International Journal of Science, Technology and Society
2022; 10(5): 192-197
http://www.sciencepublishinggroup.com/j/ijsts
doi: 10.11648/j.ijsts.20221005.15
ISSN: 2330-7412 (Print); ISSN: 2330-7420 (Online)

Acoustic Modules to Help with Spatial Distancing

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To cite this article:

Quentin Lagarde, Bruno Beillard, Serge Mazen, Julien Leylavergne, Corentin Azais, Ibrahim Kamal. Acoustic Modules to Help with Spatial Distancing. *International Journal of Science, Technology and Society*. Vol. 10, No. 5, 2022, pp. 192-197. doi: 10.11648/j.ijsts.20221005.15

Received: September 12, 2022; **Accepted**: September 26, 2022; **Published**: October 17, 2022

Abstract: The COVID-19 pandemic has highlighted the need for a means of enforcing a spatial distance between individuals, of 1 meter or more (depending on the health policy of each country). Despite some urgent initiatives, nothing has really been conclusive. Currently, some devices have been implemented but using technologies that threaten individual freedom, are complex to implement and expensive (fixed camera or mobile robots with artificial intelligence). Thus, the objective is to design a rapidly functional prototype free of these problems. This article proposes a spatial distancing equipment using sensors (transmitter / receiver) with ultrasounds already existing in the trade, thus respecting the regulation in force on the acoustic emissions. The use of 4 sensors, connected to an Arduino microcontroller, allows to cover an area around the person of 360 degrees. When one of the sensors emits an acoustic wave, only the other 3 listen, avoiding the effects of reverberations. So, if one of the 3 perceives a wave, it means that another similar device is emitting in a radius too close and therefore that the recommended distance is not respected. The user will be warned by a sound or light signal. The prototype designed was quickly functional, adaptable for distances ranging from 20cm to 4m depending on the desired distance, and inexpensive. On the other hand, it is for the moment rather bulky but in the case of a marketing is quite possible to miniaturize it.

Keywords: Acoustics, Barrier Gestures, COVID-19, Distance Measurement, Spatial Distancing, Ultrasonic Sensors

1. Introduction

VAROUS so-called barrier measures have been put in place by many countries to combat the spread of SARS-cov-2 and to protect the most vulnerable individuals.

In France, the *Haut Conseil de la Santé Publique (HCSP*) recommends a physical distance of at least 1 meter between 2 individuals [1]. As a rule, a free space of 4m² around a person is recommended by these experts, especially in the school context [2].

The decree n°2020-548 of May 11, 2020 prescribing the general measures necessary to face the epidemic of COVID-19 within the framework of the state of sanitary emergency came to recall the importance of the respect of the physical distancing "in any place and in all circumstances" [3].

How can this spatial distancing be respected to ensure one's own health safety and that of others? A sound or light signal should be used to warn of non-compliance with this rule.

Many devices can address this issue as shown in Figure 1. Most of them require prior infrastructures to be put in place, such as camera detection with artificial intelligence and/or facial recognition [4-6]. They are therefore intrusive and do not comply with the General Data Protection Regulation (GDPR) [7]. This is also the case for communication systems using WiFi, Bluetooth, ZigBee, [8-10]. The others because of their prices are not suitable for large-scale deployment such as drones or robots [11, 12].

Ultrasonic techniques are widely used in industry for various sensing applications [13]. The adaptation of already existing ultrasonic sensors can allow to answer this specific problem to have a quickly functional spatial distancing aid module without the deployment of a particular infrastructure, inexpensive, without using personal data.

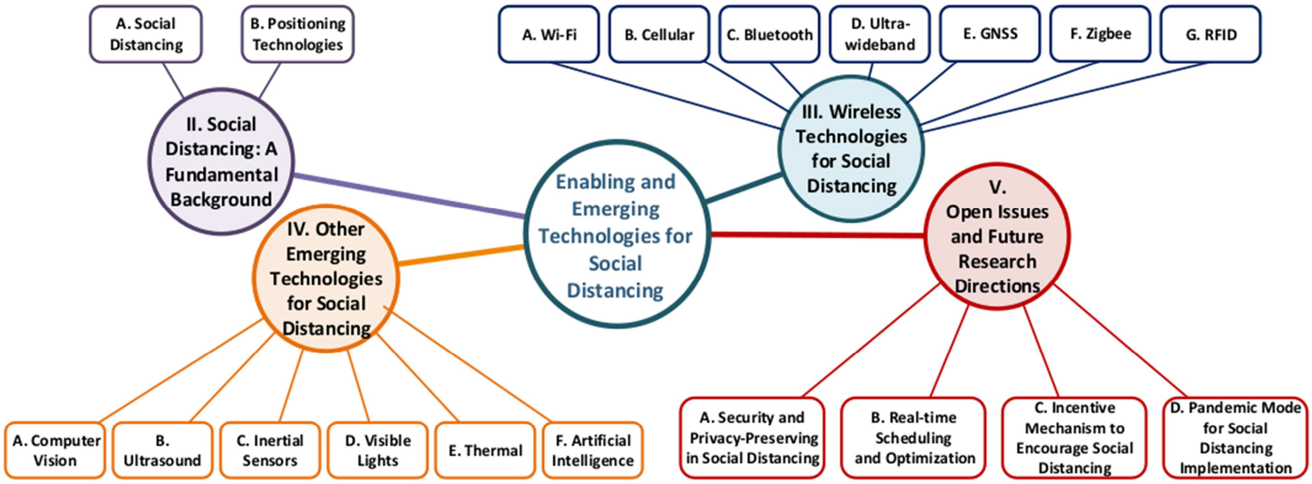

Figure 1. *The different technological possibilities to respect the spatial distance [14].*

2. Methods

The sensor used is the HC-SR04 (Figure 2) [15] compatible with the Arduino microcontroller.

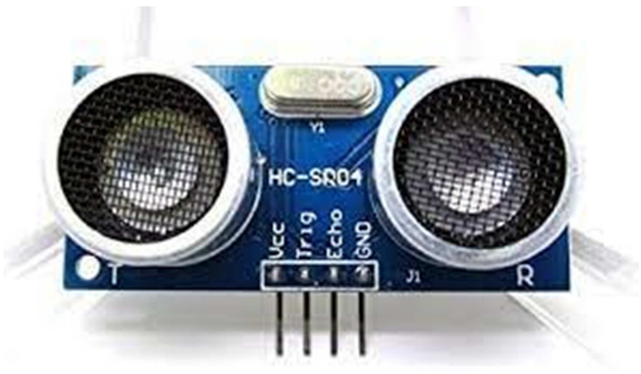

Figure 2. *Ultrasonic Sensor HC-SR04.*

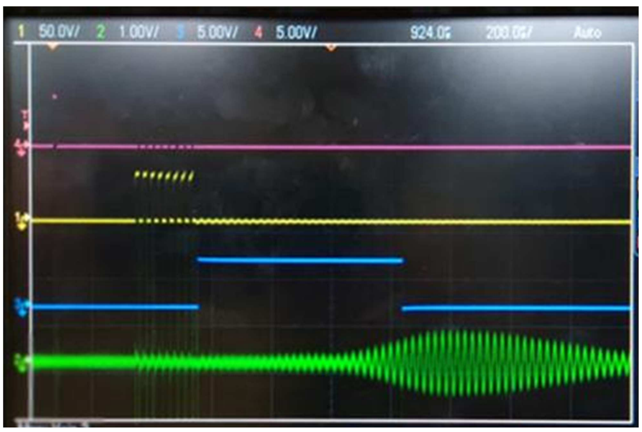

Figure 3. *The different signals emitted and received by the HC-SR04 sensor observed on the oscilloscope. The pink curve represents the Trigger, the yellow curve the pulses emitted at 40kHz, the blue curve the Echo and the green.*

Originally, the Ultrasonic sensor allows to measure a distance between the sensor and an object at a range between 2cm to 4m. It consists of a transmitting part and another receiving part (Figure 2).

To understand how it works, the signals emitted and received by the sensor can be seen on Figure 3. The Trigger (pink curve) triggers the sending of 8 pulses emitted at 40kHz (yellow curve) which will excite the transmitter membrane and generate the acoustic wave, which triggers the passage to the high state, the Echo (blue curve).

2 solutions:

1) An object is present in the detection zone. In this case the signal received (green curve) comes from the reflection of the signal emitted on the object. The shape of the signal corresponds to the oscillations of the membrane of the ultrasonic transmitter. When the signal is strong enough to be perceived, it exceeds the detection threshold. The echo returns to the low state. The distance between the object and the sensor is proportional to the time the Echo spends in the high state.
2) If no object is present, the Echo returns to the low state after a time corresponding to its detection limit.

Based on the basic principle of the sensor, distancing devices with a transmitter/receiver of the type HC-SR04 exist in the literature [16]. It detects nearby persons in a 60° direction (Figure 4) with distance measurement. However, it also detects all surrounding objects. Moreover, the presence of several devices disturbs its operation by giving distorted distances and consequently does not allow to know if the spatial distancing is respected.

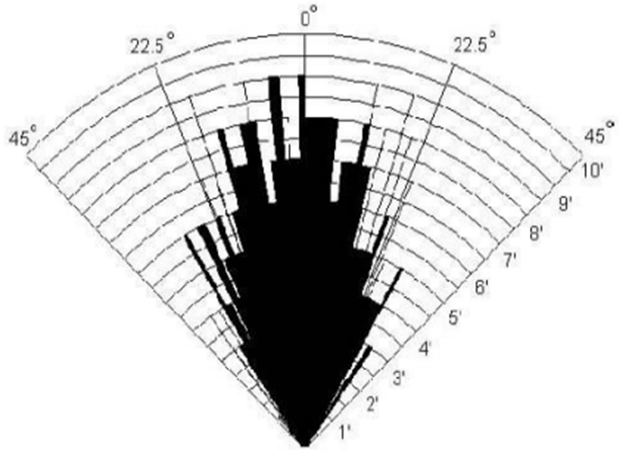

Figure 4. *Sensor directivity performance HC-SR04 [15].*

To overcome the problems described above, the idea is to associate for the same module, 4 ultrasonic sensors Transmitters/Receivers in 4 different directions to have a 360° vision (Figure 5).

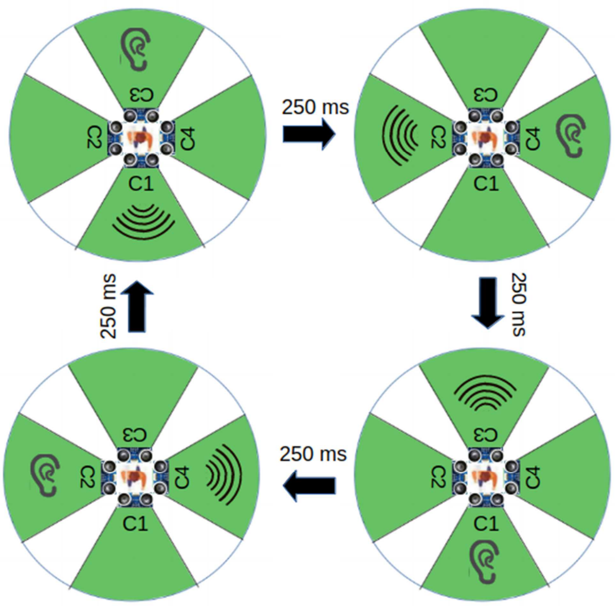

Figure 5. *Representation of the spatial distancing device with the 4 ultrasonic sensors allowing a 360° vision.*

In the case of our prototype, the transmitter C1 will be connected to the receiver C3 (and not to the receiver C1 as initially configured) and vice versa and the transmitter C2 will be connected to the receiver C4 and vice versa. Thus, when C1 emits its acoustic wave, the receiver C3 starts listening. In turn, the sensors and their associated receivers transmit and listen. Thus, a receiver hears a wave only if it comes from a neighboring device and not from a reflection of its own mechanism.

To determine if the person with the device is entering the safety zone, the detection threshold is adjusted so that the receiver will or will not perceive the wave (Figure 6).

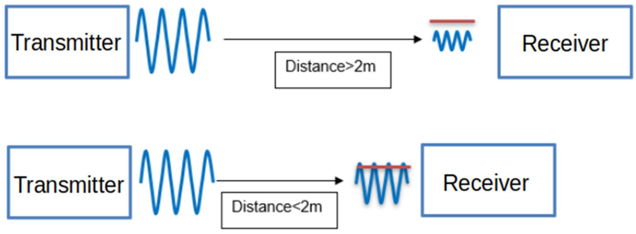

Figure 6. *Principle of the operation by threshold of detection of the sensor with Ultrasounds to determine the distance to be respected. In the first case, the signal is too attenuated for the receiver to detect the emitted wave meaning that the distance is respect.*

The range is set by using the attenuation as a function of the propagation of the acoustic wave to adjust the range of the device.

3. Results and Discussions

The prototype of the spatial distancing aid module with the four ultrasonic sensors is as shown in Figure 7.

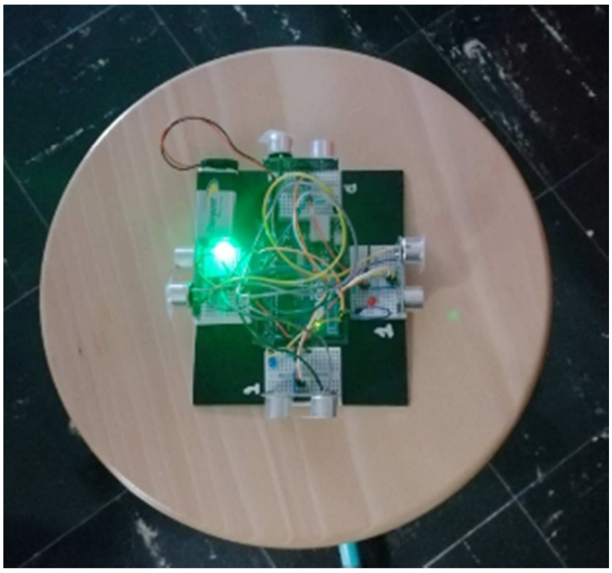

Figure 7. *Prototype of the acoustic spatial distancing aid.*

When the green LED is lit continuously, it means that it does not detect other devices in its field of view. The Echo (blue curve Figure 8) automatically drops after 180 ms. The value returned by the receiver to the Arduino when the sensor does not receive a signal, called the empty value, corresponds to a value greater than 1200 (Figure 10). Thus, as can be seen in the code programmed in Figure 9, as soon as the receiver returns this empty value, the LED remains lit.

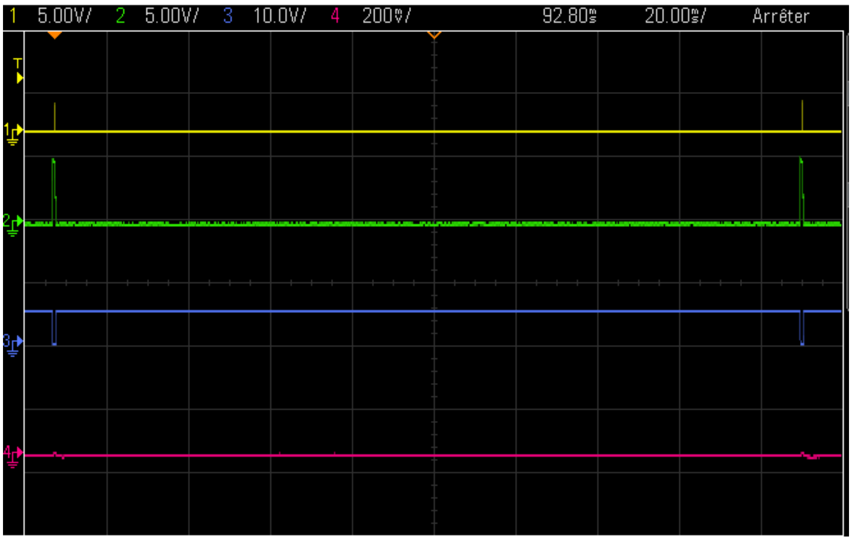

Figure 8. *The different signals emitted and received by the HC-SR04 sensor when there is no transmitting device in front of it, observed on the oscilloscope. The yellow curve represents the Trigger, the green curve the pulses emitted at 40kHz, the blue curve the Echo and the pink curve the received signal.*

```
#define LED 3            // Attach pin D3 Arduino to pin LED

#define echoPin_1 6      // Attach pin D6 Arduino to pin Echo of a first sensor
#define trigPin_1 7      // Attach pin D7 Arduino to pin Trig of a first sensor

#define echoPin_2 8      // Attach pin D8 Arduino to pin Echo of a second sensor
#define trigPin_2 9      // Attach pin D9 Arduino to pin Trig of a second sensor

#define echoPin_3 10      // Attach pin D10 Arduino to pin Echo of a third sensor
#define trigPin_3 11      // Attach pin D11 Arduino to pin Trig of a third sensor

#define echoPin_4 12      // Attach pin D12 Arduino to pin Echo of a fourth sensor
#define trigPin_4 13      // Attach pin D13 Arduino to pin Trig of a fourth sensor
//********Defines variables********//
// Variable for the duration of sound wave travel
long duration_1;
long duration_2;
long duration_3;
long duration_4;
// Variable for the distance measurement
int distance_1;
int distance_2;
int distance_3;
int distance_4;

int Time = 250;         // Variable repeat time delay
int Even = 1200;        // Variable break-even 1200 or 2200 depending on sensor

void setup() {
//Inisialize LED status
  pinMode(LED, OUTPUT);
  digitalWrite(LED,HIGH);
//Inisialize First Sensor status
  pinMode(trigPin_1, OUTPUT);
  pinMode(echoPin_1, INPUT);
//Inisialize Second Sensor status
  pinMode(trigPin_2, OUTPUT);
  pinMode(echoPin_2, INPUT);
//Inisialize Third Sensor status
  pinMode(trigPin_3, OUTPUT);
  pinMode(echoPin_3, INPUT);
//Inisialize Fourth Sensor status
  pinMode(trigPin_4, OUTPUT);

Serial.println("Ultrasonic Sensor");
Serial.println("4 capteur");
}


void loop() {

//************************First Sensor****************************************************//
  // Activation of all sensors except the one on the reception side for 10us
  digitalWrite(trigPin_1, HIGH);
  digitalWrite(trigPin_2, HIGH);
  digitalWrite(trigPin_4, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin_1, LOW);
  digitalWrite(trigPin_2, LOW);
  digitalWrite(trigPin_4, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration_1 = pulseIn(echoPin_1, HIGH);
  distance_1 = duration_1 / 58;
  // Displays the distance on the Serial Monitor
  Serial.print("Distance_1: ");
  Serial.print(distance_1);
  Serial.println(" ");
  // Distance less than the event
  if (Even >= distance_1){
   digitalWrite(LED,LOW);
   }
  delay(Time);

//************************Second Sensor****************************************
  // Activation of all sensors except the one on the reception side for 10us
  digitalWrite(trigPin_2, HIGH);
  digitalWrite(trigPin_3, HIGH);
  digitalWrite(trigPin_1, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin_2, LOW);
  digitalWrite(trigPin_3, LOW);
  digitalWrite(trigPin_1, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration_2 = pulseIn(echoPin_2, HIGH);
  distance_2 = duration_2 / 58;
  // Displays the distance on the Serial Monitor
  Serial.print("Distance_2: ");
  Serial.print(distance_2);
  Serial.println(" ");
  // Distance less than the event
  if (Even >= distance_2){
   digitalWrite(LED,LOW);
   }
  delay(Time);

//************************Third Sensor*****************************************
  // Activation of all sensors except the one on the reception side for 10us
  digitalWrite(trigPin_3, HIGH);
  digitalWrite(trigPin_4, HIGH);
  digitalWrite(trigPin_2, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin_3, LOW);
  digitalWrite(trigPin_4, LOW);
  digitalWrite(trigPin_2, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration_3 = pulseIn(echoPin_3, HIGH);
  distance_3 = duration_3 / 58;
  // Displays the distance on the Serial Monitor
  Serial.print("Distance_3: ");
  Serial.print(distance_3);
  Serial.println(" ");
  // Distance less than the event
  if (Even >= distance_3){
   digitalWrite(LED,LOW);
   }
  delay(Time);

  Serial.print(distance_4);
  Serial.println(" ");
  // Distance less than the event
  if (Even >= distance_4){
   digitalWrite(LED,LOW);
   }
  delay(Time);

//********LED Reset********//
  digitalWrite(LED,HIGH);

}
```

Figure 9. *Arduino programming code allowing the device to know if the distancing is respected or not.*

If this is not the case, the LED starts to flash, indicating that the device is receiving an acoustic wave and that the spatial distance is no longer respected. In fact, the Echo, goes down when the receiver detects a certain threshold level, corresponding to a value lower than the idle value. For example, Figure 11, 2 devices are located face to face at less than 1 meter from each other. The receiver 1 of the devices see a value lower than 1200. Thus, the distance is no longer respected and the LED flashes.

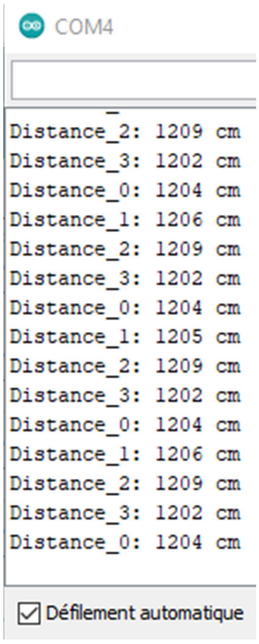

Figure 10. *Distance displayed by the Arduino serial monitor for receivers 1, 2, 3 and 4 of device 1 without any other device around.*

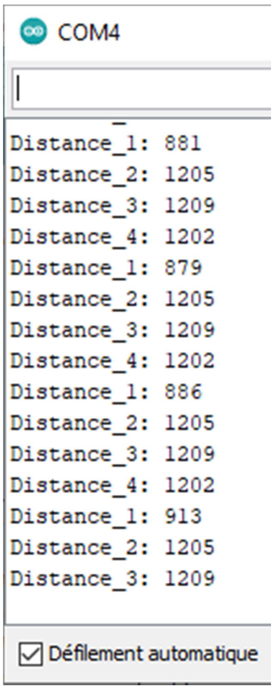

Figure 11. *Distance displayed by the Arduino serial monitor for receiver 1, 2, 3 and 4 of device 1 with the presence of a 2nd device at 1m.*

4. Conclusion

The device presented in this paper is a spatial distancing aid module that aims to maintain a physical distance between individuals to limit the spread and contamination of COVID-19.

The system uses 4 ultrasonic sensors and a micro-controller allowing a 360° detection of any other person having at his disposal a similar device. If the recommended distance is not respected, a sound or light signal is emitted to warn people that they are no longer respecting the recommendations.

The use of ultrasonic sensors allows to have a quickly functional product, adaptable and respecting the legislation with a possible marketing. In fact, the reversing radars of cars use the same technology. In the case of a commercialization, it would be necessary to entirely revise the device so that it is miniaturized and completely adapted to this problem of distancing.

This device can be used for other applications such as isolation measures for sick animals.

Acknowledgements

This work is part of the MADS (*Module d'aide à la distanciation spatiale*) research project, funded by the Nouvelle-Aquitaine region as part of the AMI FLASH *Recherche et innovations COVID* [grant number 10485720].

Thanks to the students of the IUT du Limousin, Mesures-Physiques department who participated to projects and internships on this prototype for their contributions to its design.

References

[1] «Coronavirus SARS-CoV-2: Barrier and physical distancing measures in the general population ». https://www.hcsp.fr/Explore.cgi/AvisRapportsDomaine?clefr=806 (accessed on May 9, 2022).

[2] J.-F. Delfraissy et al., «Children, Schools and Family Environment in the Context of the COVID-19 Crisis», p. 11, 2020.

[3] «Decrees, orders, circulars GENERAL TEXTSMINISTRY OF SOLIDARITIES AND HEALTH Decree No. 2020-548 of May 11, 2020 prescribing the general measures necessary to deal with the epidemic of COVID-19.pdf».

[4] S. Das et al., «Computer Vision-based Social Distancing Surveillance with Automated Camera Calibration for Large-scale Deployment», 2021, p. 1-6.

[5] A. Gupta, D. Thapar, et S. Deb, «Smart Camera for Enforcing Social Distancing», 2021, p. 349-354.

[6] V. Bharti et S. Singh, «Social Distancing Violation Detection Using Pre-Trained Object Detection Models», 2021, p. 319-324.

[7] «The General Data Protection Regulation - RGPD | CNIL». https://www.cnil.fr/fr/reglement-europeen-protection-donnees (accessed on May 11, 2022).

[8] L. Thakare, R. Dohare, et N. Akhtar, «P-Tracer: Proximity Detection for Contact Tracing», in 2021 International Conference on COMmunication Systems & NETworkS (COMSNETS), janv. 2021, p. 116-118. doi: 10.1109/COMSNETS51098.2021.9352738.

[9] M. F. Ali, Moch. Z. S. Hadi, R. W. Sudibyo, et H. Briantoro, Design of COVID-19 Tracing System based on Bluetooth Low Energy», in 2021 International Electronics Symposium (IES), sept. 2021, p. 374-379. doi: 10.1109/IES53407.2021.9594000.

[10] A. H. Mutlag, S. Q. Mahdi, S. K. Gharghan, O. N. M. Salim, A. Al-Naji, et J. Chahl, «Improved Control System Based on PSO and ANN for Social Distancing for Patients With COVID-19», IEEE Access, vol. 10, p. 63797-63811, 2022, doi: 10.1109/ACCESS.2022.3183124.

[11] Z. Chen et al., «Autonomous social distancing in urban environments using a quadruped robot», IEEE Access, vol. 9, p. 8392-8403, 2021.

[12] A. Majd, D. Biström, C. Tigerstedt, et L. Espinosa-Leal, «Social and Service Robots Deployed for Social Distancing-Optimization and Placement», 2021, p. 1-9.

[13] S. Muthumari et A. Singh, «Review of various ultrasonic techniques employed in modern industries», Int. J. Eng. Sci. Technol., vol. 3, n° 4, 2011.

[14] C. T. Nguyen et al., «Enabling and Emerging Technologies for Social Distancing: A Comprehensive Survey and Open Problems», IEEE Access, vol. 8, p. 153479-153507, 2020, doi: 10.1109/ACCESS.2020.3018140.

[15] «HCSR04.pdf». Accessed on May, 12 2022. [Online]. Available from: https://cdn.sparkfun.com/datasheets/Sensors/Proximity/HCSR04.pdf

[16] F. A. Naqiyuddin, W. Mansor, N. Sallehuddin, M. M. Johari, M. Shazlan, et A. Bakar, «Wearable Social Distancing Detection System», 2020, p. 1-4.