Bilkent University

Department of Computer Engineering

Senior Design Project

Third Eye

Analysis Report

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Analysis Report

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1. Introduction

A year ago, most of us did not know about a term which we are using in everyday life nowadays: social distancing. With the emergence of the COVID-19, all our lives had changed, and we had to adapt accordingly [1]. Although the virus itself affected the whole world immensely, both in an economic and in a social sense, the world keeps spinning and people keep on living with their lives [2]. With it comes the need for social distancing.

Social distancing, in its most basic form, is to refrain from getting close with other people in crowded spaces. Research about social distancing proved it to be useful in ceasing the spread of the virus to a crucial point. It is believed that 3-4 months of moderate social distancing can save up to 1.7 million lives and $8 trillion or $60,000 per US household [3]. Thus, it is of utmost importance to realize the role of social distancing in fighting COVID-19.

Although the benefits of social distancing are undoubtable, there are still many people that do not care about it and keep on violating spacing rules and advice in crowded spaces [4]. This brings the need for a regulation system for the crowds and that is where *Third Eye* steps in. With our project, we aim to put this problem on the table and come up with a viable solution that will minimize this issue.

However, *Third Eye* does not only aim to regulate social distancing but to provide useful data to the users as well. It will analyze the crowds and where the people's interest peaks. Then it will inform the users how the crowd moves, and which parts of the market are trending. For example, a shopping center overseer will be able to check out the data that *Third Eye* offers and see the trending sections of the mall.

In this report, we will provide the overall analysis for the system of our project, *Third Eye*. First, existing systems with their scopes, similarities and differences between them and *Third Eye* will be discussed. Afterwards, a brief description of the proposed system will be given. The requirements for the project will be listed, including functional, non-functional and pseudo requirements. Then the system model diagrams will be provided. Use cases of the system will be used to derive scenarios which will be discussed in detail considering the possible choices of users and real-life conditions. The proposed object and class model of the project will be given. Also, dynamic models of the system will be provided and explained in detail. User interface - navigational paths and mock-ups will be presented. Last, the report will be concluded with other analysis elements on the social dimensions of the project.

2. Current System

A similar product had been in the works in the past, but that was strictly for CCTVs and for social distancing usage only [5]. We are extending it to commercial areas and for commercial success as well. There is also AxxonSoft which is very similar to what we aim to do, but with the downside of not providing useful information and statistics to the user [6].

It is also known that human detection in surveillance is on the rise, thus resulting in a great number of libraries and sources for us to use and expand upon [7].

3. Proposed System

3.1 Overview

Third Eye is a smart surveillance tool that uses artificial intelligence, machine learning and computer vision to make use of the video footage from a surveillance camera. The tool is innovative in the sense that it will have extra features that other commercial products don't have. Such as enforcing social distancing between people by using the footage and giving warnings via sound speakers or flashing some LEDs when social distancing rules are broken. Other than that *Third Eye* will also do what many other smart surveillance systems can do. Such as providing data and statistics using surveillance footage.

Advanced Techniques such as machine learning and AI will constitute the backbone of *Third Eye*. The software will mostly revolve around these topics.

Third Eye will be working on a desktop and the software will need to be installed along with the camera. *Third Eye* will enable the user to enforce social distancing and gather data about their customer profiles.

3.2 Functional Requirements

The system should:

- Receive the camera feed accordingly to where it will be used.
- Adjust the "social distancing" distance according to the camera's height.
- Actively process the input feed and be ready to alarm the user if the calculated social distancing rules are violated.
- Compare the data if multiple connected camera feeds are given to the system.
- Analyze and store the data where the user will be able to see which parts of the mall/workspace is being populated most.
- Be able to work with possible external alarming systems (such as a megaphone in a mall).
- Should work on a Windows OS (Possibly Unix variants etc.).

Main users of this project will be shopping malls and other business locations that may need to track the social distance and collect data about the crowd.

The user can/should:

- see the distance between different human groups.
- collect data about the crowd in specific times.

3.3 Nonfunctional Requirements

Reliability

The system should:

- correctly identify people and the number of people in a crowd in order to generate correct outputs.
- work with a variety of different video formats.
- work with different color ranges [8].
- be able to differentiate the human body from the environment in different situations or places [8]. It shouldn't confuse other living and non-living beings with the human body.
- not collect and store the imagery without the knowledge of the crowd. If saving the data is the case, there should be warnings about the situation or consent from the crowd should be taken by the users.
- not confuse already formed groups (families, couples, etc.) with social distance violations.

Extensibility

The system should:

- be sustainable and maintainable, in other words, should be open to updates.
- have a flexible infrastructure so that after the Covid-19 pandemic, it could be used for different purposes other than social distancing.

Usability

The system should:

- be user-friendly. Users should be able to perform the actions easily.
- give clear outputs. The outputs should be self-explanatory. Users should not be confused with the results.
- work with different formats of video input or convert given formats into the desired one. This way the user is not bothered with that.

Accessibility

The system should:

- be manually installed to computers according to the needs of the customer.

Efficiency

The system should:

- work in real-time in order to identify the violations of social distancing in an area so that the authorized people can act on the situation immediately.
- analyze the data and return results in a short time frame so there will be minimal delay between the results and the real-time.
- use minimum resources. It shouldn't allocate too many resources.

3.4 Pseudo Requirements

Issue Tracking

- Github will be used for version control.
- Google spreadsheets will be used for issue tracking. Each member will be equally assigned their tasks through the spreadsheet. The contribution done by each member will be easily seen. Improvement of the project will be observed.

Testing

- Testing of the project will be done with the already recorded input which is in the dataset.
- Testing of the Third Eye's real time part will be done with cameras connected to the system by group members.

External Tools and Technologies

- Python will be used for the development of the software.
- NVIDIA's Jetson Nano Will will be used.
- Libraries and frameworks like OpenCV and Imutils will be used in computer vision processes.
- Cameras will be used for real time data streams.
- Already recorded video footage will be used for data inputs.

3.5 System Models

3.5.1 Scenarios

Scenario 1

Use case name:	Check Social Distancing Measures
Participating actor/s:	User
Entry condition/s:	User should be in the main menu.
Exit condition/s:	User clicks *Back* or *Exit* button.
Flow of events:	User: 1. clicks the *Social Distancing Measures* button. 2. reviews the social distancing on the provided live camera feed. 3. sees the customers on the left hand side of the screen with their relative numerical identifications (as objects). 4. sees any regulation infringements on the right-hand side of the screen. 5. clicks the *Back* or *Exit* button.

Scenario 2

Use case name:	Check Commercial Statistics on Live Feed
Participating actor/s:	User
Entry condition/s:	User should be in the main menu
Exit condition/s:	User clicks *Back* or *Exit* button.
Flow of events:	User: 1. clicks the *Commercial Statistics* button. 2. chooses the *Live Feed* option. 3. reviews the given statistical data at the sides of the screen. 4. presses *Additional Information* button to get further information about the customer base. 5. clicks the *Back* or *Exit* button.

Scenario 3

Use case name:	Check Commercial Statistics on Recorded Feed
Participating actor/s:	User
Entry condition/s:	User should be in the main menu.
Exit condition/s:	User clicks *Back* or *Exit* button.
Flow of events:	User: 1. clicks the *Commercial Statistics* button. 2. chooses the *Recorded Feed* option. 3. reviews the given statistical data at the sides of the screen. 4. presses *Additional Information* button to get further information about the customer base. 5. clicks the *Back* or *Exit* button.

Scenario 4

Use case name:	Check Crowd Analytics
Participating actor/s:	User
Entry condition/s:	User should be in the main menu.
Exit condition/s:	User clicks *Back* or *Exit* button.
Flow of events:	User: 1. clicks the *Commercial Statistics* button. 2. chooses the *Crowd Map Statistics* option. 3. reviews the given statistical data at the center and the sides of the screen. 4. clicks the *Back* or *Exit* button.

Scenario 5

Use case name:	Check Further Information About the Project
Participating actor/s:	User
Entry condition/s:	User should be in the main menu.
Exit condition/s:	User clicks *Back* or *Exit* button.
Flow of events:	User:

User:
1. clicks the *Credits* button.
2. chooses the *About Third Eye* option.
3. reviews information and goes back to the *Credits* screen.
4. chooses the *Team* option.
5. sees the information about the team and goes back to the *Credits* screen.
6. chooses the *Contact* option.
7. establishes contact with the team if needed.
8. clicks the *Back* or *Exit* button.
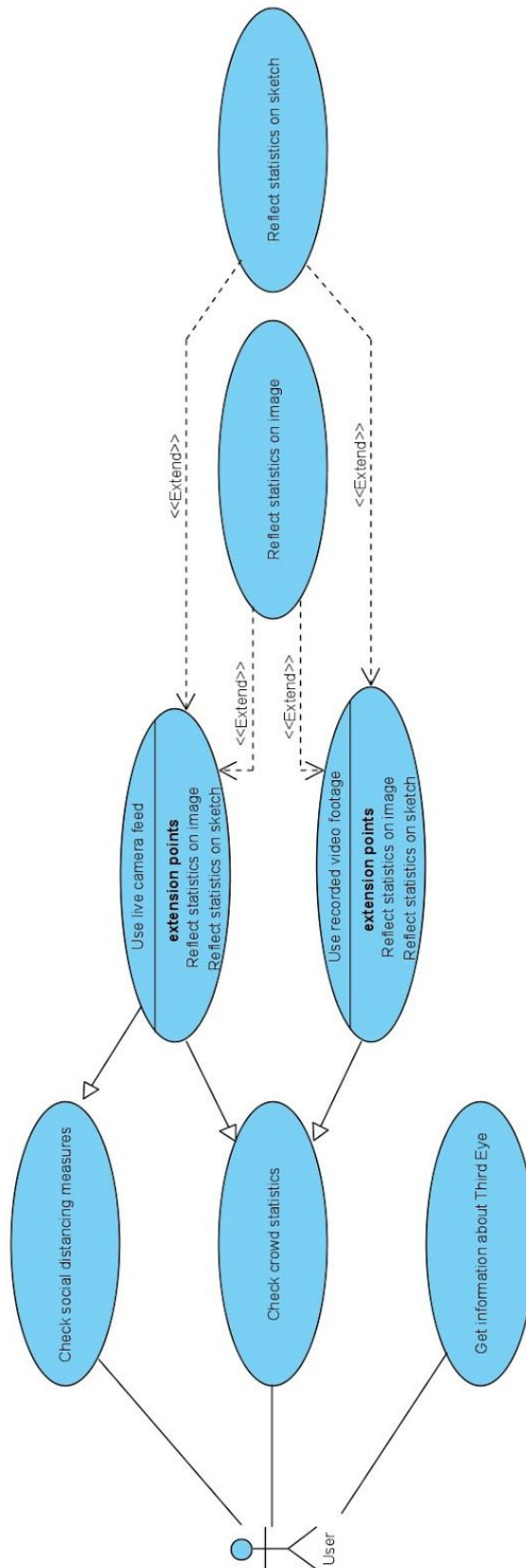
3.5.2 Use Case Model

Figure 1: Use-Case Model
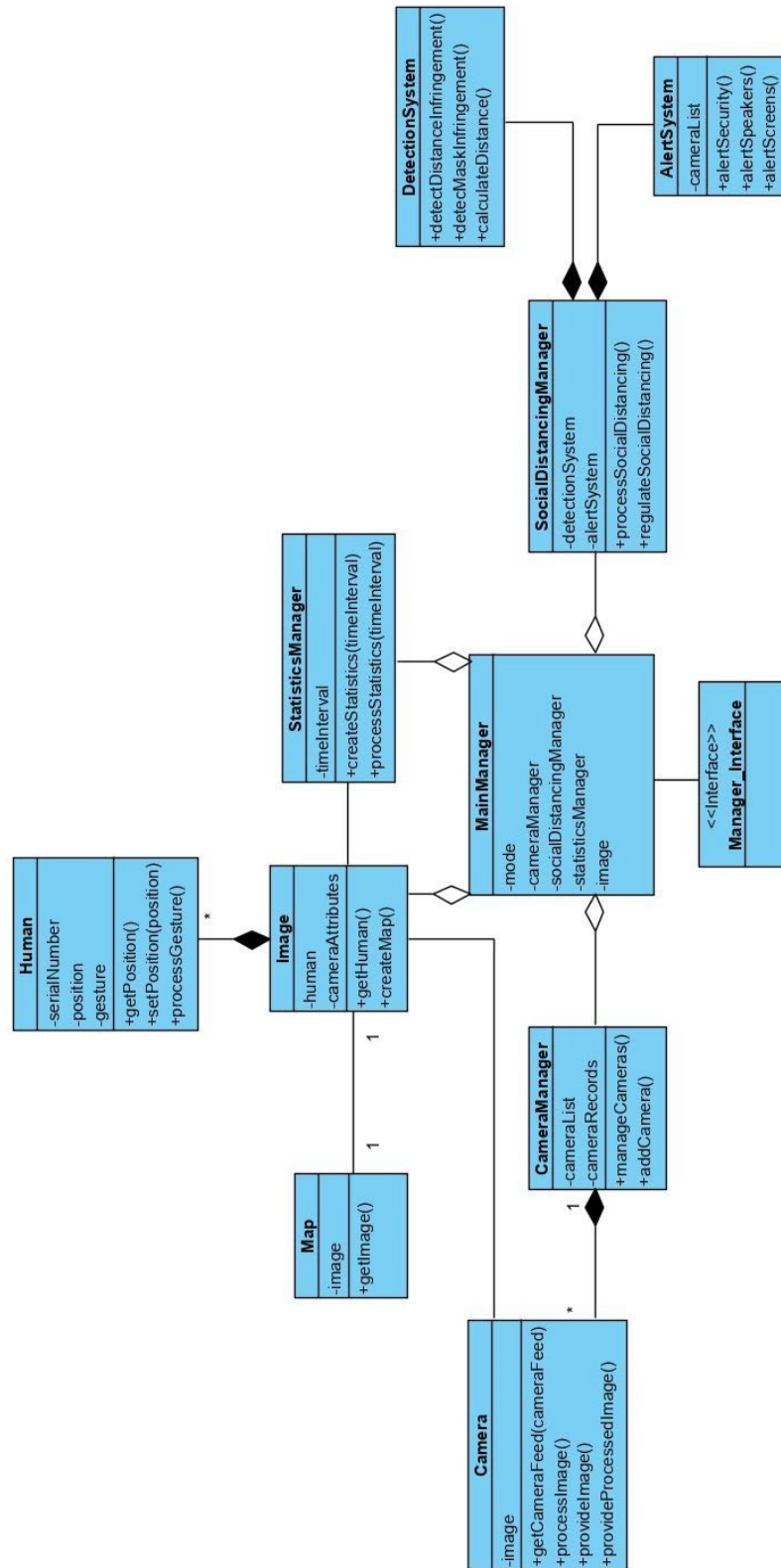
3.5.3 Object and Class Model

Figure 2: Object Class Diagram

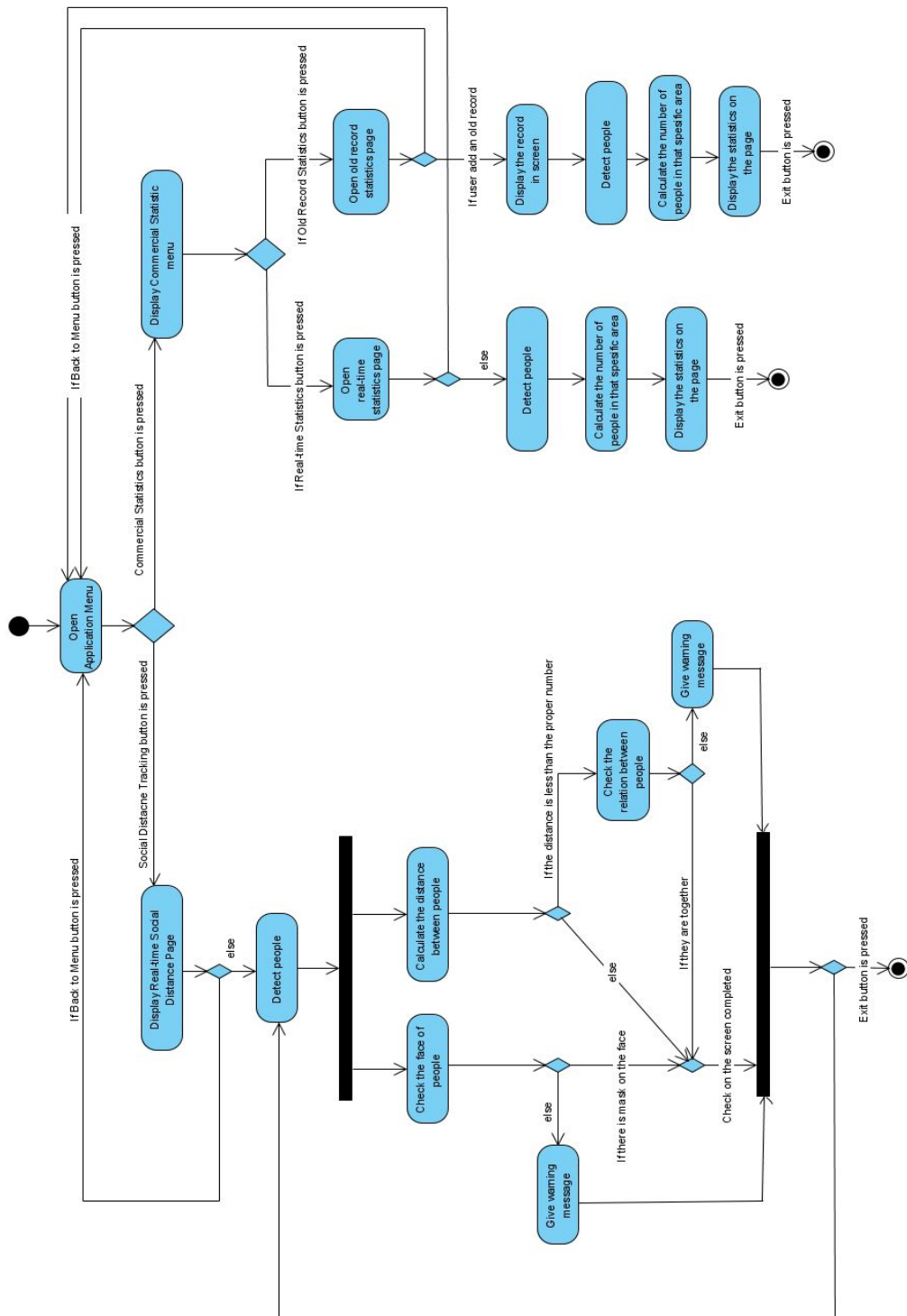## 3.5.4 Dynamic Models

Activity Diagram

Figure 3: Activity Flow Diagram

Sequence Diagrams

Enforce Social Distancing Sequence Diagram

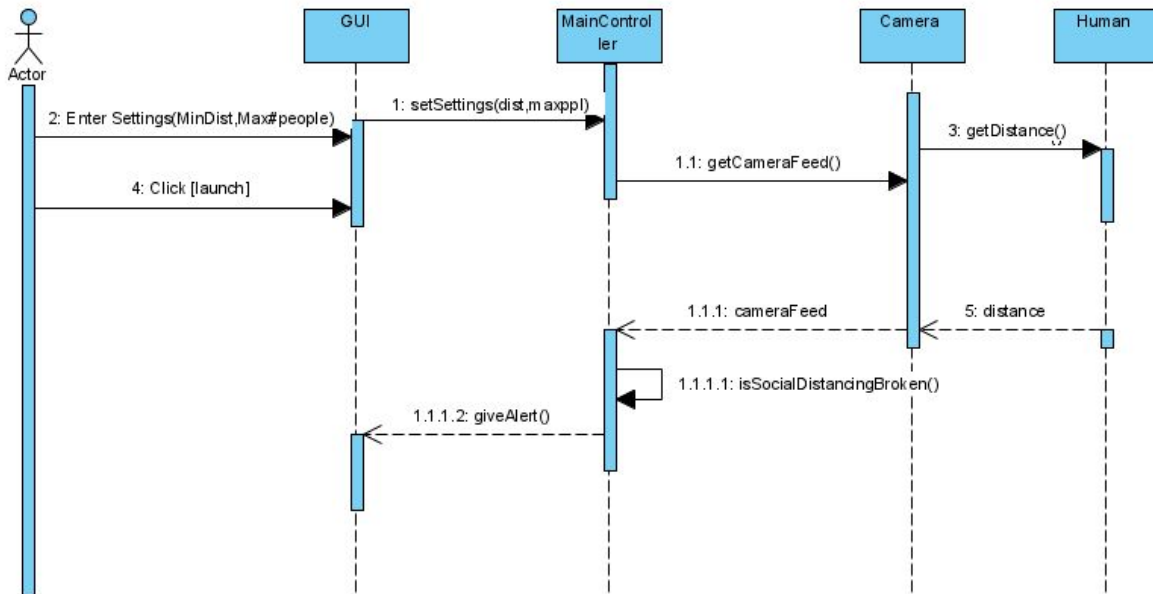Figure 4: Social Distancing Sequence Diagram

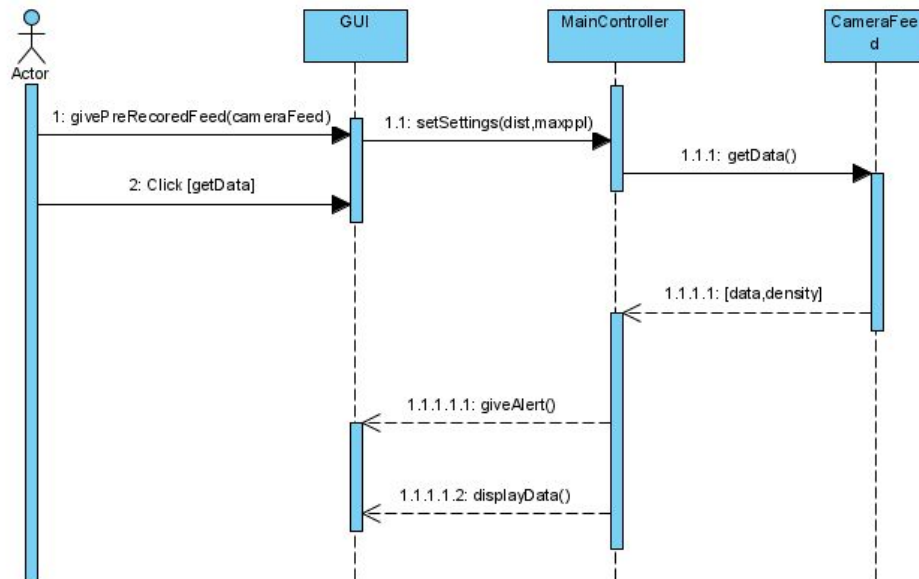## Gather Statistics Sequence Diagram

Figure 5: Crowd Statistics Sequence Diagram

3.5.5 User Interface - Navigational Paths and Screen Mock-ups

Main Page

The main page is also a welcome page. The user will be presented with three options to select, these options are; real time social distancing, commercial statistics and credits.
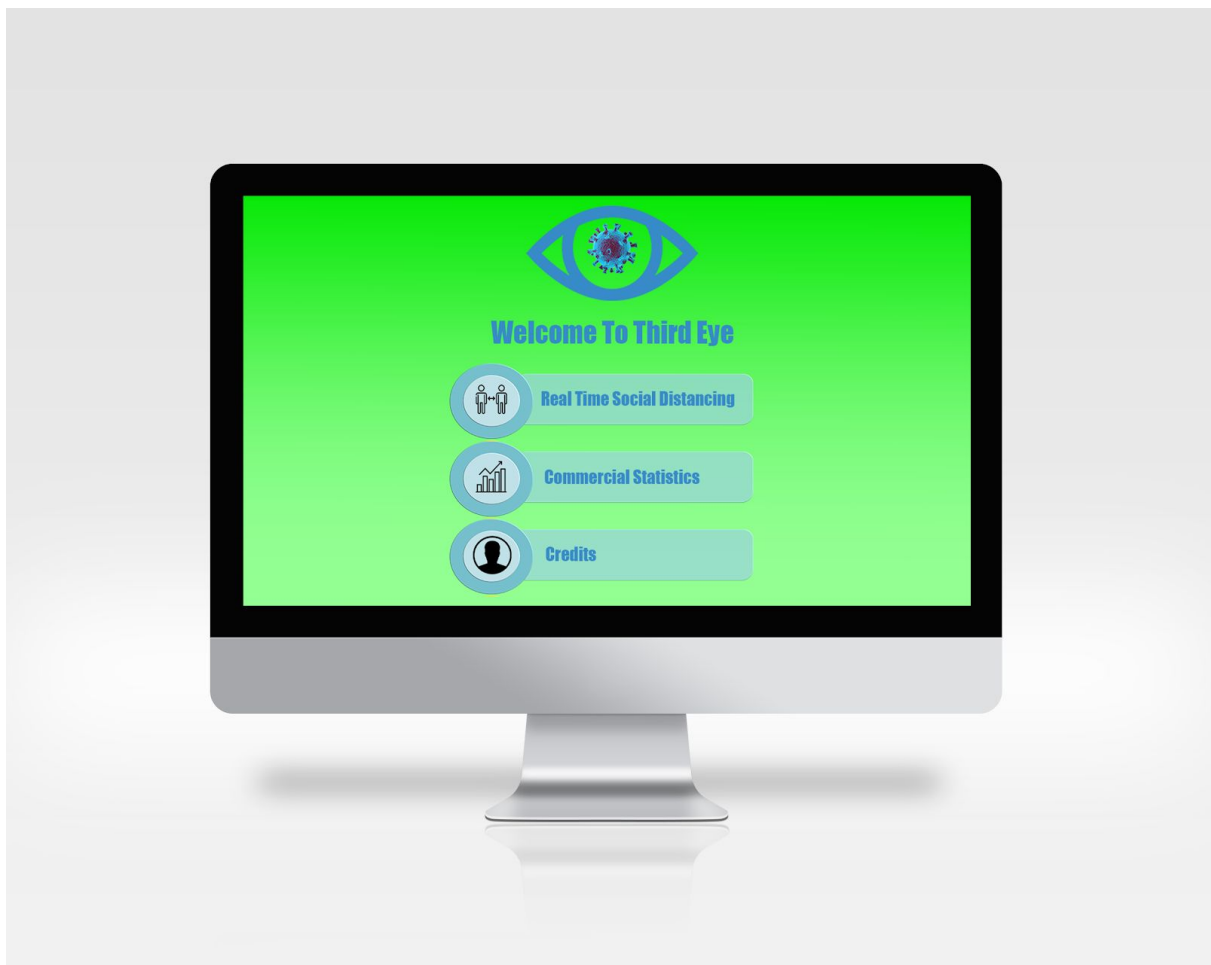
Figure 6: Main Page

Real Time Social Distancing Page

This page is an active tracker page, users can track the violations and see the person id assigned to each person. Users can go back to the main menu if he/she clicks to the "Go Back" button in the bottom right.

Figure 7: Real Time Social Distancing Page

Statics Page

In this page, there are two options for users to choose from. These options are Real Time Statics and Past Statics. Users can go back to the main menu if he/she clicks to the bottom right "Go Back" button.
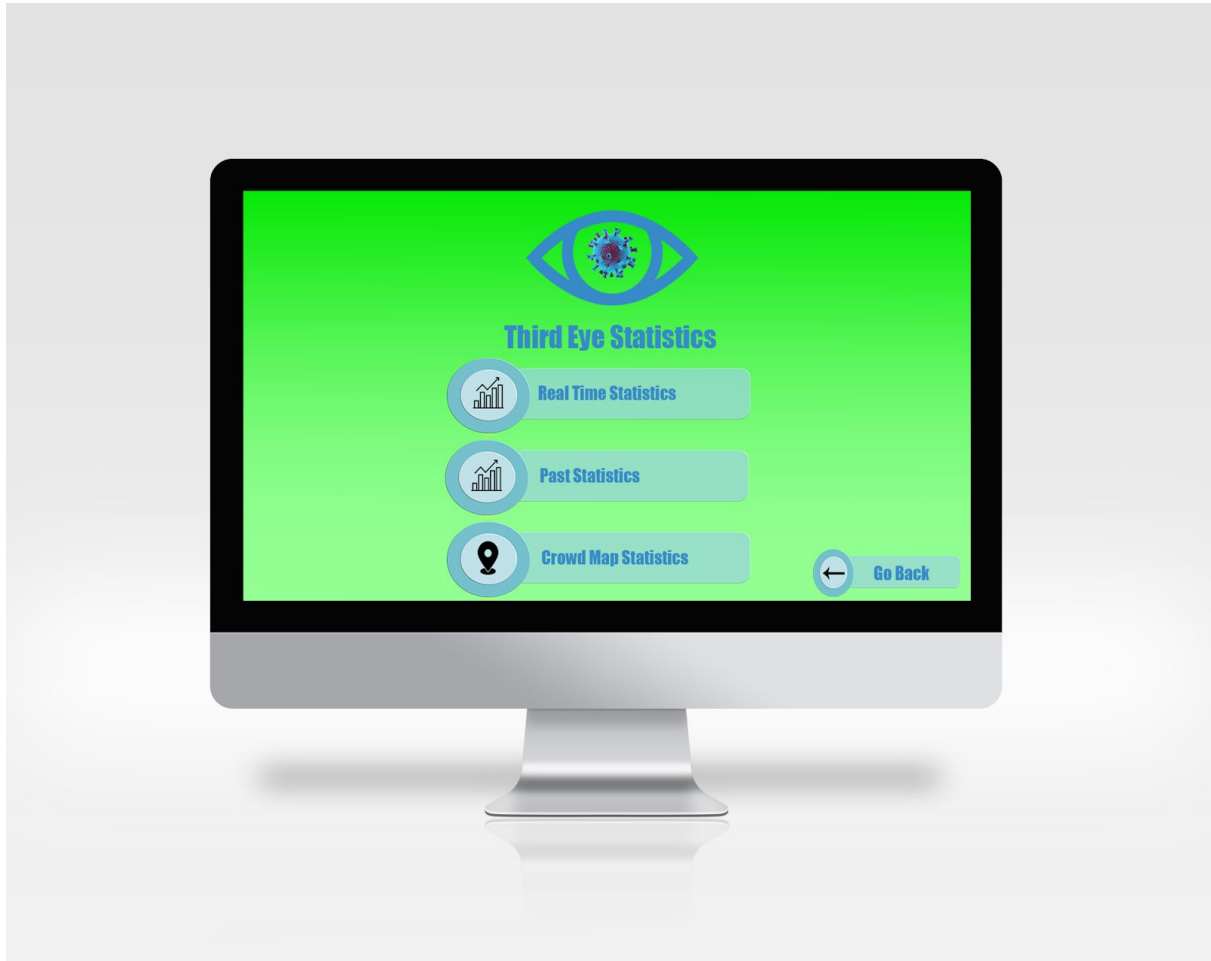
Figure 8: Crowd Statistics Page

Real Time Statistics Page

In this page, users can see the real time statistics of social distancing. Users can go back to the main menu if he/she clicks to the right bottom "Go Back" button.

Figure 9: Real Time Statistics Page

Crowd Statistics Map Page

Users can observe where the crowd concentrates on the map of the area. The statistics can be obtained for both real time camera feeds and recorded footage.

Figure 10: Crowd Statistics Map Page

Credits Page

In the credits page the user will be presented with three options to select, these options are; *About Third Eye*, *Team*, *Contact*. In the "*About Third Eye*"page, there will be a description about our project. In the team page, there will be our team information. In the contact page, there will be our contact information. Users can go back to the main menu if he/she clicks to the right bottom "Go Back" button.
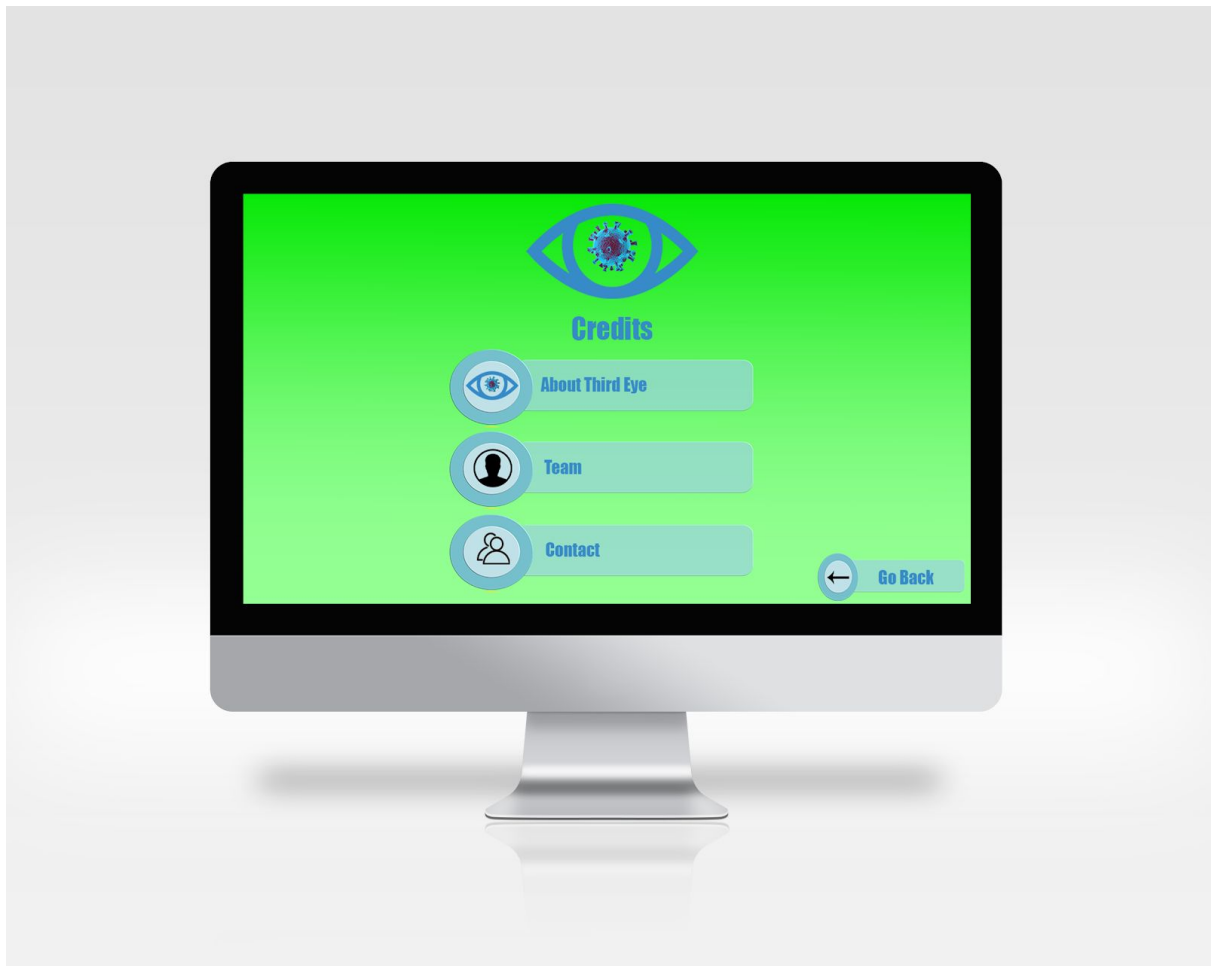

Figure 11: Credits Page

Navigational Path

Navigational path for our project *Third Eye* is shown below. Users can go back to the previous pages but for simplicity, go back relation is not shown in the figure.
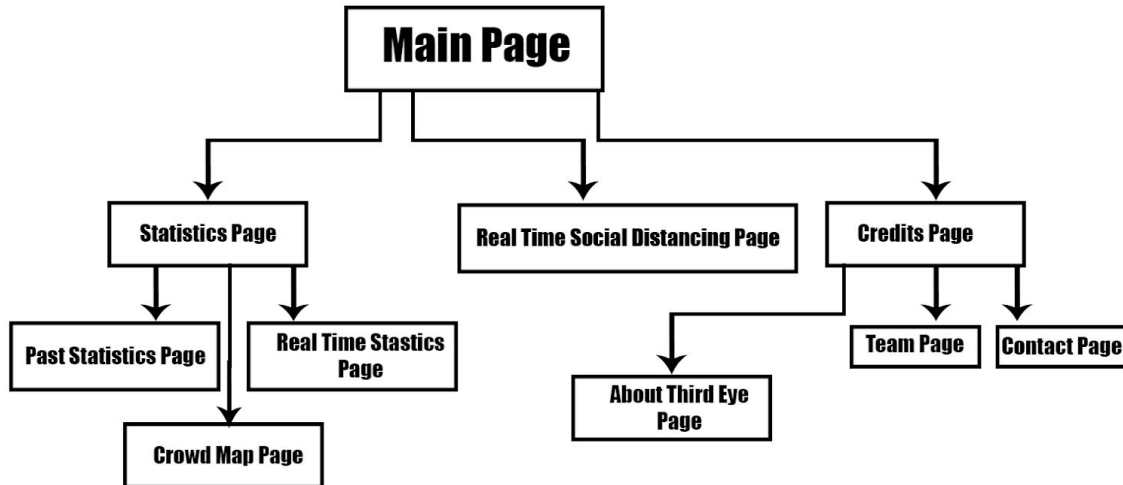
Figure 12: Navigational Path

4. Other Analysis Elements

4.1. Consideration of Various Factors in Engineering Design

Public Health

Public health is the key factor in our project. The idea behind the project is to detect the social distance between people and resist the spread of today's biggest issue COVID-19 virus. Also, there is a possibility that the project will be a good option to prevent the spread of other possible future viruses.

Public Safety

There is an indirect effect of *Third Eye* to public safety. While it gives a warning to the people closer than 1.5 meter, people will be more cautious about the strangers close to them. This may prevent or reduce the potential pick-pocketing issue in public areas.

Public Information Security

Third Eye does not collect any private information about the people who are captured by the camera. The application checks the human faces for perceiving the masks, not for detecting their faces. Also, *Third Eye* does not record any information.

The statistics about commercial causes will be about human count which is only about the numerical statistics. Therefore, it can be said that the application respects personal privacy while detecting humans and collecting statistics.

Global Factors

COVID-19 is a global issue which makes our project a global solution. It can be used in every place in the world to detect the social distance between people.

Public Welfare

Third Eye project is aimed to be used in places such as shopping malls, airplanes, and hospitals. These places normally have cameras for safety issues. We will integrate the real time camera records with *Third Eye*. This will bring new features to the cameras. The program will be free to download. Therefore, there will not be any extra cost to these places which is related to our project.

Social Factors

As we mentioned, this is a social distance tracking project. It aims to calculate the distance between people and give a warning about it. However, even if the importance of social distance is well known by people, they can choose to hang out with their family members or friends. People prefer to maintain their distance from strangers. We considered this issue and planned to bring a solution to this. AI will detect the relation between people from their gestures and evaluate them as a group. Therefore, *Third Eye* will not give a warning to those people who are willing to choose to hang out together.

Economical Factors

In addition to social distance tracking, there will be a feature for collecting data. The interests of people about the aisleways can be detected with *Third Eye* while it will hold the statistics of it. These data could be effectively used for commercial purposes.

	Effect Level	**Effect**
Public Health	10/10	Resist the spread of COVID-19 virus
Public Safety	3/10	Reduce the pickpocketing of public areas
Public Information Security	7/10	Application concerns about the data privacy which makes it reliable
Global Factors	8/10	Project will be a solution to the global issue such as COVID-19 virus
Public Welfare	5/10	*Third Eye* can be built into any system free of charge.
Social Factors	4/10	*Third Eye* will detect the relation between people from their gestures and make sure that they prefer to hang out together
Economical Factors	7/10	Collect the data for commercialized purposes

Table 1: Effect Level Table

4.2. Risks and Alternatives

4.2.1 Camera Feed Discrepancy

Cameras should be arranged in the most efficient way. If the camera does close monitoring, *Third Eye* will not be able to track the distance between people in a useful manner. The reason is that the camera will include a limited number of people in its perspective.

Another issue is the camera angle. If it is somehow skewed, it might be hard to detect the real distance between people from that angle.

4.2.2 Quality of the Camera

If the quality of the camera is not good enough, there would be an issue about detecting the relation of the people with AI technology. One of the functionalities about the project is detecting the gestures of people and making sure that they are together. Therefore, *Third Eye* will not give a warning to the people who are related to each other.

4.2.3 Detecting the Relativity of People Inaccurately

Third Eye will use the simple artificial intelligence techniques to detect that some people will willingly hang out with each other, in other words, they are relatives in some manner. However, artificial intelligence may not give the exact result about it, there is a possibility to make some mistakes. Correspondingly, the program may give the wrong warnings to people who consciously break the social distance rule, or it might detect some strangers as relatives which may cause *Third Eye* to consider them as relatives.

4.2.4 Library Failure

We are planning to use various libraries throughout our project, including the libraries of NVIDIA itself and a few additional ones such as OpenCV for our computer vision system. That being the case, there is a risk factor of a possible mismatch between the libraries and our program.

4.2.5 In-Team Problems

There is always a possibility that a team member may give up the project or there could be some conflicts among team members. However, this is a low possibility issue for this team. The team synergy seems good until this point.

	Likelihood	Effect on the Project	B Plan Summary
Camera Feed Discrepancy	High	Errors in calculations	Design the project as measuring the distances from different angles properly
Quality of the camera	Medium	Wrong warning messages may occur	Proposing new camera system which works coherently with the application
Detecting the Relativity of People Inaccurately	High	Wrong warning messages may occur	AI algorithms should be revised in order to give more accurate results
Library Failure	Low	Some functionalities according to failed library may not work correctly	Finding alternative libraries may be the solution
In-Team Problems	Low	Progress gets slower and the burden on each team member would increase	We assign a leader role for the different parts of the project to each member in the project plan. These leaders will decentralize the work

Table 2: Risk and Alternatives Table

4.3. Project Plan

Planning is really important to meet the deadlines in a project. There are multiple types of planning that can be used in a project, The type of planning we chose decomposes the project into smaller pieces. This paradigm is called the Work Breakdown Structure. In order to apply the Work Breakdown Structure paradigm project goals should be identified. These goals are given below. A Gantt Chart is useful in visualizing the continuous development process. Also, Below is our Gantt Chart that indicates the time requirements of tasks together with their starting dates and deadlines:

- Deliver Project Specifications Report.
- Build a website for the project.
- Deliver Analysis Report.
- Study NVIDIA Jetson Nano and Python libraries.
- Deliver High-Level Report.
- Complete human detection system on still Images.
- Select a camera to supply input for real-time human detection.
- Complete real-time human detection.
- Produce a demo.
- Deliver Low-Level Report.
- Create a user interface for the application.
- Upgrade the demo to check the distance between two humans.
- Upgrade the demo to collect organized information from the camera feed.
- Expand the demo into a working project.
- Deliver Final Report.
- Optimize the project.
- Prepare the Project Demo and Final Presentation.

Work Package	Leader	Members	Deadline	Deliverables
1(Done)	-	-	-	Project Specification Report
2(Done)	-	-	-	Website
3.1	Alkım	Goktug, Eren	20 Nov. 2020	Analysis Report
3.2	Berke	Alperen, Alkım	20 Nov. 2020	Analysis Report
3.2	Goktug	Eren,Berke	20 Nov. 2020	Analysis Report
3.3	Eren	Alperen, Goktug	20 Nov. 2020	Analysis Report
3.4	Alperen	Alkım,Berke	20 Nov. 2020	Analysis Report
4.1	Alkım	Goktug, Eren	25 Nov. 2020	Jetson Nano
4.2	Berke	Alperen, Alkım	25 Nov. 2020	Python libraries
5.1	Goktug	Eren,Berke	21 Dec. 2020	High Level Report
5.2	Eren	Alperen, Goktug	21 Dec. 2020	High Level Report

|				
6.3	Alperen	Alkım,Berke	26 Dec. 2020	Human detection on still images
6.4	Alkım	Goktug, Eren	26 Dec. 2020	Human detection on still images
7.1	Berke	Alperen, Alkım	28 Dec. 2020	Select a camera
8.1	Goktug	Eren,Berke	30 Dec. 2020	Real time human detection
8.2	Eren	Alperen, Goktug	30 Dec. 2020	Real time human detection
9.1	Alperen	Alkım,Berke	20 Dec. 2020	Demo
9.2	Alkım	Goktug, Eren	20 Dec. 2020	Demo
10.1	Berke	Alperen, Alkım	8 Feb. 2021	Low level Report
10.2	Goktug	Eren,Berke	8 Feb. 2021	Low level Report
11.1	Eren	Alperen, Goktug	14 Feb. 2021	GUI
11.2	Alperen	Alkım,Berke	14 Feb. 2021	GUI
12.1	Alkım	Goktug, Eren	17 Feb. 2021	Check distance
12.2	Berke	Alperen, Alkım	17 Mar. 2021	Check distance
13.1	Goktug	Eren,Berke	17 Mar. 2021	Collect info
14.1	Eren	Alperen, Goktug	20 Mar. 2021	Working Project
14.2	Alperen	Alkım,Berke	20 Mar. 2021	Working Project
15.1	Alkım	Goktug, Eren	15 Apr. 2021	Optimize Project
15.2	Berke	Alperen, Alkım	15 Apr. 2021	Optimize Project
16.1	Goktug	Eren,Berke	30 Apr. 2021	Deliver last demo
16.2	Eren	Alperen, Goktug	30 Apr. 2021	Deliver last demo
16.3	Alperen	Alkım,Berke	30 Apr. 2021	Deliver last demo

Table 3: Project Work-plan Table
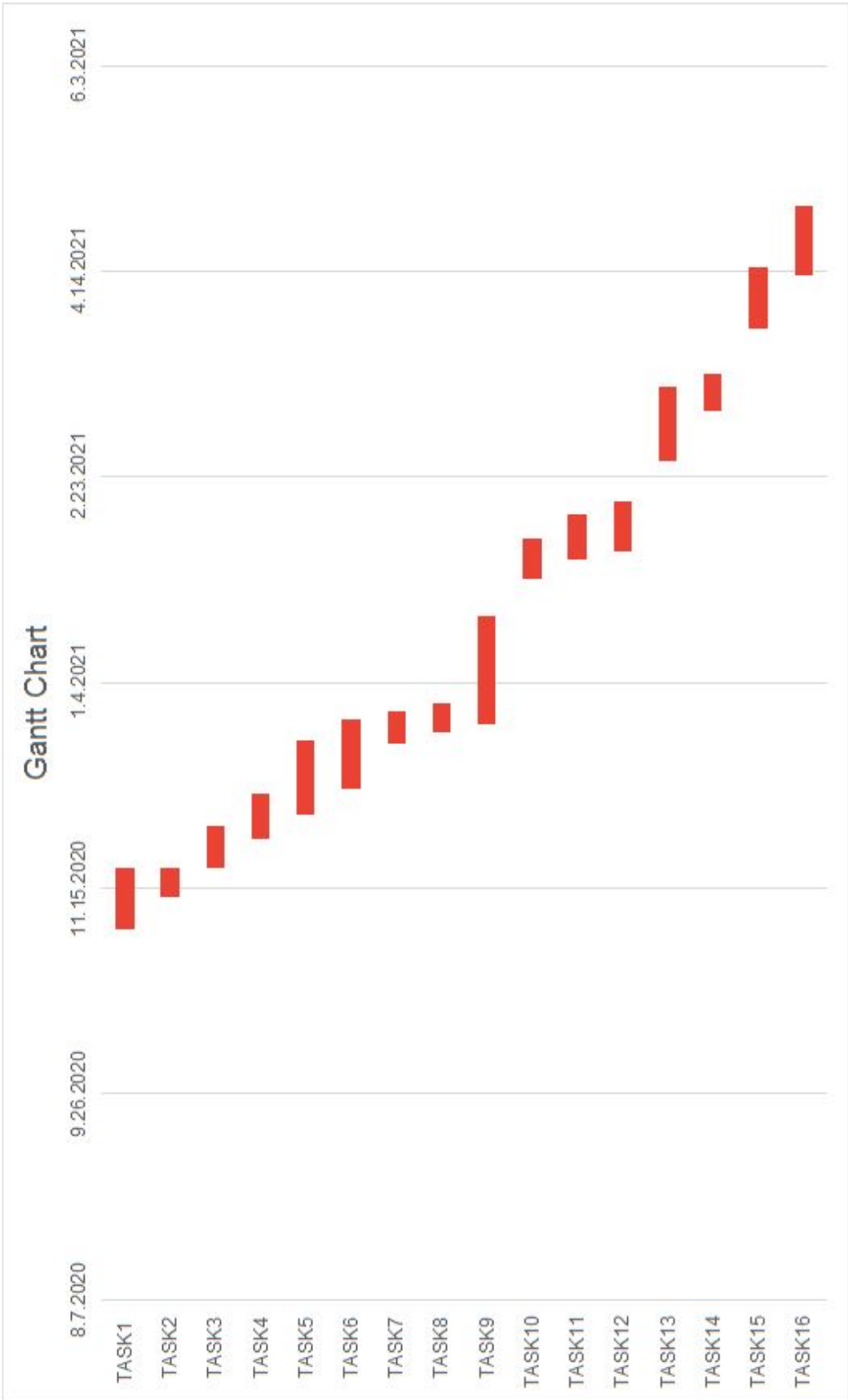
Figure 13: Project Gantt Chart

4.4. Ensuring Proper Teamwork

Teamwork is critical in the development process of a product, and ensuring that it is done properly is a must. Thus, we put great emphasis on the distribution of workload and do our best to circulate the roles and responsibilities for different parts of the project evenly. Since it seems that we will be doing our project in the quarantine period under the light of the recent news, the distribution of the work became even more important for us.

In order to ensure this will be done successfully, we are using a number of technologies at our disposal. These are mainly Jira, Slack and GitHub.

- **Jira:** We are planning to use Jira Software for the collaboration and to manage the workload of our project, as well as addressing any possible problems through it. After a research on similar tools, we have seen that Jira has all the useful use-cases that we needed and therefore we have decided to use it.

- **Slack**: We are also planning to use Slack as our main communication platform to use for various things such as setting up meetings, using it as a channel for discussions, setting up polls and reminders, etc.

- **GitHub:** We will be using GitHub as the repository of our project as well as our version control system in the implementation process. This will enable us to track down each member's contribution to the product. GitHub also has an integrated contribution tracker system which shows the commits and contributions of each member accordingly to their branches.

We are expecting that everybody in our project group will have around equal work at the end of the year.

4.5. Ethics and Professional Responsibilities

Our project is a smart surveillance tool that uses surveillance cameras for enforcing social distancing between people and analyzing the crowds where the people's interest peaks for commercial purposes. Keeping people under surveillance is a sensitive subject instead of privacy. It is our ethical responsibility to protect people's privacy. In our project, *Third Eye*, human detection will detect humans anonymously, not by identification so this prevents many possible privacy problems for the project.

In many countries, the security of personal information is protected by laws. In Turkey, there is a protection of personal data law which is known as KVKK, according to this law, it is a professional responsibility for us to keep personal data private and not to

share this data with any third party organization. We also consider personal data security for ethical responsibility. We will not share any personal data with a third party in any condition. When we need statistical data, the information we keep can be used but it is important that this information cannot contain any personal data.

As a team, it is our Professional responsibility to hold meetings weekly where we will discuss further plans and go over what has been done in the past week. The workload and the future of the Project will be discussed democratically in these meetings and the workload which we decide in these meetings will be distributed fairly. It is also our Professional responsibility that the source code of the Project will be kept private.

It is our ethical responsibility to check licenses for the APIs, libraries ,and tools before usage. Also, we will adhere to the Code of Ethics and General Data Protection Regulation (GDPR) [11].

Since there will be surveillance through cameras wherever the *Third Eye* is being used, as an ethical responsibility, there need to be warning signs put up and cameras placed accordingly to the regulations.

We believe that finishing this project on time with a reviewable product is our responsibility. For fulfilling our responsibility, we will run to our schedule and prepare good documentation with proper diagrams.

4.6. New Knowledge and Learning Strategies

As we discussed with our team, we consider that we have a lack of knowledge for building our project. To improve our knowledge, we brainstormed for specifying which advanced techniques, external tools and technologies should we use for our project. After specifying techniques, tools and technologies we determine our learning strategies for getting qualified knowledge. Also determining our learning strategies will gain us a considerable amount of time.

Below are some advanced techniques which we will be using for our project:

- Artificial Intelligence
- Machine Learning
- Computer Vision

Real-time human detection algorithms will use computer vision and artificial intelligence techniques, so we need to have the proficiency to use these techniques. Most of us know these techniques but we decided to enhance our knowledge about these techniques. We will use a literature review and online-based research learning strategies for these advanced techniques.

We will need to use some external tools and technologies for *Third Eye*. Below are some external tools and technologies which we will be using for our project:

- Python
- NVIDIA's Jetson Nano
- Libraries, Frameworks such as OpenCV or Imutils.

We will use Python for developing the software. We all are familiar with the Python language but we are determined to enhance our Python skills with online learning and learning by doing strategies. We will use NVIDIA's Jetson Nano human detection development kit for detecting people with cameras. This is a new technology for us and we decided to learn this technology with online learning and learning by doing. We will also use libraries and frameworks like OpenCV or Imutils for our project, so we decided on online learning and learning by doing learning strategies.

Lastly, we considered that we need to learn software project management for managing our project professionally. Learning software project management will gain us a perspective instead of managing time, ensuring teamwork efficiently ,and what a leader or a member is supposed to do while managing. We will use literature review and online learning strategies for learning software project management. We will also meet with our advisory professor regularly to get help and information.

5. Glossary

GitHub: An online platform that provides hosting for software development version control using Git.

Jira: A software that helps manage agile and software development projects.

OpenCV: A library of programming functions mainly aimed at real-time computer vision developed by Intel[9].

Jetson Nano: A development kit for AI applications that reduces complexity and effort for developers. Jetson Nano is a small, powerful computer that lets you run multiple neural networks in parallel for applications like image classification, object detection, segmentation, and speech processing. All in an easy-to-use platform that runs in as little as 5 watts[10].

6. References

[1] "Naming the coronavirus disease (COVID-19) and the virus that causes it," World Health Organization. [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-2019)-and-the-virus-that-causes-it. [Accessed: 11-Oct-2020].

[2] I. Chakraborty and P. Maity, "COVID-19 outbreak: Migration, effects on society, global environment and prevention," Science of The Total Environment, vol. 728, p. 138882, 2020.

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