximity, such as within talking distance. When people are close together, the virus can be transmitted through tiny droplets from an infected person's mouth or nose when they cough, sneeze, speak, or breathe. These droplets can easily be inhaled by another person, leading to infection. Second, the virus can also spread in environments with poor ventilation or in crowded spaces. Tiny droplets, known as aerosolized particles, can linger in the air for some time, gradually accumulating and increasing the likelihood of being inhaled by others. Third, individuals may contract the virus by touching their face, nose, mouth, or ears, after coming into contact with contaminated surfaces or objects in public spaces. Social distancing is a public health practice that aims to prevent sick people from coming in close contact with healthy people to reduce opportunities for disease transmission [6, 7].

History: Received: 30 January 2025; Revised: 12 March 2025; Accepted: 18 March 2025; Published: 5 April 2025
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The COVID-19 pandemic has had a profound impact on society and the global economy. With millions of lives lost worldwide, it has caused widespread anxiety, as many people mourn the loss of loved ones. The pandemic has also reshaped transportation and travel, with international travel restrictions and mandatory quarantines for those arriving. Education has been significantly affected as well, with students forced to transition to online classes [8]. The immediate response everywhere to the outbreak of the virus was closure of university campuses and so universities began offering some core programmes in education and research by adopting digital technology [9]. The pandemic also affected employment, with many people losing their jobs, contributing to a rise in poverty. As a result, the nature of globalization will never be the same as it was before. Furthermore, we also understand the sacrifice of our frontliner during Covid-19 Pandemic Beng [10] and the application of deep learning for Covid-19 [11].

The Covid-19 pandemic has highlighted the importance of maintaining social distancing to prevent the spread of contagious diseases. The primary challenge in avoiding infection, particularly in crowded public spaces, offices, and schools, is ensuring proper social distancing. Many people struggle with accurately identifying and maintaining the required distance. Therefore, the goal of this paper is to identify an effective method for detecting a one-meter distance between individuals and to design a wearable social distancing device that reminds people to keep their distance. By implementing this solution, it can contribute to creating a safer environment in crowded areas.

A social distance monitor that utilizes a magnetic field proximity sensor is an alternative approach for maintaining social distancing. Wave sensing is a non-contact sensing technique based on the propagation properties of waves [12-14]. The wearable device is made up of two sub-systems: a transmitter and a receiver. A magnetic field is continuously generated on the transmitter side at a frequency of 20 kHz using an H-bridge, as shown in Figure 1 [15]. On the receiver side, coils arranged along three axes will detect the induced voltage, which is then filtered, amplified, and converted into a digital signal.

The magnetic field proximity sensor is highly reliable in supporting social distancing, as it is resistant to various temperatures, water, and dust [16]. The magnetic field proximity sensor has constraints, as its measurement precision depends on the intensity of the magnetic field produced by the transmitter [17, 18].

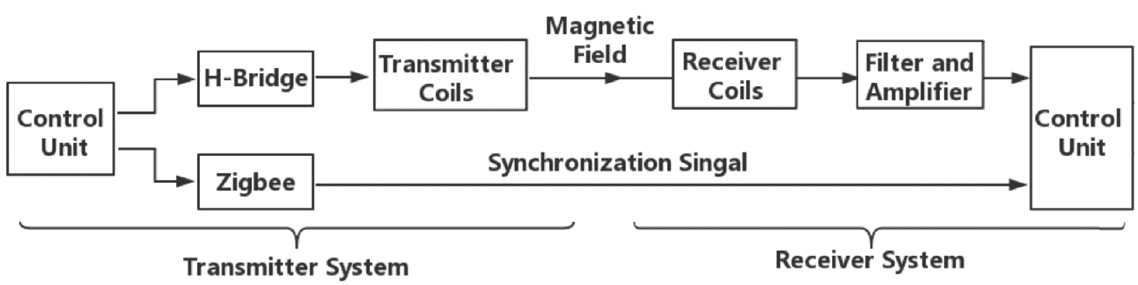

Figure 1.
The system architecture of magnetic proximity sensor.
Source: Bian, et al. [15].

A head-mounted device that combines proximity and thermal sensing is designed to detect and assess the distance between two people [19, 20]. It is assumed that each sensor's measured distance follows an error distribution, and the product of the probability density functions of the measured distances determines the position of the obstacle [21]. The device is designed as a hat, allowing it to be easily shared among different individuals without the need for disassembly. The DFRobot URM09 analogue ultrasound distance sensor is a suitable proximity sensor because it can detect distances up to 520 cm, provides an analogue output, and features built-in temperature compensation, reducing measurement errors to an accuracy of ±1.

Additionally, 2 Qwiic Grid-EYE can be mounted on top of the hat. A person's presence within a preset range can be detected by these infrared sensors, which offer fast processing speeds to transmit output signals [22]. The design of this head-mounted sensor will feature multiple analogue ultrasound devices, allowing it to detect a 360-degree range. When the ultrasound detects a person's presence, the infrared sensor will rotate towards them, and the buzzer will activate if the person moves too close, as shown in Figure 2.

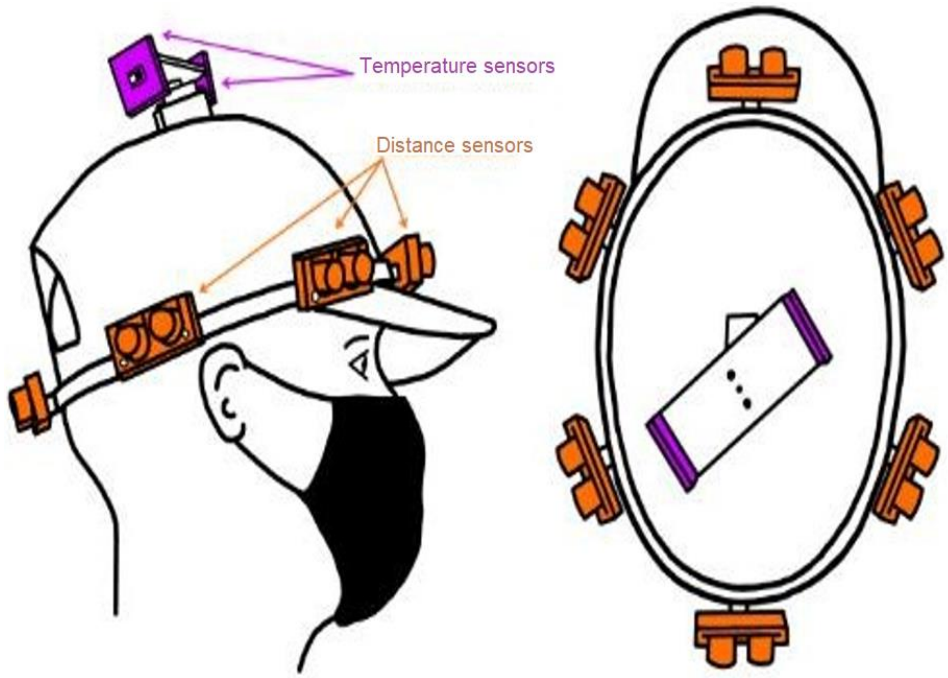

Figure 2.
Head mounted sensor mobile location social (side and top view).
Source: Tsujii, et al. [21].

Mobile crowd sensing (MCS) offers an alternative method for maintaining social distancing by suggesting safe walking routes for smartphone users. Smartphones are equipped with various sensors, including magnetic field sensors, proximity sensors, light sensors, and heat sensors, to support this functionality [23-28]. The mobile crowd sensing application gathers data from the sensors embedded in smartphone circuit boards. Mobile crowd sensing is an excellent tool due to its ability to process large data arrays. One of the key advantages highlighted by the author is its scalability [29-32].

The scalability of mobile crowd sensing is enabled by its capacity to collect data over vast areas, especially in environments where crowds surround the smartphone devices [33]. With high scalability, the mobile crowd sensing software outperforms software that relies on physical touch networks. Additionally, the mobile crowd sensing application offers great flexibility. When a user moves to a new area, the smartphone typically requires sensor settings to be adjusted. However, this issue is addressed when other people with smartphones are nearby. In such cases, the mobile crowd sensing application can quickly detect the number of people in the vicinity.

The mobile crowd sensing application does not compel users to follow a recommended route. Since humans are diverse and have varying interests, they will naturally go to different places. Therefore, the application collects data and notifies other users with the app to avoid entering specific areas. Furthermore, the mobile crowd sensing application ensures the privacy of its participants is maintained [34]. Mobile crowd sensing (MCS) can anonymize both user location data and the information collected from various sensors on smartphone devices. Additionally, the mobile crowd sensing application will notify users when their battery is low, allowing them to be aware of their battery level and charge their devices accordingly.

Kinect is a stereo depth sensor that generates a valuable data structure known as a range image, where each pixel at point (u, v) is mapped to its corresponding depth. This simplifies the use of traditional pixel localities even within a point cloud, as the point cloud inherently maintains this relationship. The Kinect can be used to accurately measure the distance between two individuals, facilitating precise distance detection and measurement [35, 36]. There are quite a few applications such as badminton movement recognition and analysis system, framework to enhance the learning of disabled students [37].

Radio frequency identification (RFID) is a form of communication that applies electromagnetic in the radio frequency portion of the electromagnetic spectrum to detect an object, animal, or person [39-41].

2. Material and Methods

2.1. Hardware Development

The ultrasonic sensor HC-SR04 is used to detect the distance of an object. By measuring the distance, it can easily determine if a person is approaching within one meter. A piezoelectric buzzer, which produces an audible sound wave, is used as an alarm. The buzzer will alert and remind the user not to stay too close to others.

A passive infrared (PIR) sensor detects infrared light emitted by objects. Any object with a temperature above absolute zero radiates infrared energy, which possesses a longer wavelength in the electromagnetic spectrum. When exposed to changes in infrared radiation from a body and object, the pyroelectric material in the sensor generates an electrical charge. The PIR sensor is specifically used to detect infrared radiation from a human body, as it is designed to sense changes in radiation caused by moving objects.

2.2. Software Development

The initialization code for the components in the Arduino Integrated Development Environment (IDE) is displayed in Figure 3.

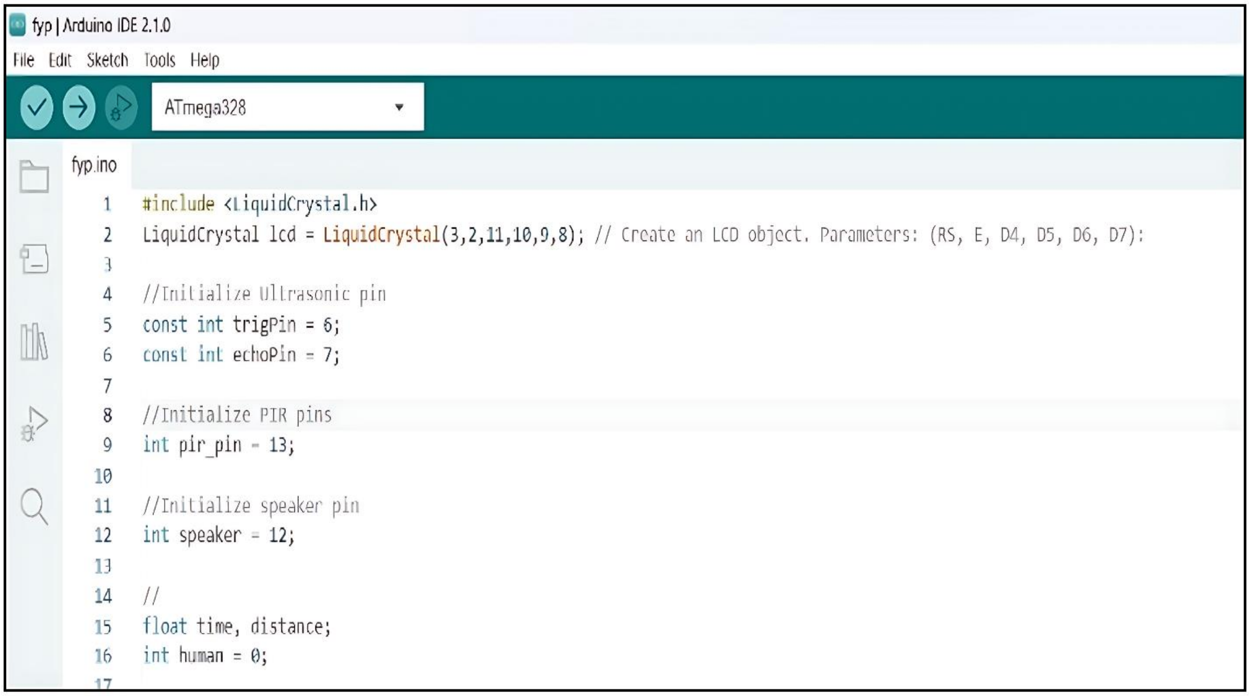

Figure 3.
The code for initialization.

First, #include <LiquidCrystal.h> is added on line 1 to enable communication between the Arduino and the LCD. In the second line, the Register Select pin, enable pin, and Data pins are initialized.

Each pin is assigned to establish the connection between the Arduino Uno and the LCD. After initializing the LCD pins, the pins for the ultrasonic HC-SR04 sensor are configured, with the trigger pin connected to pin 6 and the echo pin to pin 7.

Next, the PIR pins are initialized to pin 13, and the speaker pin is set to pin 12. In the end the initializations are declared, various variables are defined including time, distance, and human for the ultrasonic sensor.

In the void setup function, as shown in Figure 4, the 16x2 LCD is set up by declaring lcd.begin(16, 2), which defines the number of columns and rows. The same method can be applied to a 20x4 LCD. Afterward, the trigger pin is placed as an output, and the echo pin as an input for the ultrasonic sensor.

Following that, the speaker pin is declared as an output, and the PIR pin is set as an input. Additionally, Serial.begin(9600) is included to enable the Arduino Uno to send output data to the Arduino IDE serial monitor.

```
void setup()
{
    lcd.begin(16, 2); // Specify the LCD's number of columns and rows. Can be change to (20, 4) for a 20x4 LCD
    pinMode(trigPin, OUTPUT);
    pinMode(echoPin, INPUT);
    pinMode(speaker, OUTPUT);
    pinMode( pir_pin, INPUT);


  Serial.begin(9600);

}
```

Figure 4.
Void setup function.

The loop function, where instructions are executed repeatedly, is depicted in Figure 5. Initially, a variable named "human" is labelled to save the binary data obtained from the PIR sensor. Next, Serial.println (human) is employed in the if/else loop.

When the PIR sensor detects a human, the binary data signal will be set to '1'. This triggers a 10µsec pulse to the trigger pin, and the pulse duration is stored in the time variable. The distance is then calculated by multiplying 0.01723 with the time variable. Once the distance is calculated, the Serial Monitor will display the distance, labelled in centimetres.

ISSN: 2576-8484
Vol. 9, No. 4: 362-378, 2025
DOI: 10.55214/25768484.v9i4.5982

```
void loop (){

human = digitalRead(pir_pin);
Serial.println(human);

  if (human ==1){
    digitalWrite(trigPin, LOW);
    delayMicroseconds(2);

    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);

    time = pulseIn(echoPin, HIGH);
    distance = 0.01723*time;
    Serial.print(distance);
    Serial.println("cm");

    if (human ==1 && distance<100){

      tone(speaker, 1000);
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Stay");
      lcd.setCursor(0,1);
      lcd.print("Away");

```

Figure 5.
Void loop function.

Additionally, if the data signal from the PIR sensor is "1" in binary and the distance is within 1 meter, the buzzer will be triggered. Once the buzzer is triggered, 'Please maintain' and 'distance' will be displayed on the LCD for 2 seconds. After 2 sec, the buzzer will stop, and the message "You are safe" will appear on the LCD.

2.3. Simulation

Before proceeding with hardware development, various components for the social distancing sensor were set up and tested using a simulation platform called Tinkercad. Tinkercad is user-friendly and offers a wide range of components. It also includes a text editor with libraries like LiquidCrystal and Servo motors, which are compatible with Arduino boards. Additionally, Tinkercad supports both

Python and C++ programming languages. Figure 6 shows the setup of the social distancing card, along with the corresponding code.

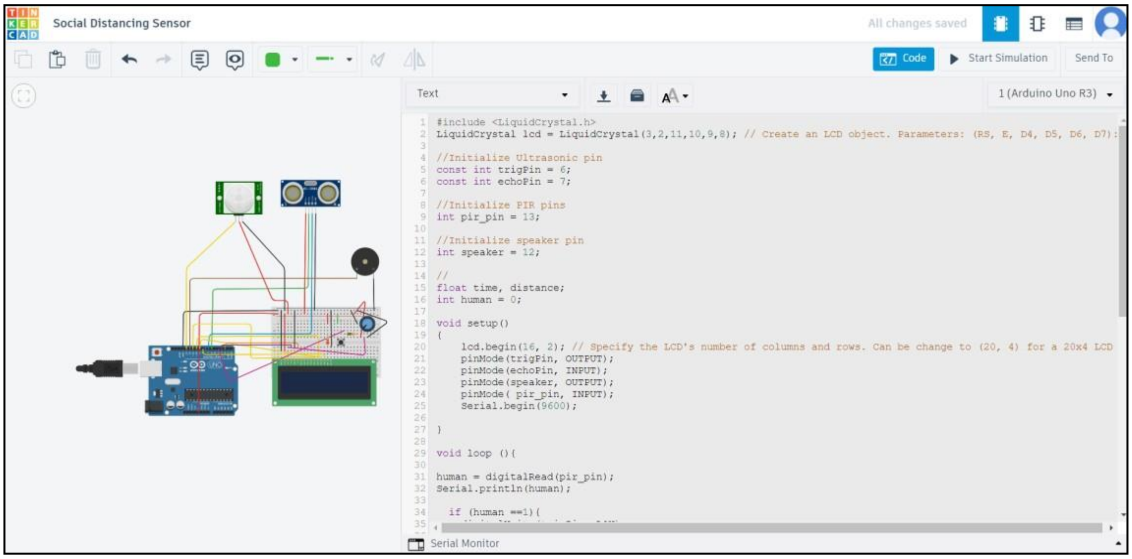

Figure 6.
Social distancing sensor setup.

The Proteus Design Suite is used for microcontroller simulations because it allows real-time simulation when the code is written in Atmel Studio. The code can be directly imported into the Proteus Design Suite, as illustrated in Figure 7.

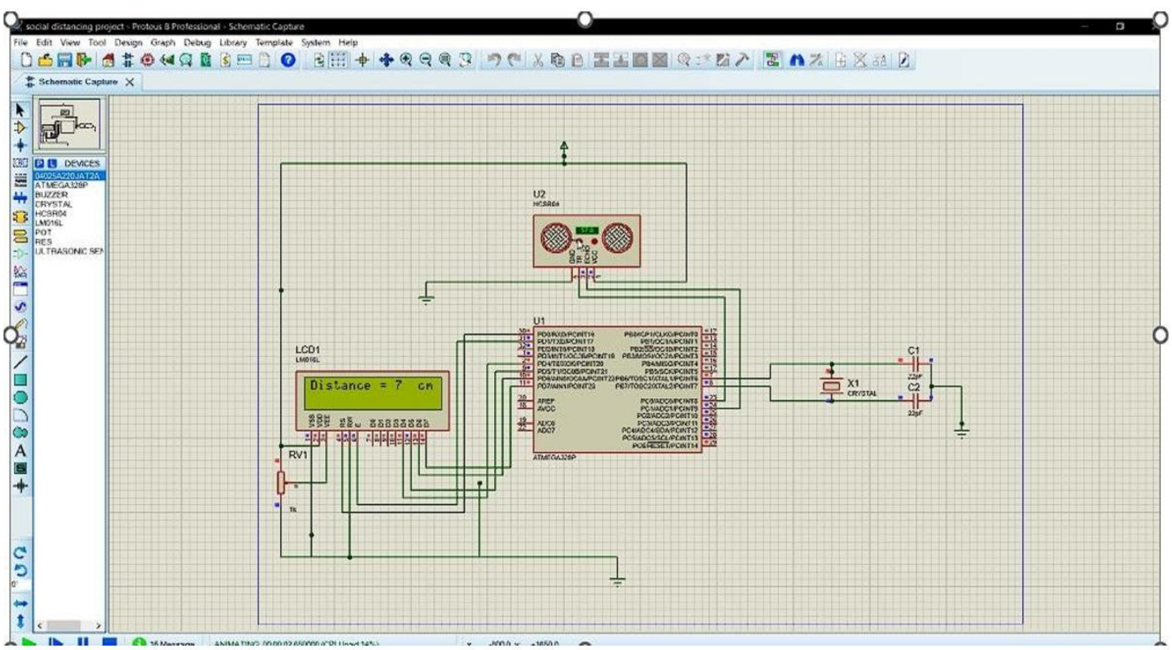

Figure 7.
Simulation by Proteus Design Suite.

Figure 8 shows the schematic diagram of the setup for the social distancing card based on microcontroller, including the pin connection for each component.

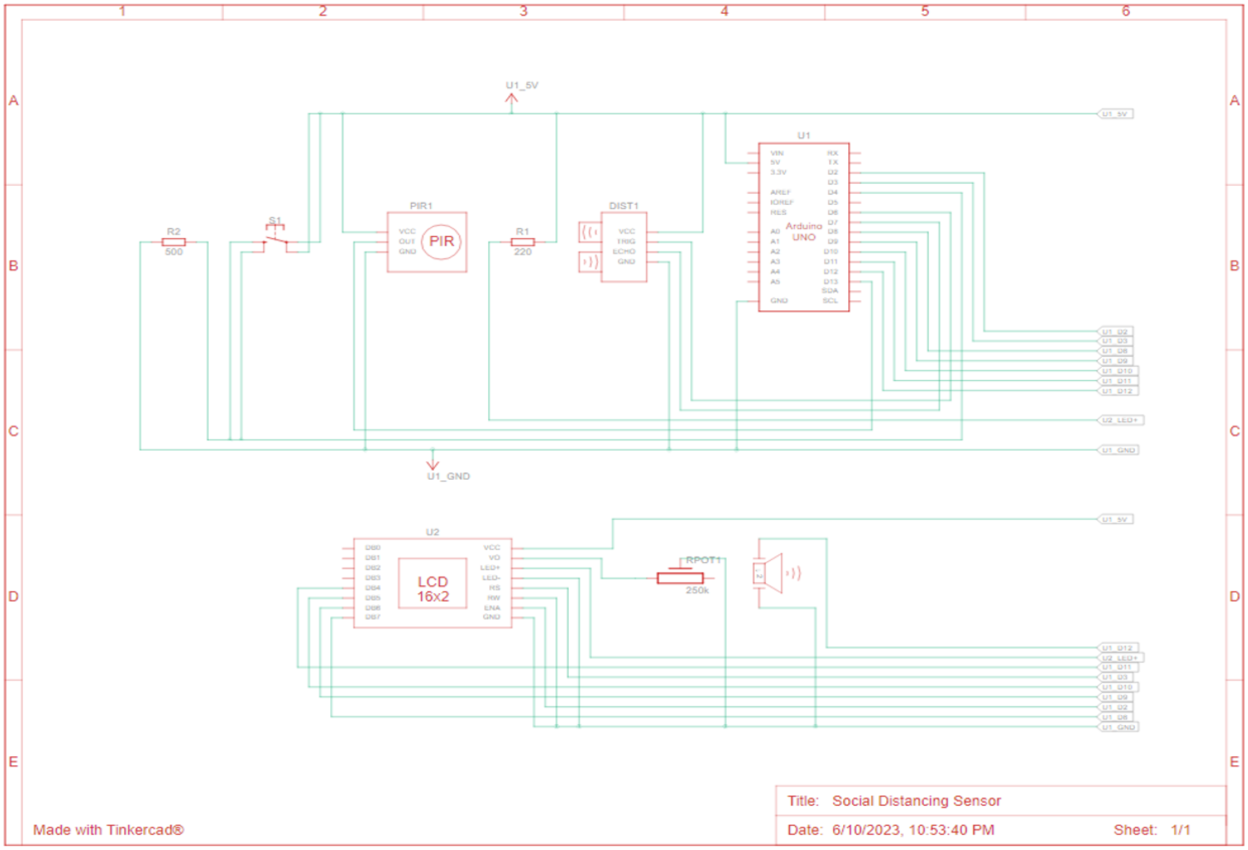

Figure 8.
Schematic diagram of a wearable social distancing circuit.

2.4. Block Diagram

The block diagram is shown in Figure 9. The ultrasonic and PIR sensor function as input sources for the microcontroller, which detects and calculates the distance between the wearer and the other person. The buzzer and LCD proceed as output devices, with the measured distance displayed on the LCD, followed by the buzzer alerting the user to maintain a 1m distance.

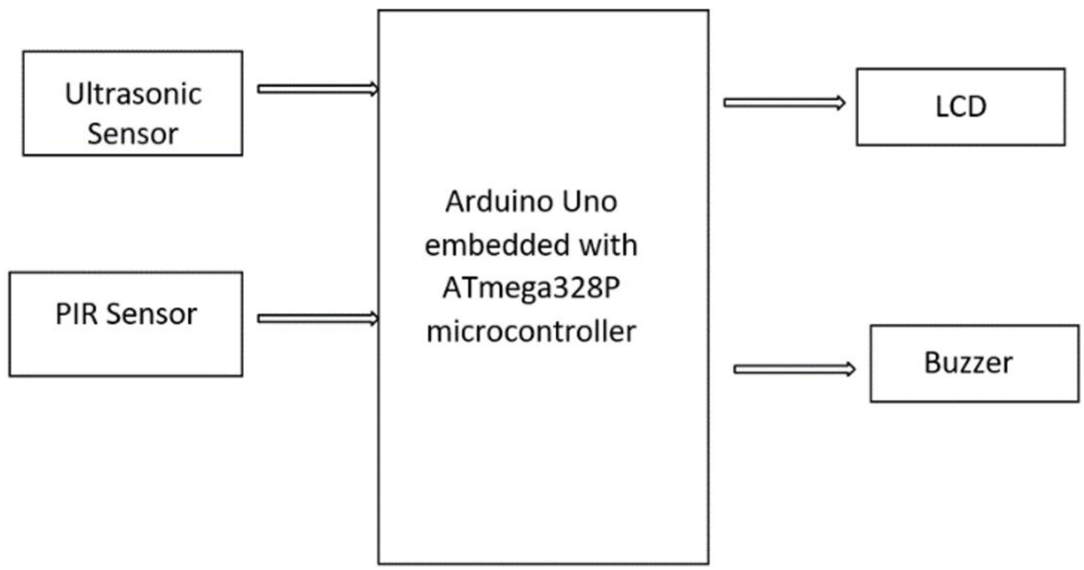

Figure 9.
Block diagram of social distancing card.

2.5. Flow Chart

The process flow chart for social distancing using Arduino Uno microcontroller is shown in Figure 10. The ultrasonic sensor calculates the distance between the user and another person once it detects an object. If the other person is situated more than 1 meter away, the LCD will display the distance along with a safety warning.

If the ultrasonic sensor detects a person within the 1m range, the buzzer will sound for 2 sec to alert the user and those near to sustain social distancing. After that, the LCD will show an alerting message. Once the buzzer is turned off, the LCD will revert to displaying the safety warning message with the distance.

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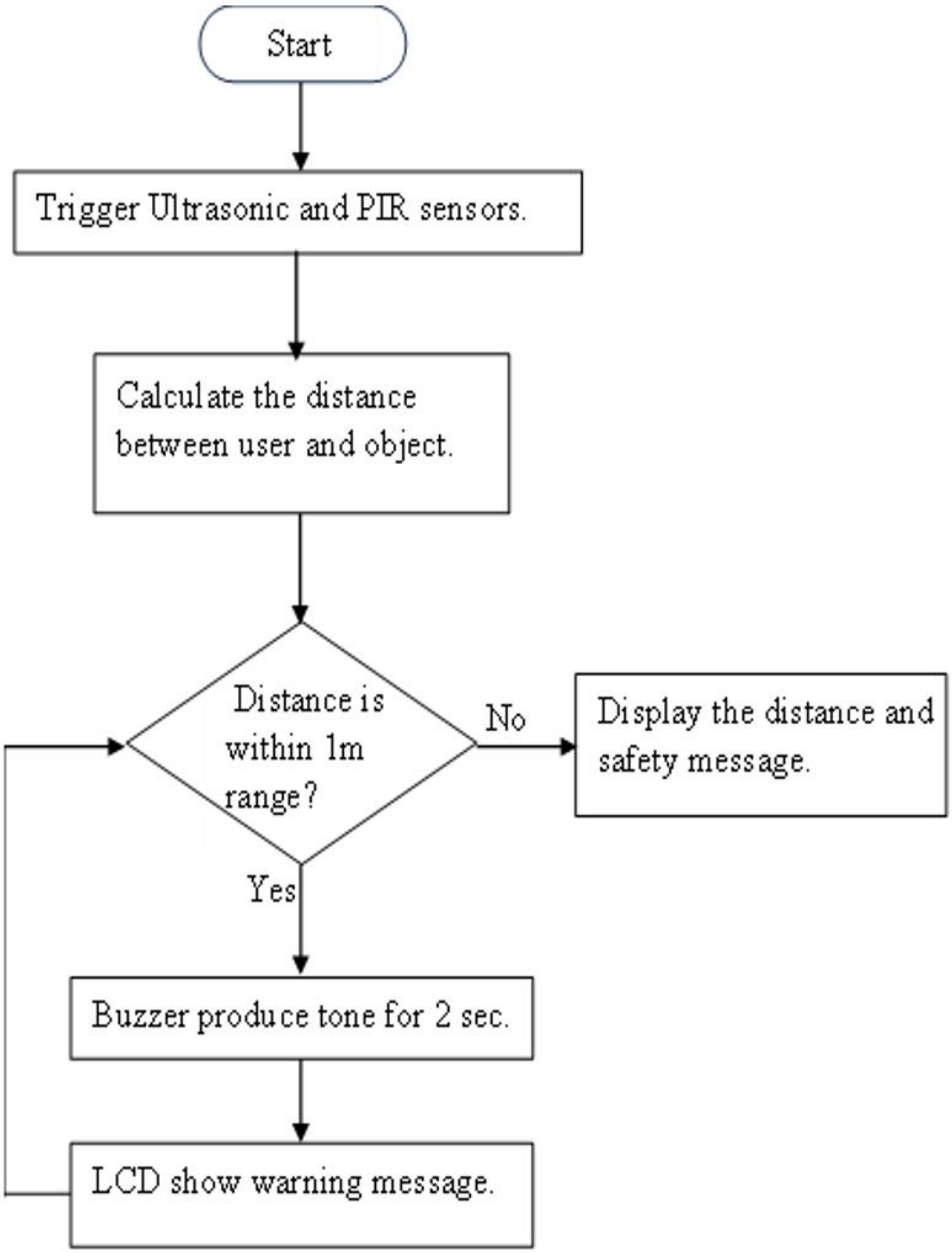

Figure 10.
Social distancing card flowchart.

3. Result and Discussion

The experimental results for the distance readings of the ultrasonic sensor, assessing its accuracy at normal room temperature, are presented in Table 1. Distances of 25 cm, 50 cm, 75 cm, 100 cm, and 125 cm were used as variable setups. Once the distances were set, a typical human subject was positioned in front of the ultrasonic sensor, as illustrated in Figure 11(a) and (b).

Once the measurements were recorded, the difference between the set distance and the distance measured by the ultrasonic sensor was calculated. It was noted that the ultrasonic sensor did not provide an accurate distance, exhibiting an average margin of error of ±0.04m. Subsequently, the

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 4: 362-378, 2025
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ultrasonic sensor's performance was measured at room temperature and in different locations to determine if the sensor's readings were influenced by varying environmental conditions.

Table 1.
The Distance Between the Fixed Value and Reading value by Ultrasonics Sensor.

Set distance	Distance measured by ultrasonicsensor	Difference between ultrasonic reading and original value
0.25 m	0.2506 m	0.0006 m
0.50 m	0.5569 m	0.0569 m
0.75 m	0.8026 m	0.0526 m
1 m	1.0732 m	0.0732 m
1.25 m	1.2602 m	0.0102 m

(a) (b)

Figure 11.
(a) Standing human 25cm distance from ultrasonic sensor,
(b) LCD Display when standing at 25cm.

The temperature was simulated under various conditions using a hair blower, taking into account different temperature levels. To measure the temperature accurately, an LM35 temperature sensor, as depicted in Figure 12, was used. The corresponding code was written to ensure the correct temperature reading, as shown in Figure 13.

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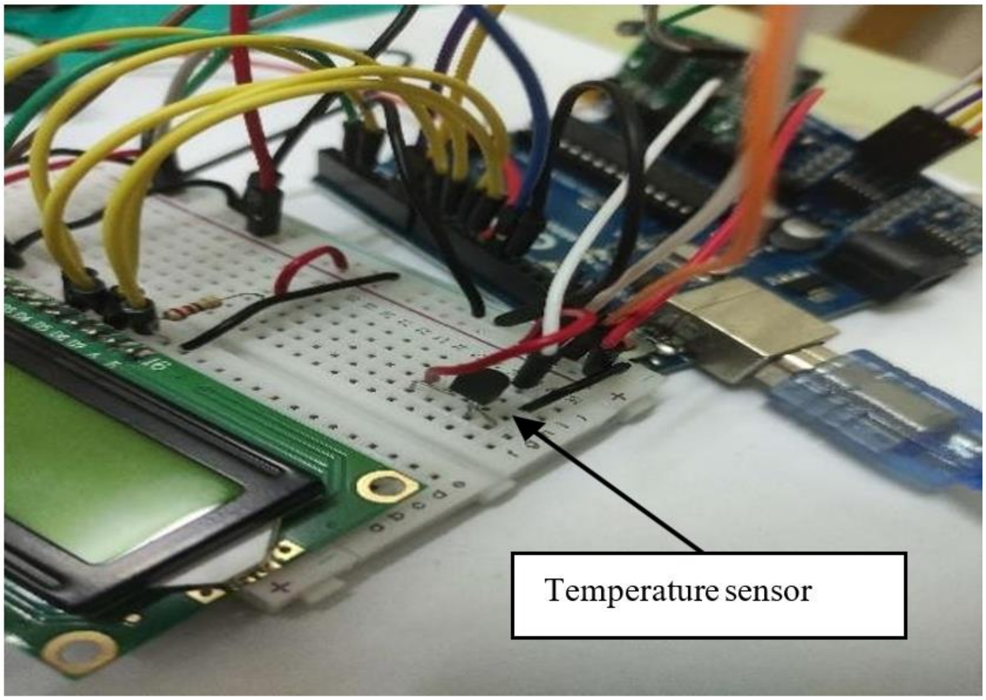

Figure 12.
LM35 Temperature sensor testing.

Temperature: 27.83*C
Temperature: 28.32*C
Temperature: 31.74*C
Temperature: 32.23*C
Temperature: 38.09*C
Temperature: 53.22*C
Temperature: 66.89*C
Temperature: 77.15*C

Figure 13.
The temperature value reading from serial monitor of Arduino IDE.

A hair dryer was used to blow air over the LM35 and ultrasonic sensor to record the distance data in Table 2. After collecting the data, it was observed that the temperature had little impact on the distance measurement.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
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Table 2.
The Distance Measure in Different Temperature.

Temperature	Distance (Fixed)	Distance reading by ultrasonic	Distance difference between ultrasonic reading and original value
25°C	0.25 m	0.2691 m	0.0191 m
28°C	0.25 m	0.2703 m	0.0203 m
30°C	0.25 m	0.2901 m	0.0401 m

However, if the ultrasonic sensor is subjected to a temperature of 27°C in the field for a duration of 2 hours, it may overheat, risking damage to its components. Consequently, the sensor will be unable to provide any readings, as depicted in Figure 14.

Figure 14.
LCD display value from damaged ultrasonic sensor.

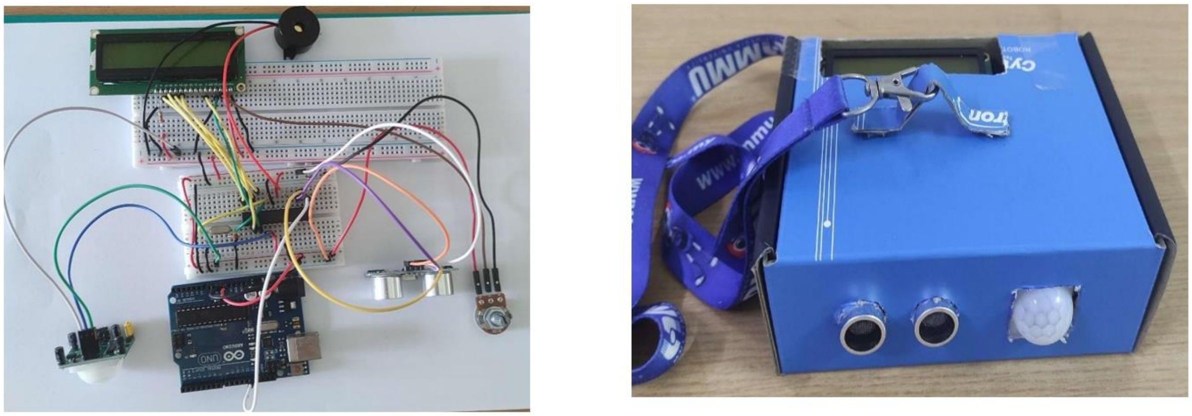
Once testing is complete at various temperatures and different motions, including standing, walking, and running, the recorded data for 0.5 m in front of the ultrasonic sensor is presented in Table 3.

Table 3.
The Difference of Motion Data.

Motion	Distance (Fixed)	Distance reading by ultrasonic	Difference between ultrasonic reading and original value
Standing	0.5 m	0.509 m	0.009 m
Walking	0.5 m	0.5213 m	0.213 m
Running	0.5 m	0.7066 m	0.2066 m

After testing the motion, a few modifications were made for both standing and walking position. However, during dynamic motion (running position), the ultrasonic and PIR sensors were insufficiently responsive, leading to erroneous distance measurements from the ultrasonic sensor.

When the sensors were evaluated under various scenarios, including different motions, temperatures, and normal room temperature, the results showed that both the ultrasonic and PIR sensors remained within an acceptable range for use as social distancing input sources. However, users should be mindful of the surrounding temperature and the running motion of nearby individuals. Figure 15 displays the prototype of the microcontroller-based wearable social distancing card.



(a) (b)

Figure 15.
Microcontroller based wearable social distancing card (a) Cricut, (b) Prototype.

4. Conclusion and Recommendations

By leveraging modern sensor technologies, this wearable device not only aids in measuring and alerting individuals to maintain safe distances but also contributes to fostering a safer environment in public spaces. This paper underscores the importance of technological innovations in bolstering public health efforts during global health crises like the COVID-19 pandemic.

Therefore, a microcontroller-based wearable social distancing card provides an effective solution to help reduce the spread of the deadly virus. While a vaccine serves as a preventive measure rather than a cure for COVID-19, the microcontroller-based wearable card remains useful in ensuring that users maintain a safe distance of one meter.

The objectives of the paper have been successfully achieved, namely, ensuring a one-meter social distance between individuals.

The microcontroller-based wearable social distancing card can be improved further by incorporating additional features, such as a humidity sensor, allowing it to measure air temperature and record data for analysis. This data could help improve the accuracy of the ultrasonic sensor. Moreover, the prototype can be refined to create a more compact and wearable social distancing device. The microcontroller-based card shows great potential for future improvements and possible industrial applications.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Acknowledgment:

The authors would like to thank the Centre for Advanced Robotics (CAR), Faculty of Engineering and Technology (FET), Multimedia University (MMU), Malaysia for always seeking and supporting individuals who aspire to be validated in their fields.

Copyright:

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