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# Social Distancing System

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# I. Abstract

By 31 December 2019, the world has faced the infamous COVID-19 pandemic, also known as the coronavirus [1] that brought many challenges to our lives. One of the most important ones is to keep our distance from each other although that might seem something easy to do it's easier said than done. Since we are humans, we are social by our nature so it's difficult to always keep a safe distance from each other all the time especially in business meetings or family gathering. So, simply the problem here is that how can we keep track of everybody's distance in the workplace, schools, mosques, airports, etc. so that everyone can be safe during any pandemics. By building a system that can provide monitorization and surveillance over physical distance and safety measurements we can greatly reduce the chance of getting an infection in any room that can contain human gatherings of any kind. Thus, this project can help people overcome any pandemics that are related to physical distance by securing a safe environment for everyone also, accelerate the process of returning to workplaces by installing the system in building hence, ensuring a safe environment for all the people.

# II. Definitions, acronyms, and abbreviations

**Table 1: Definitions and acronyms table**

| Term | Definition |
|---|---|
| **SDS** | Social Distancing System |
| **A.I** | Artificial Intelligence |
| **IoT** | Internet of things |
| **Wi-fi** | Wireless fidelity |
| **Drone** | A small an unpiloted aircraft |
| **Web Application** | A computer program that uses web browsers performs various tasks over the Internet. |
| **SSD** | Single Shot Detector |
| **OpenCV** | Open Computer Vision Library |
| **DSI** | Display Serial Interface |
| **CCTV Camera** | Closed-Circuit Television |
| **CSI** | Camera Serial Interface |
| **The administrator** | Someone responsible for the monitorization of the system |
| **The maintainer** | Someone responsible for the maintenance of the system |
| **The public** | The People in the monetarized environment |

# III. Keywords

social distancing system, detection, violation, AI, raspberry pi, SDS, web application, admin, public, maintainer, data, computer vison, sensor, monitoring, COVID, face mask, occupancy

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# Chapter One: Introduction

# 1.1 Introduction

According to the World Health Organization, the most common way for the Coronavirus to spread is by close contact between people [2]. Unfortunately, many people ignore that fact which leads to more virus spread thus to more infected people and more deaths. More than 30 million Coronavirus Cases and 950,000 death in 213 countries [3]. Coronavirus is just an example of many other vicious viruses that have been in the past and might come again in the future and if we know something about these viruses is that they always evolve to come back stronger. If we are not prepared well to face these pandemics, we might face many souls losses in the future. We learned a lot of things through this COVID-19 pandemic one of the important lessons is how valuable and challenging to secure a safe environment for everyone.

The importance of the Social Distancing System comes into the picture when people are returning to their normal daily routines during pandemic or restricted safety measurements such as wearing face mask most of the time and avoiding physical contact with each other. The problem with this is there is no granted way to ensure that these safety policies are being applied in the desired place.

Here's how the Social Distancing System project will help brighten things up, we'll be developing a solution that composes of both hardware & software that will be able to ensure the social distance policies are being followed. the system can detect if a person is wearing a face mask and it can detect violation regarding Social distancing also, it can monitor the occupancy of the room in real-time matter. Our main goal is to minimize the spread of viral infections such as (COVID-19) and help people return quickly and safely to their normal lives.

In this proposal will provide an overall view of the project starting with the **aims and objectives** that we are going to achieve through this project. After that, we will be giving a general description of the **methodology** in fulfilling the aims and objectives. Then, a simple **timetable** that shows our project timeline followed by the team qualifications showing every member's skills and capabilities. Lastly, there will be a **conclusion** at the end of this proposal.

## 1.2 Background

In our project, we will be using a small single-board computer called raspberry pi 4 with 1. 5GHz processor and 4GB of ram that can plug into monitors, keyboards, and mouses with the ability to performs just like a desktop computer, in addition to raspberry pi cameras v2 add-on board that comes with 8 megapixel and support 1080p30, 720p60 video modes and Lepton® 3.5 micro thermal camera with a temperature range up to +80˚C.

Using the camera with computer vision is one of the most important sub-filed of artificial intelligence in the last two decades, by applying a neural network to detect, find and track objects with different algorithms and approaches such as single shot detector (SSD) algorithm using optical flow [4] implemented by open computer vision (OpenCV) the most powerful and popular open-source computer vision and machine learning software library. Furthermore, surveillance camera systems have been improving using supervised machine learning algorithms with different applications like the ability to detect strange events and movements especially for elderly people in case of person fall or behave in an unusual way [5].

One of the technologies used today by Hikvision a leading company that provides advanced security cameras and solutions, the thermographic bullet camera (DS-2TD2637B-10/P) model that can measure the body temperature in scenarios where there is large people flow with ± 0.5 C accuracy and face mask detection [6].

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## 1.2 Aims and Objectives

### Aim:

This project aims to design, implement, and test an integrated social distancing system to help us implement the precautionary measures and keep the environment safe and stable. The system helps to minimize the spread of infection and detect Distancing violations regarding physical distancing and improving the process of returning safely to normal life. It is a web-based system. When people move in the field of view of our system, the system will detect their fever, if they have a face mask or not, calculating the relative distance of each person compared to the other people and the system will have an occupancy counter to ensure social distancing for large spaces.

### The objectives:

1- Design an integrated social distancing system.
2- Study Web-based systems.
3- Learn more about cameras and sensors used for monitoring systems.
4- Learn more about machine learning technology, specifically (image recognition).
5- Learn more about Artificial intelligence.
6- Implement the social distancing system.
7- Develop a website application to manage the system.
8- Enhancing our communication and personal skills.
9- Develop our technical writing skills by writing a technical report for our project.

## 1.4 Methodology

In this project that focuses on making a **safe environment**, we will be using different AI frameworks, models, and libraries implemented on raspberry pi 4 board that give powerful processing and a drone with a built-in camera to add more support to the system in addition to the

sensors (4 cameras one of them is a thermal camera) that perform several tasks and considered the main component of the system which we use to oversee the whole environment (see Figure 1 ).

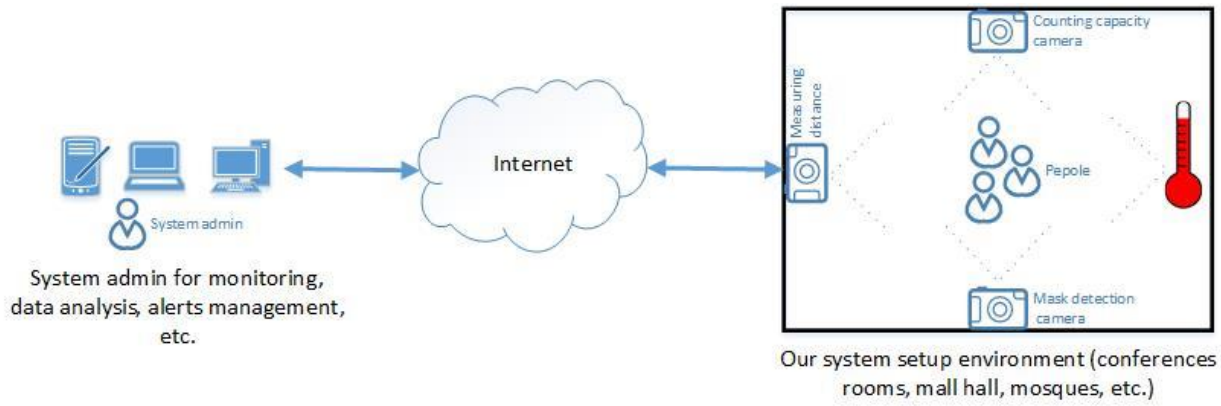


**Figure 1: Proposed system overview**

The first camera is placed on top of the door and used for monitors the site's capacity by counting the number of people entering and exiting from the site with a live display in front of the entrance for the number of people and whether it allowed to enter or not, the second one is also placed on top of the door but in a different angle with the ability to determines whether the person is wearing a mask or not.

A screenshot and violation notification are sent to the web application admin for those who do not wear any mask. The third one needs a wide view range so it should be placed at the corner of the site to measures the distance between two or more people and in case of violations of the social distance rule (2-meter distance), a screenshot and notification is sent to the web application admin and last, the human body temperature which measured using a thermal sensor and for those who have a high temperature a screenshot is taking and send to the web application admin, since all the cameras have fixed places we will be using an autonomous drone to cover the blind spots and add more support to the system the drone will take automatic round every 10 minutes and like the previous cameras if a violation is found a screenshot will be taken and send to the admin, at the end all this data is collected and analyzed by the web application system to help reduce social contact and for better understanding of the environment around us.

# 1.5 Project Timeline

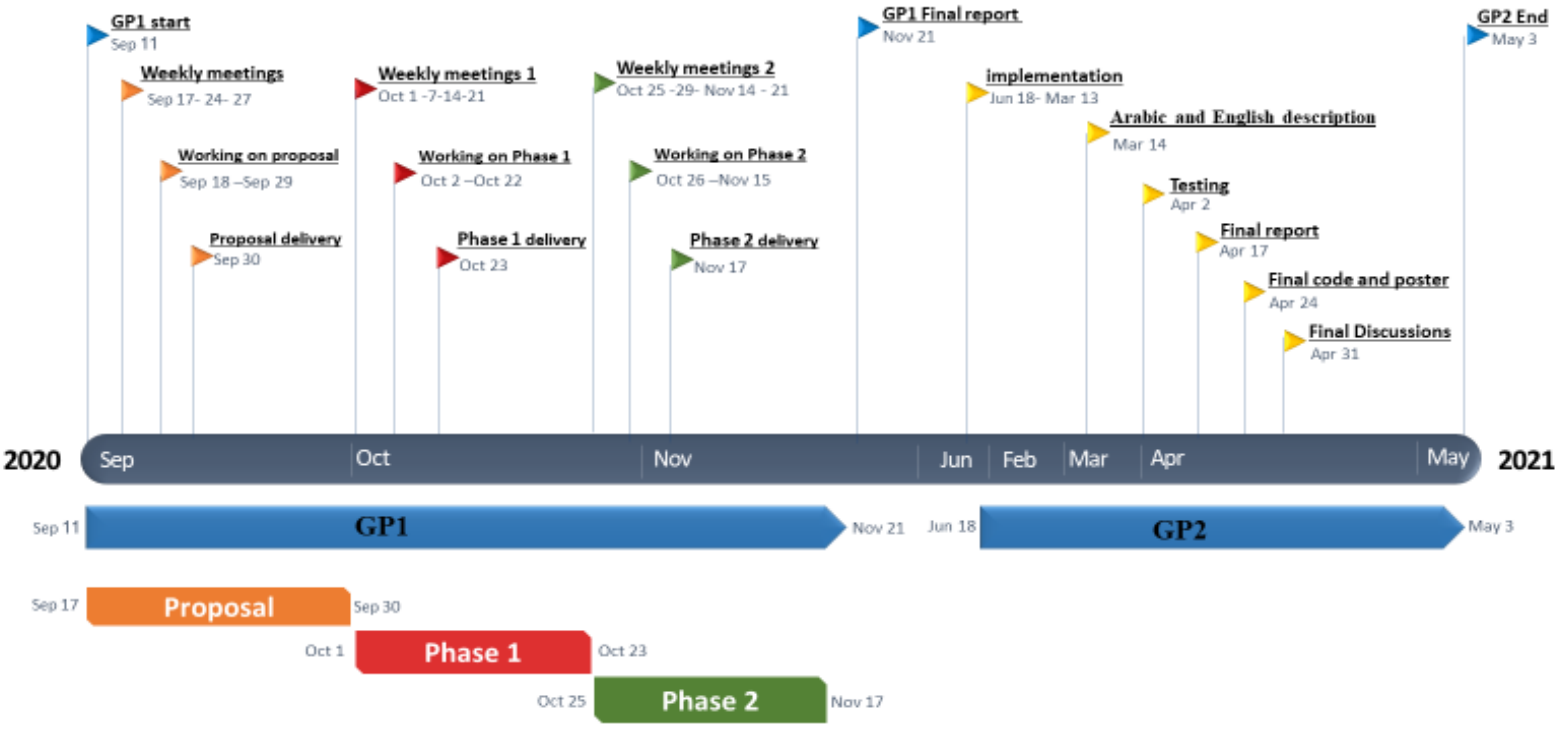


**Figure 2: Timeline of the project**

## 1.6 Team Qualifications

**Anass Markhouss**

1- Capable of managing and coordinating the team.

2- A Full Stack developer.

3- Has experience Building and implementing SQL database

**Amr AL Gamal:**

1- Very good at Providing information and resources.

2- A cloud application developer.

3- An excellent A.I. programmer.

**Mohammed Otayfah:**

1- Has a good experience Using SQL.

2- Has experience testing and validating codes.

3-A good code debugger.

## 1.7 Conclusions

In summary, the social distancing system will help us achieve social distancing and reduce the spread of infection by installing it at the entrances of buildings, facilities, or rooms that contain human gatherings to calculate the number of people in the place and detect if one of them has a fever, violates the social distancing law, or does not wear a mask. The system is linked to a website that shows all the details of what the system contains and the violations that have been detected. This will enable the people to be more responsible to avoid violations that may lead to infection. In future work, we are going to start gathering and analyzing the requirements of our proposed project. Then, designing and modeling the system, then implementing, coding, and testing the whole system. In the end, continue the process of development, improvement, and maintenance of the system.

# Chapter Two: Literature Review

## 2.1 Introduction

In this chapter, we are going to dive deep into the scientific background that is related to our project regarding the technology and the science behind it. We previously covered that the system uses artificial indulgence embedded in cameras that securely and efficiently capture and monitor the environment using different computer vision algorithms and approaches such as single shot detector (SSD) algorithm and open computer vision (OpenCV) in addition, to a thermal camera that can detect any changes in the temperature which adds to the system a huge advantage in detecting potentially infected entity in the environment. The system also supports an autonomous drone the covers most of the areas in the environment that the cameras cannot see in other words, blind spots, and by doing that it covers one of the weaknesses of the system. Last but not least the web application display the activates and violations of the safety policies in the environment to the administrator who is responsible for the monitorization of the system.

As we saw in the previous chapter that Social Distancing System is very important when it comes to following safety measurements during any pandemic and monitoring the action of the people in that environment to ensure their safety and potentially reduce the chance for any virus to spread in that environment also, the system will help the community to return safely to their daily everyday jobs and routines faster and more secure than before.

In this chapter, we have **background section 2,** which illustrates the theoretical and conceptual framework of the project including the history of the field and how it evolves to what it is today. Section 3, presents the **related work** to our project domain that includes previous work done by leading tech companies around the world and how they encounter this project problem and the solutions they have provided in this field in addition to, criticizing some weak points that each related work has. Finally, a **conclusion in section 4** that summarize the whole chapter.

## 2.2 Background

During the evolution of technology, the full dependency on the humans as a workforce becomes less day after day as a result of relying on machines both hardware and software, and one of the main challenges in the digital world is to simulate the human brain using AI (artificial intelligence)

to build a smart machine that can perform tasks as the human being. One of the artificial intelligence branches is computer vision that involves capturing, processing, and analyzing real-world images to allow machines to extract meaningful, contextual information from the physical world to demonstrate these features we need computing power and cameras.

In our project, we will be using a small single-board computer called raspberry pi 4 with a 1.5 GHz processor and 4GB of RAM (see *Figure 3*) with the ability to perform just like a desktop computer, in addition to different ports like USB 3.0 and USB 2.0 for external devices such as mouses and keyboards, 4-pole stereo audio for a headset, CSI (camera serial interface) port to connect the camera, two micro HDMI ports, USB-C power port, DSI (display serial interface) port for connecting a screen also 40 pins general-purpose input/output and micro SD card slot for extra storage finally a gigabit ethernet port which connects the board to the network by cable, the other parts of the board contains several chips like PoE (Power over Ethernet) that give you the ability to be powered through Ethernet cable along with the data, and finally, the chip that provides 2.4/5GHz wireless and Bluetooth 5.0 which give more connections methods.

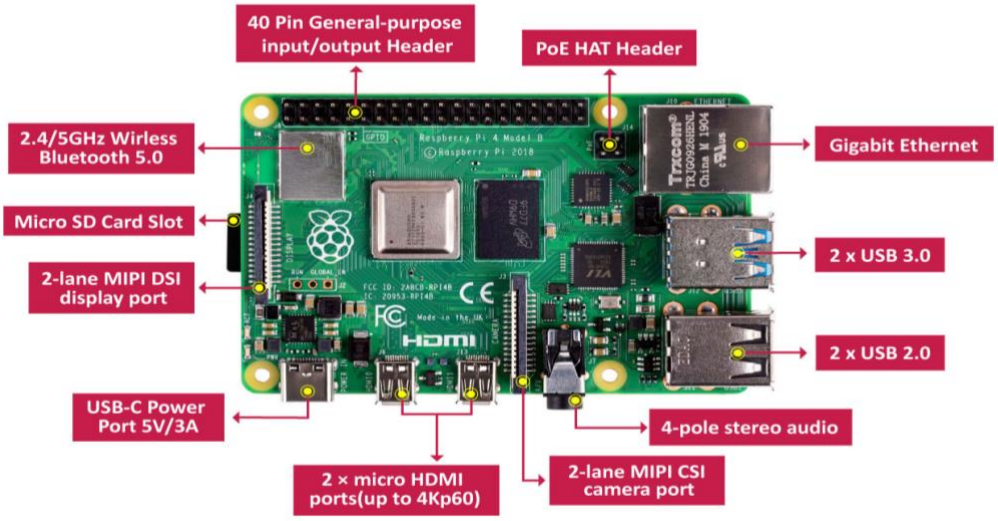


**Figure 3: Raspberry pi 4 board**

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There are two types of cameras that will be used to take high-definition videos (as shown in *Figure 4*). The first one is the raspberry pi cameras v2 with fixed focus lens and add-on board that comes with 8 megapixel and support 3280×2464 pixel static images and 1080p30,

720p60 video it can easily be plugged into the board, the second camera has the same feature regarding the number of pixels and the resolution of the video however Arducam V2 comes with the wide-angle IMX219 replacement that has 175°(D) wide-angle M12 lens, which provides a much wider field of view compared to the stock lens on the standard V2 camera module.


**Figure 4:Raspberry pi camera v2 and arducam raspberry pi camera v2 with lens**

To measure the body temperature, we will be using PureThermal 2 Lepton® 3.5 micro thermal camera. Figure 3 shows a hackable thermal USB webcam with a temperature range of up to +80˚C. It works with a standard webcam and video apps on all major platforms and for developers, its firmware, software, and hardware schematic are all open source and it can be modified.

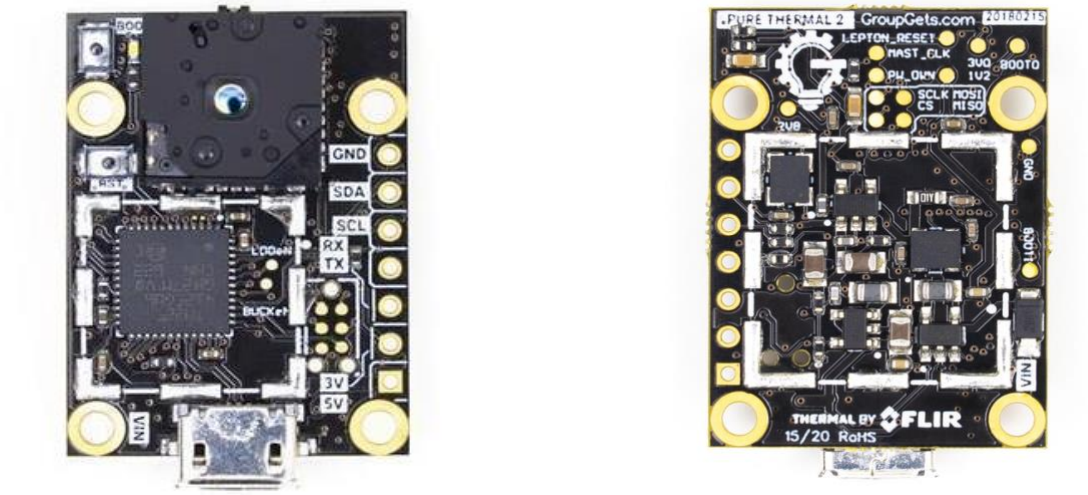


**Figure 5:PureThermal 2 Lepton® 3.5**

## 2.3 Related Work

Due to the recent events regarding the coronavirus pandemic, a lot of intention has been drawn to social distancing and crowd management focusing strongly on the technologies of computer vision and in that regards many companies began to invest and develop their own social distancing systems and because of that there are many products in that regard we will take some of them and discuss their systems and how they operate. In the following, we are going to show briefly the most related work to our project from the industry domain (Xovix [7], AxxonSoft [8], and LeewayHertz [9]).

### 2.3.1 Social Distancing Solutions with Xovis 3D Sensors

Xovis is an international market leader in intelligent people flow solutions they usually work at airports, in retail, transportation, and building management [7]. What Xovis is known for is the 3D Sensors technology which is a ceiling-mounted sensor similar to the human eye that captures the scene below using stereo vision as shown in (Figure 6 and Figure 7) below:

**Figure 6: Xovis® 3d sensor**

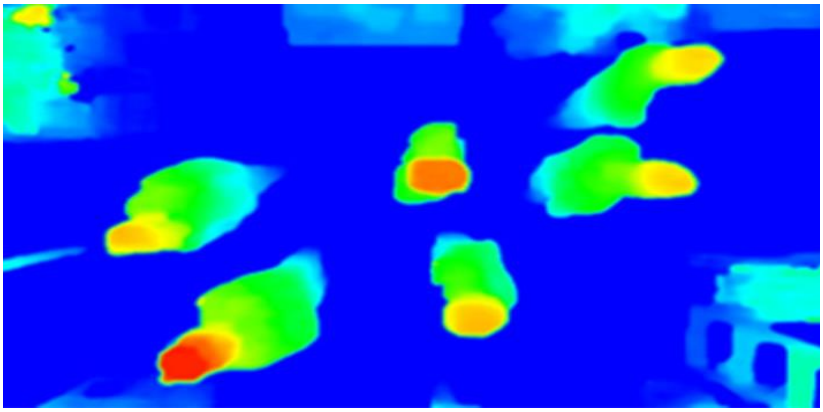

**Figure 7:Sensor view of the xovis 3d person tracking and counting system**

This 3D sensor has two wide-angle lenses that are combined and powered with artificial intelligence features such as facial recognition, tracking, and counting objects. So, by using the 3D sensor Xovis was able to create a physical distancing system that can perform the following face mask detection, monitor distance, occupancy management, and a dashboard that analyzes the data taken from the sensors. Although all of that was great and Xovis built a strong physical distancing system; Xovis has some limitations:

1. the vision of the 3D sensor is static which means that it does not cover much ground thus leaving some blind spots that the system is unaware of.
2. The whole system relies only on the Xovis 3D sensor and if anything happened whether it was technical or physical to the sensor the system cannot function well making it one point of failure.
3. Finally, the system does not record any safety policies volition in the environment.

### 2.3.2 Social Distancing Solutions with AxxonSoft

AxxonSoft is a leading developer of Video Management and Physical Security Information Management software that specialized in video surveillance and security solutions. They provide a solution called "#STOPCOVID19" which is the part that is related to our project [8]. The" #STOPCOVID19" is a collection of tasks that aim to minimize the spread of viral infections. AxxonSoft's social distancing solution consists mainly of five sub-systems:

I. Social distancing violation detection.
II. Face mask detection.
III. Fever screening camera integration.
IV. Access restriction for employees with fever.
V. Real-time occupancy monitoring.

The main limitations we found in AxxonSoft are as follow:

1. AxxonSoft solution is not mobile, the cameras cannot cover all the area since they are installed in only one place which leaves room for blind spots that the five systems combined are unaware of.

2. Also, usability issues, each system has its own web portal, interface, design, and functionality separately while it would have been much better to build one system that gathers all of the other systems under one roof giving the system one uniform identity rather than five of them. Making it easier for the staff to learn how to operate one system instead of five systems.

### 2.3.3 Social Distancing Solutions with LeewayHertz

LeewayHertz is a software development company that 100+ digital products for small-medium companies and enterprises. They have products in all fields such as machine learning, internet of things, computer vision, etc. Also, they have provided their own solutions regarding the social distancing problem which is a total of 10 solutions. we will talk only about 2 of them the "**Face Mask Detection System using Artificial Intelligence**" and "**Social Distancing Alert System Using Artificial Intelligence**". The Face Mask Detection System uses existing Internet Protocol cameras or IP cameras and Closed-circuit television cameras also known as CCTV cameras powered with computer vision and artificial neural networks to detect whether a person is wearing a mask or not. The Social Distancing Alert System is an AI platform that also uses existing cameras combined with computer vision to detect if people are at safe distance and adhere to social distancing or not. The system finds the gap between two people that are detected in the camera and if the distance or gap between them is for instants less than 1 feet then the platform will generate an alarm and notify the staff about the violation.

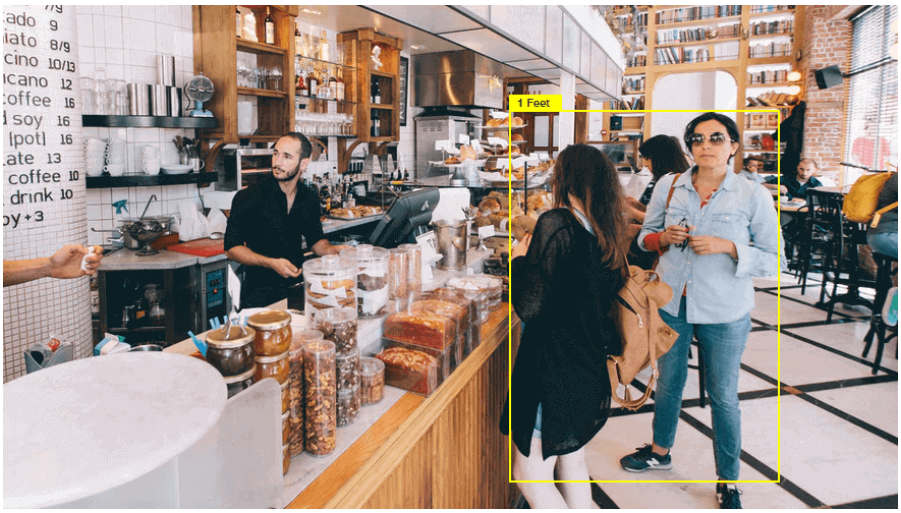


**Figure 8: Example of the detection of the gap**

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The great thing about these systems is that there is no extra hardware cost since it uses the same camera that costumer have. all it does is add the camera to their platform and allow the customer to access the platform.

We found the following downsides and limitations to LeewayHertz solutions:

1. Using an existing camera might sound great but, if the camera is not installed in a place where it has a wide view of the environment it will leave blind spots. As well if the existing camera has some technical or physical issues the systems do not cover that part since they don't install it or maintain the cameras.
2. Like the previous solutions, the systems are nonmobile, they all depend on a fixed position camera making the system more exposed to blind spots and gaps that the social distancing is unaware of which decrees the efficiency of the solution.
3. Providing 10 separate solutions is overwhelming since most of these solutions can be integrated and combined into one system giving them a uniform identity. By doing so, the process of operating the system would be easier and less complex since the user only interacts with one system that has ten features rather than ten systems that have only one feature each.

**Table 2: Social distancing solutions comparison table**

| Solutions | Xovix [7] | AxxonSoft [8] | LeewayHertz [10] |
|---|---|---|---|
| Data collection | ✓ | ✓ | ✓ |
| Violation | ✗ | ✓ | ✓ |
| Voice alert | ✗ | ✗ | ✓ |
| Extra hardware | ✓ | ✓ | ✗ |
| Dashboard | ✓ | ✓ | ✓ |
| Mask detection | ✓ | ✓ | ✓ |
| Sensors | ✓ | ✗ | ✗ |
| Mobility | ✗ | ✗ | ✗ |
| Integration | ✗ | ✗ | ✗ |

**Table *2*** shows the results of our comparison between three companies, ✓ where means satisfied the solution criteria and ✗ means not covered by the tool provided.

In contrast to the aforementioned solutions in the industry domain, we expand our research to cover some related work in published in peer reviewed conferences, journals, etc.

Lin et. al. [11] proposed a system that measures human body temperature by applying deep-learning-based face detection, object tracking, and calibrated conversion equation, to extract a subject's forehead temperature in real-time using infrared (IR) techniques that do not require any contact with skin.

First, they do face detection using Single-Shot-Detector (SSD) algorithm by train a new model based on deep-learning method after that determine the location of the face in each frame using face tracking algorithm, the next step is to locate the position of the region of interest in the face which is the forehead, the 14-bit pixel value from FLIR Lepton 2.5 is stabilized and normalized than updating using Keysight U5855A thermal imaging camera, (Figure 9) these methods are constructed on the NVIDIA Jetson TX2 and written with C++ language and OpenCV library.

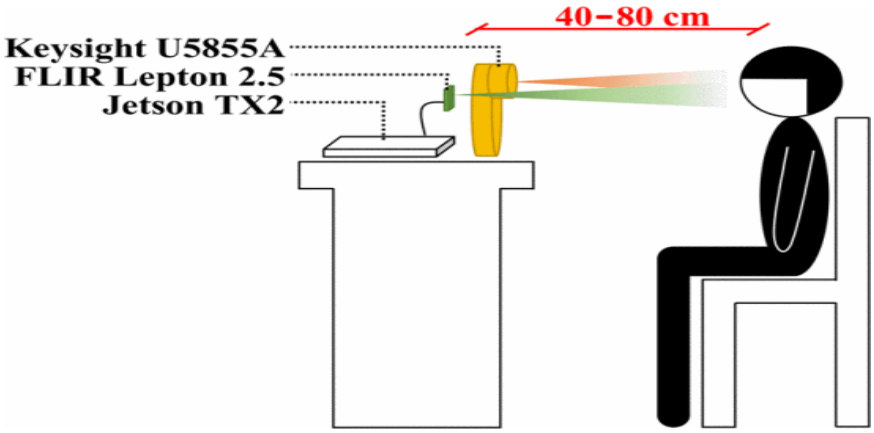


***FIGURE 9:ILLUSTRATION OF THE STUDY SETUP.***

We found the following limitation in this proposed solution:

1- The body of the person has to be in a stable position, and any movement can affect the result.
2- The distance between the thermal camera and the body has a limited range it is only within 40cm-80cm.
3- What is worth to mention that the most accurate skin measurement is in the inner canthus of the eye, but they used the forehead instead.

Yang et. al. [12] proposes an AI and an alert real-time social distancing system detection that monitor the social distancing in overcrowding spaces using a pre-trained deep convolutional neural network (CNN) to detect people with bounding boxes in a given camera frame. considering four ethical factors:

1. The system should never record the data using any way.
2. The alert should not target anyone in the environment.

3. It should be no supervisor over the system detection or warning.
4. The code should be open source and can be accessed by anyone.

The system starts mentoring in a real-time manner and If a violation is detected, a non-intrusive audio alert is emitted without targeting the person himself. And if the density in the environment is over a threshold, the system sends a signal an entrance control to help modulate the inflow into the region of interest (ROI) As shown in Figure *10*.

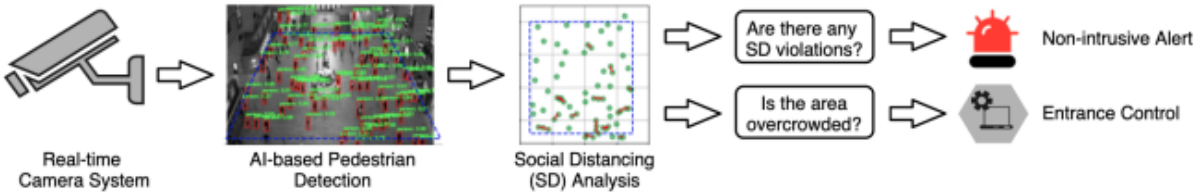


**Figure 10: Overview of the proposed system.**

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We found the following limitation in this proposed solution:

1. The system is only used in open spaces and high-density environments and it is not applicable inside indoor and small environments such as building rooms and small shops.
2. The ethical factors that they made limits the system capabilities hance, making the system more challenging to implement.

Fedele et. al [13] proposed a system and the goal was to provide a monitoring and emergency solution using Internet of Things (IoT)-based Wireless Sensor Networks that can recognize exits, assembly points, safest and shortest paths, and overcrowding from real-time data gathered by sensors and cameras, for the crowd monitoring they use an algorithm to detect and track objects and count the number of the objects (people) in the area, and for the emergency, the data collected (air temperature, humidity, and flame) from the sensors are used to estimate environmental conditions than depends on the cases an alarm is triggered and a management plan is formulated.
We found the following limitation in this proposed solution:

1- Sensor nodes and cameras are powered by solar panels which has some disadvantages like cost and weather dependency.
2- The system works outdoor only in places like public parks or university campuses.

Oransirikul et. al.[14] propose a social distancing warning system is in the sense of the distance between people who use Wi-Fi signals of smart mobile devices. When the number of people in the space increases and it becomes more difficult to implement social distancing, device owners are alerted by the system to keep their distance from other people.
The implementation of this technology requires the availability of smart mobile devices for everyone and the activation of Wi-Fi in their devices.

Jagan et. al. [15] automatically detect humans in a crowded area and when they violate social distancing constraint an alert message is shown to encourage them to follow the rules, by using a mobile robot with an RGB-D camera, a 2-D lidar to perform collision-free navigation and thermal camera to detect high fever, also the robot is combined with CCTV cameras (if available) to cover a larger area and enhanced the performance of the system. The system uses DLR state-of-the-art algorithm for collision avoidance and Yolov3 deep learning detecting and tracking scheme to identify humans, also they present a novel real-time method to estimate distances between people.
We found the following limitation in this proposed solution:

1- They do not collect, use, or benefit, from the data hence there is no analysis and statistical data that could be useful in the future.
2- The only action done by the system is displaying an alert message to encourage pedestrians to follow the rules.
3- The CCTV cameras are not the main part of the system it is only an optional addition.

Ksentini et. al.[16] proposed a social distancing detection service by combining the Internet of Things and multi-access edge computing (MEC) technologies. This service can be used with the current Corona pandemic and other pandemics by monitoring distances between people and ensuring that they apply social distancing regulations. This service is provided through a smartphone application that alerts the owners of these devices when a social distancing violation occurs. GPS details send from the application to MEC periodically. Then checks these coordinates and detects and warns violators.
This service uses an algorithm consisting of three steps, (as shown in *Figure 11*):
1- Collection GPS coordinates of users connected to the server.
2-The computation of the distance between users.

3-Detection of users violations and warn them.

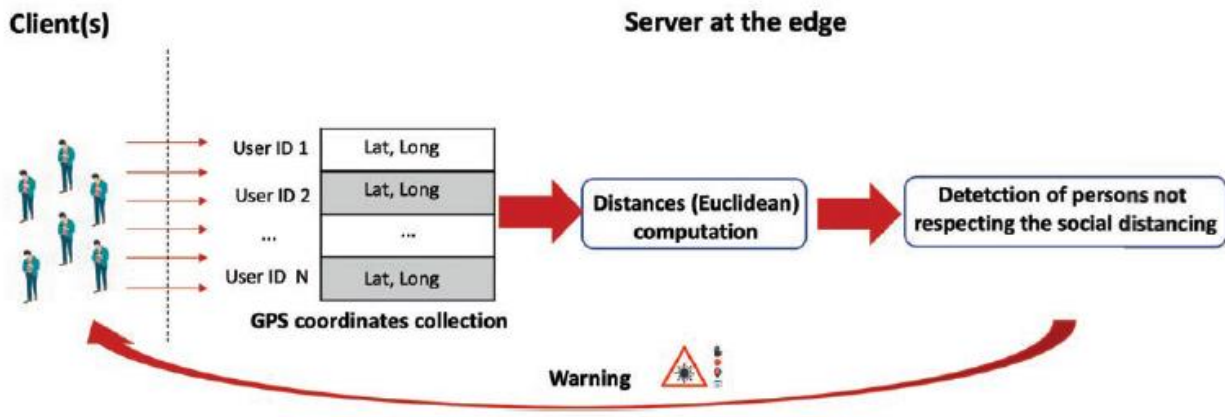


**Figure 11: The concept of the social distancing detection service.**

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This service requires everyone to own a smart mobile device, install the application on each device, and register in it.

## 2.4 Conclusions

In this chapter, we talked in detail about the scientific background of our project as well as the technologies and tools used in it such as the thermal camera, the drone, the Raspberry Pi board, the Raspberry Pi cameras, and the sensors. We also showed some of the technologies that were developed in line with the spread of coronavirus pandemic that helped implement the social distancing system in real life such as Xovis 3D [7] Sensors, AxxonSoft [8], and LeewayHertz [9], and then clarified the differences between them as shown in Table 2. Then we reviewed some scientific papers and articles that discussed related technologies used in our project which combine them into one system. In future work, we are going to start gathering and analyzing the requirements. Then, designing and modeling the system, then implementing, coding, and testing the whole system. In the end, continue the process of development, improvement, and maintenance of the system.

# Chapter Three: System Analysis

## 3.1 Introduction

This chapter aims to provide the analysis process of the project and describe the customer requirements that reflect how we are going to establish the software design of the system to meet those requirements and validate them after we finish building the system. Previously in the literature review chapter, we covered the theoretical background related work to our system and how computer vision an important branch of AI and is related to our project. Also, the set of the hardware we are going to use to implement the system's main functionalities.

The system analysis approach that we are going to use is the **object-oriented approach** since we are building a system that is composed of several small modules that can be combined together for data and processes. Also, these modules are used to fill the gap between problem and solution. By following the object-oriented approach, we believe the system can perform very well under continuous design, adaption, and maintenance.

In this chapter, we have **software requirements specification** (SRS) where we will cover the functional, non-functional requirements, and use cases. Also, a set of three subsections will be included: **user characteristics, specific requirements, system requirements.** Then, **the project management plan** is a Gantt chart showing our project plan. Finally, a **conclusion** which summarizes this whole chapter we are given.

### 3.1.1 Constraints:

This subsection provides some constraints that might limit the system performance.

- Poor connection between the devices and the web-application causes latency issues.
- The devices work in the separate area thus they need a battery as power sources to keep them running.
- Storage capacity could be an issue since the system store high-quality images.
- False data, in general, that may produce by a malfunction in software and hardware or small distracting and changing in the environment or scenario.

- The fly-time diverse from one drone to another, in our project the drone can fly from 20-30 minutes which is good but not enough to be functioning all the time.
- This system enforces many rules and tries to encourage and remind people to obey them and not to put others in danger, so in the end, it depends on human behaviors.

## 3.2 Software Requirements Specification

In our project, we have a total number of (9) functional requirements that describe the main functionality of the system and (10) non-functional requirements that describe the property of the system.

For the functional requirements:

- Temperature detection
- Face mask detection
- Gap detection
- Occupancy mentoring
- Occupancy counter display
- Sound alert
- Analysis of Data
- Data visualization
- Search engine

Non-functional requirements:

- Admin Authentication
- Asynchronous
- Accuracy
- Privacy of data
- Big storage
- Networking
- Backup (Recovery)
- User-friendly interface
- Portability
- Cloud deployment

Regarding the user interaction with the system mainly we have three users that can interact with the system (see Figure 12 and Figure 13) starting with the administrator who is responsible for mentoring the system. Then, we have the maintainers who is responsible for updating and maintain the system. Lastly, we have the public people and those are the people in the environment whose system applies to.

The public people don't interact directly with the system while the administrator and maintainers interact directly with it. The procedure of the interaction is as follow, the administrator mentors the system and check for any alerts in the environment then if any violation caused by the public people, the administrator gets an alert and a screenshot of the violation after that, he can take an action depending on the violation. The maintainers just consistently work on updating and fixing the system while also install or uninstall the system components such as the cameras, occupancy display, etc. As shown in the use case diagrams below.

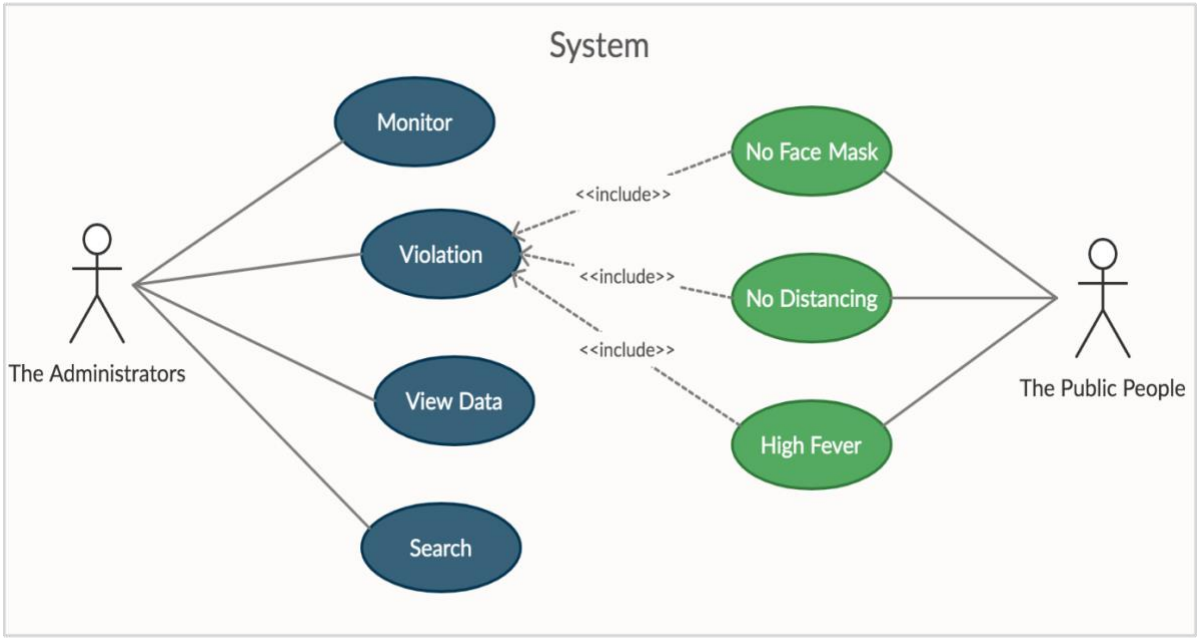


**Figure 12: Use case diagram shows admin and public interactions with the system**

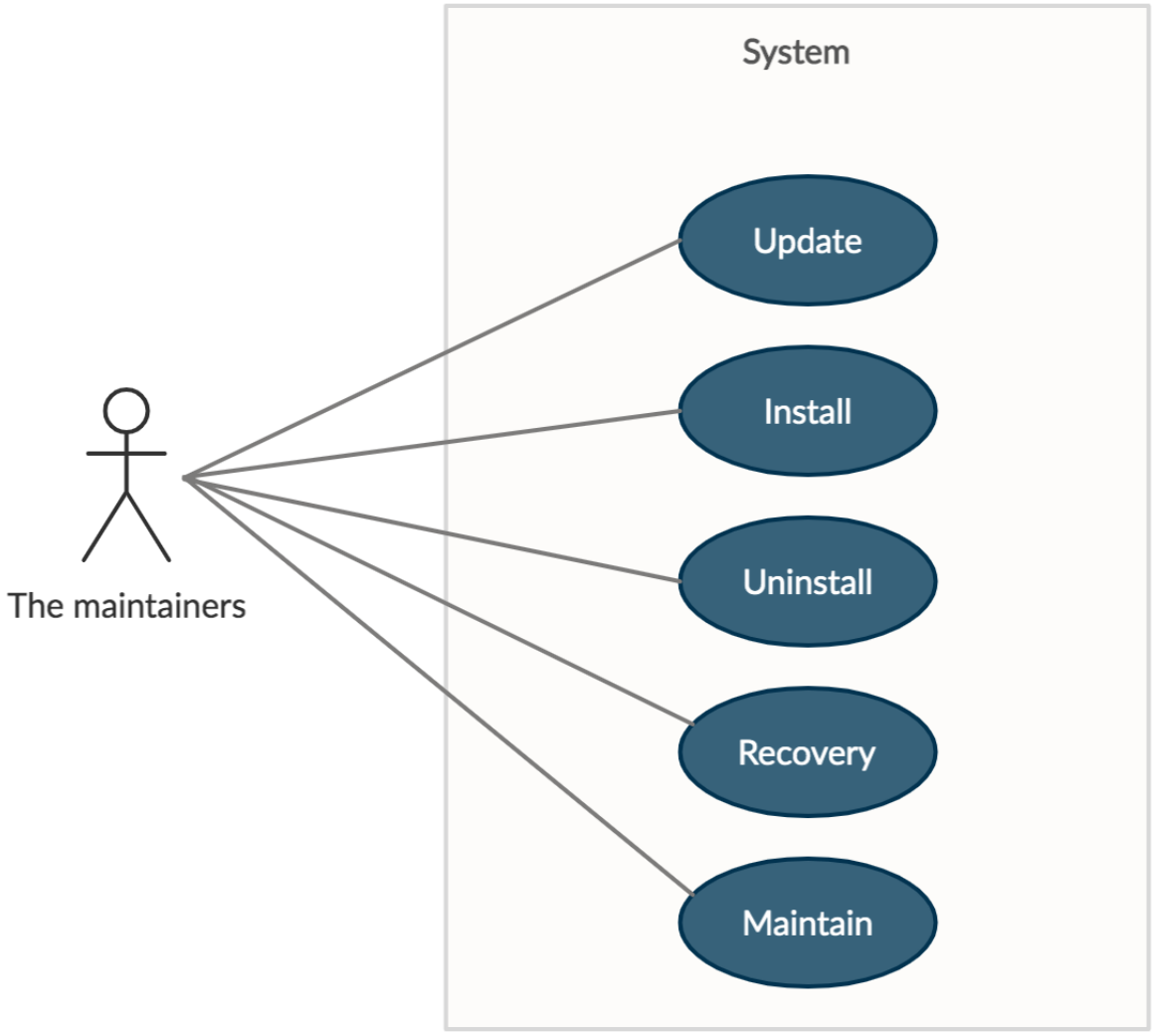


**Figure 13: Use case diagram shows staff actor interaction with the specific use cases of the system**

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In what follows, we will cover the following aspects of the system analysis: **user characteristics by** giving a general description about the users of our system. Then, **specific requirements** where we are going to describe the functionalities of the system in more detail. After that, **user requirements which** are describing the system functional and non- functional requirements. Finally, **system requirements** elaborating the user requirements in a more precise and detailed way.

### 3.2.1 User Characteristics

The Social Distancing System can be used in indoor environments such as hospitals, airports, workspaces, universities, schools, etc. We can divide the users into three categories: **The administrators**, **the maintainers,** and **the public people**.

The administrator is someone whose responsibility is to monitor and respond to the violations in the environment. He has a high privilege over the system since he can monitor the environment through the cameras, views the data and export it, and start/turn off the system. Also, he can take the appropriate action when a volition occurs for an instant if someone with no mask has entered the environment, the admin will get an alert, and then he can ask that person to either leave or wear a mask. The admin should some educational level since he will be the one who operates the system also, he should have some experience and technical skills regarding computers and web application because all of the interactions with the system is from the web.

The public people are the people in the environment, and these are the people that the system is watching and monitoring. They do not have any direct interaction with the system hence, they do not have any required experience, technical nor educational level.

The maintainers are a high experience crew that their responsibility keeps the system working in its best performance by updating it, fixing the bugs, and doing checkups to make sure that the system is operating perfectly and optimally. Also, they are the ones who install or uninstall the system in the desired environment. They must have a high educational level and technical skills since they keep the web application updated and fix any problems that may encounter the admin of that system. They simply make the admin experience better as he is the one who directly interacts with the system.

## 3.2.2 Specific Requirements

This section describes the functionalities of the system in terms of users and system requirements.

### 3.2.2.1 User Requirements

It is the requirements obtained by observing the protocols established by the world health organization and major countries to limit the spread of the pandemic, it also shows **what** the system will do and **how** it will do it as shown in Figure *14*.

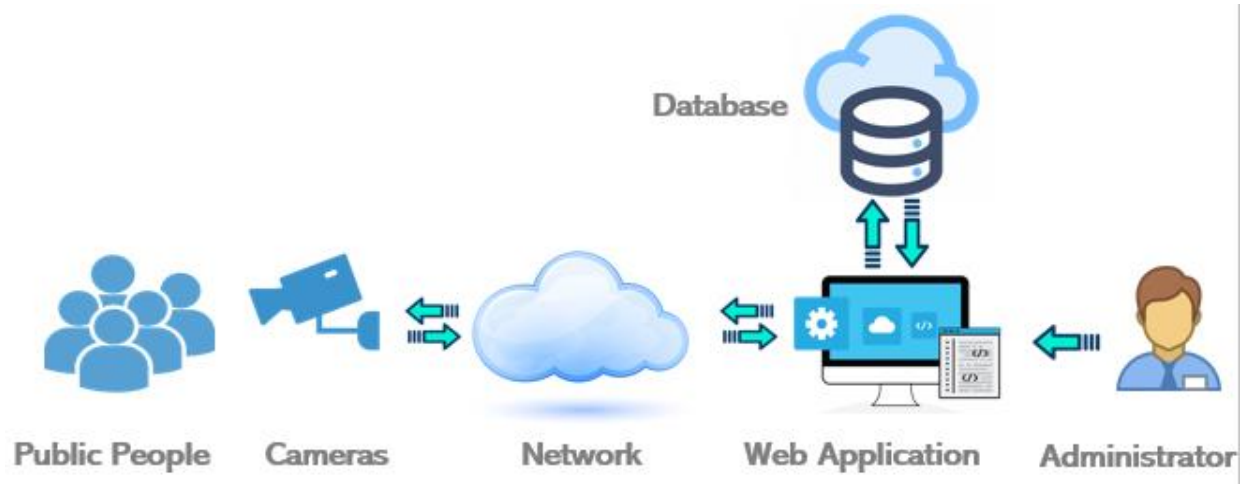


**Figure 14: Monitoring system diagram**

The main functional requirements in this context as follow:

**Automatic temperature Detection:** the SDS shall automatically determines if there are abnormal temperatures.

**Automatic Face Mask Detection:** the SDS shall determines whether a person is wearing a mask or not, and in the case that a person is not wearing it, the camera takes a snapshot of that person's face and sends it to the system to detect the violation.

**Distance Between People:** the SDS determines the distance between each two people, which must not be less than two meters, otherwise the camera takes a snapshot of them and sends it to the system to detect the violation.

**Occupancy Monitoring:** the SDS monitors the number of visitors when anyone enters the counter increases, and when anyone leaves, it decreases. When the maximum is reached, an alert is sent to the system.

**Sound Alert:** the SDS has a warning sound triggered when a violation occurs.

**Occupancy Counter Display:** the SDS has a screen at the entrance that shows the current number of visitors inside the building at this moment.

**Search Engine:** the SDS can search the data stored in the system.

**Data Analysis:** the SDS analyzes the data stored in the system to produce useful information.

**Data Visualization:** the SDS can displays the data in charts and graphs.

## 3.2.2.2 System Requirement

### Functional Requirements

This section will cover the requirements in more detail and explain the inputs and outputs and how the process is done for each requirement.

#### 3.2.2.2.1 < Temperature Detection>

**Introduction:** Detect and measure the body temperature of the person using a thermal camera.

**Input:** Stream of frames

**Processing:** The first step is narrowing the perimeter of measurement by applying a face detection algorithm using a stream of frames and focusing only on the face to ignore the other temperature sources, furthermore we narrow the perimeter again and focusing only on the eyes then determine the exact location of the inner canthus of the eyes which is the point that will be measured using thermal camera images algorithm.

**Output:** body tempter in Celsius, the image of the person in case of high temperature

### 3.2.2.2.2 <Face Mask Detection>

**Introduction:** Detect and classify the person from the live stream.

**Input: a** stream of frames.

**Processing:** The first step is to train a model using a Convolutional neural network using a large set of positive and negative examples, after that we need to find the location of the face from the stream of frames, and using the trained model that decide wither a person is wearing a mask or not.

**Output:** Image of the person who is not wearing any mask.

### 3.2.2.2.3< Distance Between People>

**Introduction:** With the rule that states the minimum distance between people is 2-meter this function detects the violation of this rule.

**Input:** a stream of frames.

**Processing:** The first step is to detect the human body using a deep learning pose estimation model that shows 15 different points, then calculate the distance between two or more human-based on the difference between the points and check if they in the safe range or not.

**Output:** Image of the people who violate the social distancing.

### 3.2.2.2.4 <Occupancy Monitoring >

**Introduction:** This function counts the number of people entering and exiting the place.

**Input: a** stream of frames.

**Processing:** The first step is to initialize a counter and mark each moving person by processing the stream of frames then track the person until he/she crosse the imaginary line which will be created at the edge of the door and based on the direction of the person the counter increase and decrease.

**Output:** Counter and state message.

### 3.2.2.2.5 <Sound Alert>

**Introduction:** This function is triggered when a violation has occurred.

**Input:** None

**Processing:** when the function is called, it means that a violation occurs thus a specific sound is going to play for 5 seconds on the area where the violation is occurred and notifying the admin.

**Output:** Sound.

### 3.2.2.2.6 <Occupancy Counter Display >

**Introduction:** This function keeps the people update on the state of the place.

**Input:** the output of the occupancy function

**Processing:** To know whether a place is crowded or not a screen with some information will help, to do that first connect the main system to the screen, then from the output of the **occupancy** function display the content which is the number of people and the state.

**Output:** state of the place.

### 3.2.2.2.7 <Search Engine>

**Introduction:** This function provides a search through the database.

**Input:** Query

**Processing:** Connect to the database which holds the violations data and apply the query based on time and date which will give easy and fast access to data.

**Output:** Information.

### 3.2.2.2.8 <Data Analysis>

**Introduction:** Based on the collected data, statistical methodologies are applied.

**Input:** Data

**Processing:** The data will be structured, filter, and classified using a variety of statistical functions within python panda library to give the random data more meaning, it will show the number, type, date, comparison, etc.

**Output:** Information

### 3.2.2.2.9 <Data Visualization>

**Introduction:** This function provides a graphical representation of information and data.

**Input:** structured data

**Processing:** By obtaining the information from the **data analysis** function and using python Plotly library that can represent the data in different formats like charts, tables, and graphs which improve readability.

**Output:** charts

## Non-Functional Requirements

For the system to provide its full potential some services and constraints must be achieved such as the following:

- **Admin authentication** using the log-In system and 2FA (two-factor authentication) to ensure that no one can access and modify the data except authorized people.
- Running the whole functions in **multiprocessing mode** which enables two or more functions to run at the same time to give the system more productive.
- **Accuracy** is the big part of the system since measuring and classifying live stream can cause false and incomplete data which causes mistakes, so we need to filter the data and keep only high-quality measurements.

- **Security and privacy of data** are critical since it contains images and information of the violated people, so we secure the data be applying encryption methods and limit the access to only authorized people.
- While the system is running for a long time it will keep gathering a huge amount of data, so we need a huge **SQL storage** that provides a flexible way to store and retrieve data.
- **Networking** is playing a big part in this system since it consists of multiple and separate hardware that sends data and communicates using wi-fi to a single dashboard.
- Provide **backup** copies to recover from unplanned events and crashes, the backup could be on a physical disk or the cloud.
- The system **interface** should be friendly and easy to use, which allows the admin to navigate through the system with no difficulties.
- The system should be **compatible** and work on multiple browsers.
- Deployment on **cloud or server** to have a portable system that can be accessed from anywhere.

## 3.3 Project Management Plan

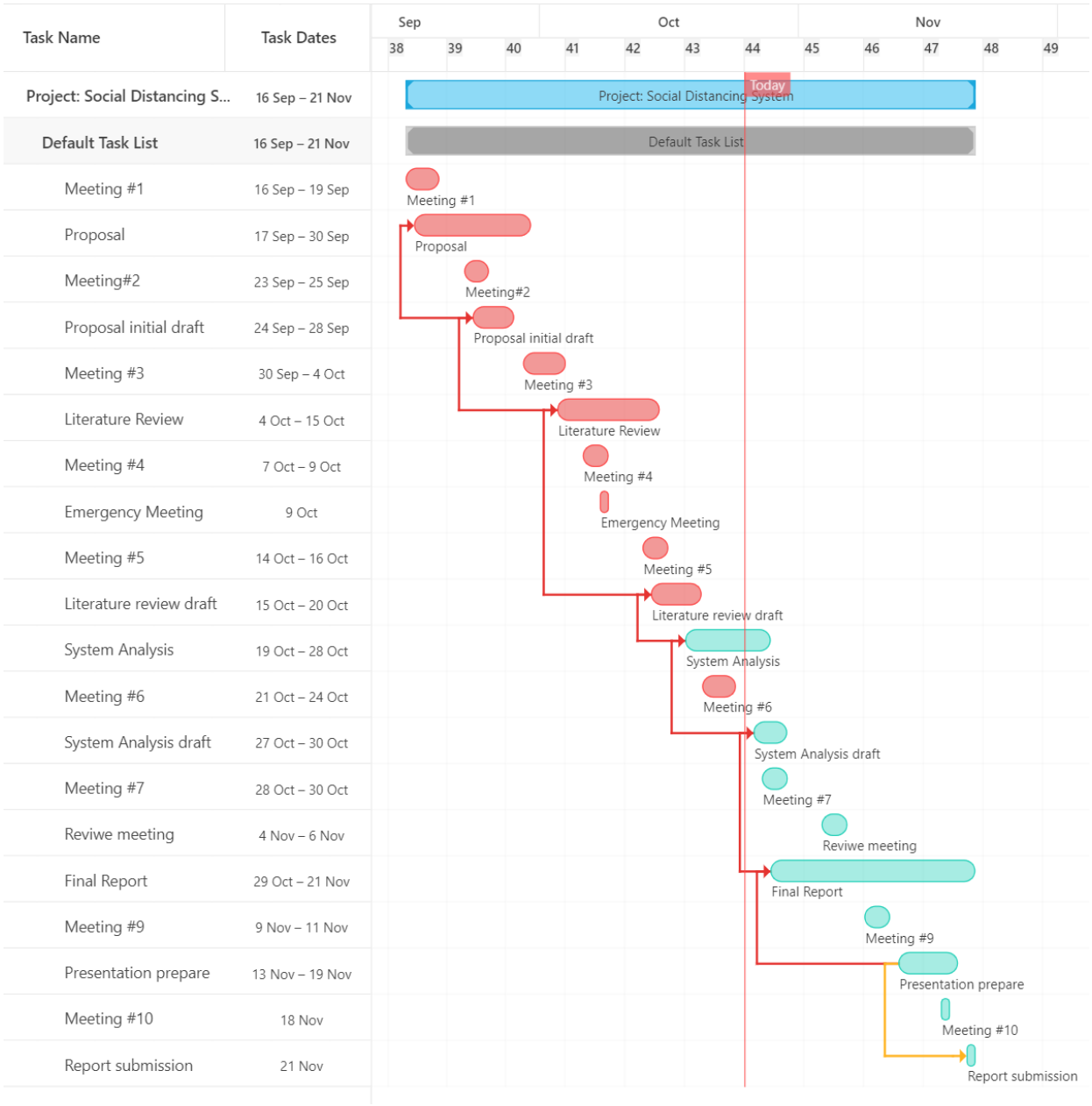


***Figure 15: Project Management Plan***

## 3.4 Conclusions

In this chapter, we explained the most important characteristics of SDS's stakeholders. Then we talked about the constraints of our project. Then we explained the properties and requirements of our project to general users and experts, as we explained the way the system works using use case diagrams as shown in Figure 12, Figure 13, and Figure 14. We also explained in detail what the system will provide in functional requirements sections and how it should work in non- functional requirements sections. In future work, we are going to start designing, implementing, coding, and testing the whole system. In the end, continue the process of development, improvement, and maintenance of the system periodically.

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