The Making of a Controlled-Population System out of Ultrasonic Sensors

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***Abstract*—With overcrowding being a factor that proliferates the transmission of disease-causing microorganisms, the main objective of this study is to make a Controlled-Population System out of ultrasonic sensors. The purpose of the Controlled-Population System includes improving the implementation of health restrictions such as social distancing and limited area capacities. The device also aids in reducing the workload of security guards which serves as a counter that detects and limits the number of people who enter an enclosed space. Arduino Uno, a programmable microcontroller, was used to contain the program and interface every component. The counting system is triggered when a mobile body passes through both fields of vision of the sensors. The device uses a buzzer that sounds off an alarm to alert the person that the room has exceeded the maximum capacity and thus, must exit the room. The results of the study proved the Controlled-Population System effective in terms of the latency between the sensors and the counter, the accuracy of counting at walking speed, and the maximum distance of detection.**

***Index Terms*—ArduinoUno, Buzzer, Controlled-Population System,Overcrowding, Ultrasonic Sensors**

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I. INTRODUCTION

In December 2019, it was reported that the first novel human coronavirus occurred in Wuhan, China. The World Health Organization declared that the large family of viruses causes respiratory illness through droplets and airborne transmission. People of all ages rapidly got infected, while the elderly were vulnerable. Some severe experience symptoms of contracting the virus include trouble breathing, constant pain, or even death (World Health Organization, 2021). The severity and rapid spread of the Covid-19 virus hindered people from continuing their routines as human-to-human transmission protocols were established (Centers for Disease Control and Prevention, 2022).

The global pandemic has effectively challenged people to isolate and stay safe. Society relies on the interaction among its members to evolve and sustain itself. However, the pandemic caused a mandate for people to isolate themselves. The sudden requirement tested the resilience of healthcare systems among nations, as seen by the number of cases each country would come out with (United Nations Covid-19 Response, 2022). Though there was a pandemic around the globe, it did not hinder citizens from being uncooperative with the rules and regulations of disease prevention. As reported by Mounk (2020), two of the reasons why this is the case is due to selfishness and ignorance, adding to the fact that younger people are less strongly affected by the disease, possibly encouraging them to go out in public for their own trivial needs selfishly.

With the rising pandemic and infected cases, it is only necessary that health restrictions were implemented. These preventative measures, known as “health restrictions,” were established to control the population in one space. Also, it encourages social distancing to decrease the chance of getting infected all at once. During the first few months of the pandemic, national leaders recognized that the virus was life-threatening and established guidelines that affect public gatherings, transportation, tourism, education, and health facilities. In Qatar, they first handled contact tracing and released an app called EHTERAZ which visualizes an individual's health status: Negative, Positive, or Quarantined.

Due to the lockdown, it was a priority to instill proper protocols to limit the spread of the virus. The Ministry of Public Health urged guidelines essential for public safety on February 29, 2020. Receiving the COVID-19 vaccine, wearing masks in public places, keeping a 1-meter distance from other people, sanitizing one’s hands, and avoiding contact with one’s face. Regular checking of the EHTERAZ app was done at the entrances of public

facilities to ensure an individual's health status (Ministry of Public Health, 2020). These protocols finally made it possible for people to go back outside with regard to the guidelines set.

Overcrowding is a factor that controls the proliferation of the transmission of disease-causing microorganisms. People often visit markets, stores, and public buildings, resulting in adverse health outcomes and infectious diseases. Over 95% of Covid cases come from urban areas and depend on humans' interactions with their environment (Mitlin, 2020). Long periods of commuting and household crowding foreshow a higher number of transmissible coronavirus cases in urban areas. So, overcrowding and lack of access to proper households prevent the implementation of a key Covid protocol that many are pressed to follow, which is to practice social distancing.

Due to Covid-19, restrictions on entrances are enforced, and standby guards and security personnel carry these out. This study would be beneficial in maintaining the implementation of social distancing and mandated capacities of areas as devices such as the Controlled-Population system function as a people counter device that could limit the entrance of subjects in an enclosed area. Dor Technologies, Inc (2021) explained that people counter devices are most commonly used in retail stores and buildings to track their popularity and advertising effectiveness. In this case, the device can pick up on the number of subjects entering the enclosed area and successfully notify authorized personnel if the number goes past the limit. Provided the world's current situation, this device would prove helpful in adhering to social distancing rules and regulations and can lessen the spread of the virus.

The ultrasonic sensors were the main component in making the Controlled-Population System. The sensor sends ultrasonic waves and receives them back when an object or person enters or exits through them. The sensor then calculates the distance of the entity by figuring the time between the emission and reception of the wave. With the Wi-fi module and the Arduino Uno Interface, communicating with and coding the system to do the actual counting would be convenient. The system would be programmed such that when the number of people counted exceeds a specific number, the buzzer would be triggered to sound off an alarm.

The main objective of this study is to make a Controlled-Population System out of ultrasonic sensors. Specifically, this research aims to determine the latency or the delay of transmission between the sensor and the counter, the device's audio volume in decibels, the accuracy of registered people count, and the distance at which the Controlled-Population System will count a person. The study hypothesized that it is possible to make a Controlled-Population System using ultrasonic sensors.

This study benefits the Philippine School Doha (PSD), the Qatari and Filipino communities, and future researchers. The outcomes of this study aided the Philippine School Doha student and faculty body by limiting the number of people able to occupy an enclosed area, such as classrooms, staff rooms, or utility closets, creating a safe and uncongested environment.

Additionally, the study would raise PSD students' and staffs' awareness regarding the importance of enclosed spaces with controlled amounts of inhabitants, one of the main benefits being decreased transmission of viral illnesses. The implementation of the device would also help eliminate the possibility of issues such as room-hopping and truancy.

This study could also assist Qatar in making a crowd-free environment and encourage residents and visitors to be mindful of their distance from one another. As a result, it would be less likely for people in Qatar to have caught the virus since each person who has entered the room has fewer people to be wary of in terms of distancing themselves from others. In addition, the research contributed to the improvement and sustainability of Qatar as the study utilizes an Arduino Uno interface and ultrasonic sensors that lessen the workload of assigned personnel. As for the urban parts of the Philippines, the Controlled-Population system serves as a simple, reliable, and sustainable way to undergo social distancing. Through this, people could become more aware of how they distance themselves from others and protect themselves in this pandemic.

Moreover, future researchers can use the results, data, and information presented in this study as references while researching social distancing systems. They can utilize this study to check the accuracy of other researches in the field. Issues in their investigations will be reduced due to this research, as will the usage of similar factors and procedures to make better-quality systems.

The study could prove a security measure for quarantined areas such as the high containment laboratories in the Centers for Disease Control, which contain all the known viruses and diseases. Our product can provide a countermeasure to ensure that a certain number of scientists may enter these areas to decrease the chance of transmission.

II. Research Questions

The main objective of this study is to make a Controlled-Population System out of ultrasonic sensors. Specifically, this research aims to answer the following questions:

- What is the latency in counting the Controlled-Population System between the sensors and the counter?
- What is the accuracy of the registered people count of the Controlled-Population System at:
  - walking and
  - running speed?
- How far is the distance at which a person will be counted by the Controlled-Population System?

III. Methodology

The research utilized the experimental design. Tanner (2018) stated that experimental design is the type of research that aims to determine "cause and effect" relationships of defined variables under controlled conditions, create products with certain materials, test the feasibility and effectiveness of products, create comparisons between two specific products, and more. The hypothesis was used to investigate the linkbetween the independent and dependent variables. In this study, the

ultrasonic sensors are the independent variable, and the Controlled-Population System is the dependent variable. The quantitative method was used to organize the experiment and to ensure that the correct type of data was available to answer the research questions as clearly and efficiently as possible. This method is required as it provides a high level of control over the variables and shows the relationship between them.

A. Research Locale

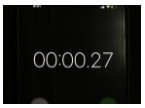
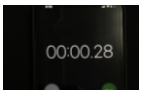
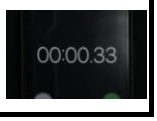
The research study was conducted in Voltaat Makerspace, specifically in Building 52 Street 958, Zone 32, Madinat Khalifa North Area (Zone 32), Doha, Qatar. The office space provided all necessary materials and equipment for making the Controlled-Population System.

IV. RESULTS

This section presents the results and interpretations of the data that were collected during the testing procedure in relation to the research questions.

1.) The Latency Between the Sensors and the Counter

Table I
The Latency Between the Sensors and the Counter

Trials	Arduino Software	Delay (milliseconds)	Photos
First Trial of Measurement	delay for 260 milliseconds	270 milliseconds	
Second Trial of Measurement	delay for 260 milliseconds	280 milliseconds	
Third Trial of Measurement	delay for 260 milliseconds	330 milliseconds	

The latency between the ultrasonic sensors and the counter of the Controlled-Population System was tested using a timer which recorded the time it takes between a person passing through both sensors and the result showing in the serial monitor. Table I shows the different trials in determining the delay in milliseconds produced by the system. In the first trial of measurement, the delay was 270 milliseconds which was 10 milliseconds slower than the set delay in the Arduino Software. In the second and third trials, the delay was 280 milliseconds and 330 milliseconds respectively.

Evaluating the results, the average time of delay it took for the sensors to count was 293.3 milliseconds. These show minimal changes in the detection delay of the sensors and counter making it reliable and fast in counting. Compared to commercial visitor counters such as V-Count that uses state-of-the-art 3D active stereo vision technology with a delay that ranges from <100 milliseconds, the latency of the Controlled-Population is virtually unnoticeable. More than one trial was conducted to see if there were significant changes in the latency of the Controlled-Population System.

2. The Accuracy of the Registered People Count of the Controlled-Population System at:

2.1 Walking speed

Table II
Accuracy of the Controlled-Population System at Walking Speed

Trials	No. of people counted	Photos
First Trial of Measurement	9 out of 10	
Second Trial of Measurement	10 out of 10	
Third Trial of Measurement	10 out of 10	

The speed was measured through the use of a speedometer app that was held by the registered people. The accuracy of the registered people count of the controlled population system was tested by ten people passing through the sensors one by one. Table II shows the trials to test the accuracy of the registered people count of the system at walking speed or specifically 1.2m/s. The speed was measured through the use of a speedometer app installed on the registered peoples' phones. The testing procedure is needed in order to survey if the sensors work properly and according to the code. In the first trial of measurement, the system detected 9 out of 10 people. This suggested that an external element had hindered the sensors' field of view and failed to add to the counter. In the second and third trials, the system detected all 10 people who passed through. This shows that the system had a 90% accuracy in the first trial but improved to 100% in the following trials.In the past, the only way to count people in an enclosed area was to stand with a clicker and physically count people as they passed – a very tedious and error-prone method. Being able to detect with a cost-effective device can certainly aid in enforcing the mandate by sounding the alarm.

2.2Running speed

Table III
Accuracy of the Controlled-Population System at Running Speed

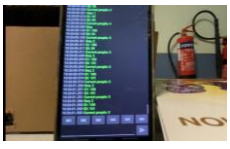
Trials	No. of people counted	Photos
First Trial of Measurement	5 out of 10	
Second Trial of Measurement	6 out of 10	
Third Trial of Measurement	5 out of 10	

Table III shows the results of the registered people passing through the sensor at running speed, specifically 1.79m/s and above according to Vinmec International Hospital (2019). The speed was measured through the use of a speedometer app that was held by the people passing through the sensors. The first trial resulted in 5 out of 10 people being counted. In the second trial, the sensors detected 6 out of 10 people. Finally, in the third trial, the sensors detected 5 out of 10 people. This indicates that the accuracy of counting became significantly less compared to the results of the registered people passing through the sensors at walking speed.

3. The Distance at which the Controlled-Population System will count a Person

Table IV
The Distance at which the Controlled-Population System will count a Person

Trials	Distance (cm)	Result	Photos
First Trial of Measurement	25 cm	SUCCESS	
Second Trial of Measurement	50 cm	SUCCESS	
Third Trial of Measurement	75 cm	SUCCESS	
Fourth Trial of Measurement	100 cm	SUCCESS	
Fifth Trial of Measurement	125 cm	SUCCESS	
Sixth Trial of Measurement	150 cm	FAIL	

Table IV tested the distance at which a person will be counted by the sensors. The distance of the person walking through was increased by 25 cm per trial until the person was too far for the system to detect. The data from the test show that the system can detect someone at a distance of 25cm in the 1st trial. The system also successfully detected someone at a distance of 50cm in the 2nd trial. The system successfully detected someone at the 3rd trial (75cm), the 4th trial (100cm), and the 5th trial (125cm). The system, however, failed to count a person on the 6th trial at a distance of 150cm. Based on the test results, the system can count a person at a distance of 125cm but not at 150cm showing a 25 cm difference between the maximum distance the system counted a person and the distance where it failed. According to the Qatar Civil Defense guidelines, the minimum width of side hinges or pivoted doors must be at least 32 inches or 81cm. This makes the Controlled Population System more than capable of detecting people through doorways. Detecting people from a distance of 125cm is beneficial for this device as it can be used for wider doors, entrances, and exits.

V. Results

The rise of COVID-19 cases in a city urged the Government to impose safety measures by restricting large numbers of people in enclosed areas like malls, offices, and schools. Before safety precautions disrupted people's lives, they could move freely and join crowds of people. This needs to be fixed in today's operations to maintain social distancing guidelines. Complaints regarding the limited capacity for social gatherings started accumulating as they found it utmost and time-consuming. Therefore, people found loopholes in the regulations or completely abandoned them. The ignorance of the simple safety restriction is one of the reasons for the rapid spread of Covid-19. As a result, people are held at checkpoints before entering enclosed spaces. The most advanced solution to ensure the mandate is properly implemented is to deploy automated people counters for 24/7, real-time traffic and occupancy monitoring, as stated by McGrath (2022).

The Controlled-Population System can functionat an efficient standard based on the data presented in the results. The results of the trials evaluating delay produced a minimal average latency of 293 milliseconds and a walking speed of 1.2m/s. The Controlled-Population System can accurately and effectively count individuals walking in and out of a room through a doorway. In contrast to the accuracy when passing through by running at 1.79m/s, the results the researchers' trials produced were not as proficient. Moreover, the Controlled-Population System successfully detected people passing through at a distance of one and a quarter meters from the device.

It is recommended to place the device at a height where the person passing through would be detected by the

Controlled-Population system appropriately, and further errors would be avoided. To avoid external factors significantly affecting the accuracy and hindering the sensors, placing the device inside the room at an average hip level of 87 cm to 120 cm could greatly reduce inaccuracy in counting.

The area where the device is placed should be free from obstruction from any object. Placing the system in a single two-way door is recommended, as the device is designed for one person per entry. Offices, classrooms, and medium-sized rooms would complement the use of the device. It is also recommended that the sensors are positioned linearly to each other but not close to avoid an overlapping field of view. During the trial runs, the Controlled-Population system could effectively detect a person passing through up to 125 cm, which lies on the standard widths of doors. As compared to the dimensions of larger areas such as automatic mall doors and hospital hallways, the system would only be able to function inaccurately. In that case, it is recommended for people to line up and wait for their turn to go inside, as it is still part of the social distancing protocol.

Furthermore, besides the LCD that shows the current count of people inside a room, the device utilizes a Bluetooth module that allows someone to monitor the count from his or her phone. However, it is limited to Android devices only. To avoid this problem, it is suggested that the module be changed into a Wi-fi module so that the count monitor can be accessible by most devices regardless of brand. It is recommended that when entering the room, the person should be at a walking speed of 1.2m/s and not stop between the sensors when passing through the initial sensor, as this would affect the counting system. The researchers found through trial and error that running would lower the counting accuracy.

Lastly, future researchers may use the Controlled-Population System to improve technologies such as microchips, metal detectors, and gate systems. It is recommended that future researchers create a Controlled-Population System with a wider scope. It would mean that a larger venue should be considered including the number of people who can enter at the same time. Instead of using ultrasonic sensors, camera scanning features may greatly improve the efficiency and effectiveness of the product.

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REFERENCES

[1] Al Jazeera. (2020, May 26). Qatar makes COVID-19 app mandatory, experts question efficiency. Breaking News, World News and Video from Al Jazeera. https://www.aljazeera.com/news/2020/5/26/qatar-makes-covid-19-app-mandatory-experts-question-efficiency

[2] Dor Technologies, Inc. (2022). People counting system and technology. Getdor.com. https://www.getdor.com/solutions/people-counting.

[3] Dubiel, VP of Integrated Insight, B. (2020). How to determine operational capacity in a COVID-19 world. Integrated Insight. Retrieved from: https://integratedinsight.com/how-to-determine-operational-capacity-in-a-covid-19-world/

[4] General Directorate of Civil Defence. (2015). QCD guidelines - bps.mme.gov.qa. QCD-Safety Guidelines. Retrieved January 18, 2023, from https://bps.mme.gov.qa/ArticleDocuments/QCD%20Guidelines_AR.pdf

[5] Lewis, D. (2022, April 6). Why the WHO took two years to say COVID is airborne. Nature. https://www.nature.com/articles/d41586-022-00925-7

[6] McGrath, L. (2022, February 15). Controlling COVID-19 retail traffic with automated people counters. Hitachi Solutions. https://global.hitachi-solutions.com/blog/automated-people-counters/

[7] Ministry of Public Health. (2022, January 20). How to Protect Yourself. Ministry of Public Health. https://covid19.moph.gov.qa/EN/How-to-protect-yourself/Pages/default.aspx

[8] Miscio, M., & Balch, P. (2022). DIY Laser People Counter: 8 Steps (with Pictures). Instructables. https://www.instructables.com/DIY-Laser-People-Counter/

[9] Mounk, Y. (2020, March 19). Four theories for why people are still out partying. The Atlantic. https://www.theatlantic.com/ideas/archive/2020/03/moral-instincts-coronavirus/608305/

[10] National Center for Immunization and Respiratory Diseases (NCIRD). (2022). COVID-19 and your health. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick.html

[11] Rubin, D., & Offit, P. (2020). We Know Crowding Affects The Spread. It may affect the Death Rate. https://www.nytimes.com/2020/04/27/opinion/coronavirus-crowds.html

[12] Seidlein, L., Alabaster, G., Deen, J., & Knudsen, J. (2020, November 22). Crowding has consequences: Prevention and management of COVID-19 in informal urban settlements. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7680649/

[13] Söderby, K. (2021) Liquid Crystal Displays (LCD) with Arduino: Arduino documentation, Arduino Documentation | Arduino

[14] Documentation. Available at: https://docs.arduino.cc/learn/electronics/lcd-displays.

[15] Tanner, K. (2018). Research Methods (Second Edition). Science Direct. Retrieved from https://www.sciencedirect.com/topics/social-sciences/experimental-research

[16] United Nations Office for Disaster Risk Reduction. (2020, March 18). Enforcing compliance with covid-19 pandemic restrictions: psychological aspects of a national security threat.

[17] Vinmec. (2019). What is the average human running speed? Vinmec Healthcare System | Vinmec.

https://www.vinmec.com/en/news/health-news/healthy-lifestyle/what-is-the-average-human-running-speed
[18] World Health Organization. (2022, January 19). Coronavirus disease (COVID-19). World Health Organization. https://www.who.int/health-topics/coronavirus#tab=tab_1