Bilkent University

Department of Computer Engineering

Senior Design Project

The Third Eye

High-Level Design Report

Alkım Önen, İbrahim Eren Tilla, Göktuğ Öztürkcan, Berke Oğuz, Safa Alperen Oruç

Supervisor: Fazlı Can

Jury Members: Can Alkan and Çiğdem Gündüz Demir

High-Level Design Report

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This report is submitted to the Department of Computer Engineering of Bilkent University in partial fulfillment of the requirements of the Senior Design Project course CS491/2.

1. Introduction

This is the High-Level Design Report of our project, *the Third Eye*. In this report, we will discuss the purpose of our application and the design goals, which will then be followed by the proposed software architecture. This section will consist of *the Third Eye's* subsystem decomposition, the mappings of it, the synchronization and concurrency issue as well as the boundary conditions. Then, we will flesh out the subsystem services and give information about the tiers that will be used by our program. We will then proceed to summarize the considered engineering factors and end our report with information about the teamwork details and workload distribution.

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 *the 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, *the 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 *the Third Eye* offers and see the trending sections of the mall.

1.1 Purpose of the system

There are several purposes of our system, which can be stated under two separate headings, non-technical and technical. Since we are aiming to construct a software that is both innovative and technically high quality, it is inevitable that stating a single purpose will fall short of explaining our objective.

First of all the non-technical purpose of our system is to enforce social distancing rules even more since many people don't take the pandemic seriously. Using machine learning and computer vision our program will automatically enforce social distancing in necessary areas with the help of a surveillance camera. So there won't be a need for

employees in stores trying to make the customers comply with the rules of social distancing.

Second, the technical purpose of our system is to function in an error-prone, secure, and efficient manner. It aims to be error-prone to ensure that there does not exist any time interval that the application is out of service. Another objective of our system is to be secure to prevent any single one of our users from feeling distrusted and to keep their data safe. Lastly, the system aims to be efficient to provide a smooth user experience.

1.2 Design goals

Reliability

The system should:

- Make sure data user data (data collected from the program and the camera feed) is safely stored.
- Be resistant and able to run and collect data 24/7.
- Make sure that the data produced is correct.
- Automatically delete older camera feed/data to make space for the new ones unless it's specifically stored.

Usability

The system should:

- Be self-explanatory and user-friendly.
- Be clear in terms of display and language.
- Present a neat and well-organized user interface.

Maintainability

The system should:

- Be able to receive updates whenever needed.
- Work for long periods of time without maintenance.

Customer Needs

The system should:

- Be easy to set up and use for the customer.
- Save and store data for the customer.

1.3 Definitions, acronyms, and abbreviations

UI : User Interface. The user interface (UI) is the point of human-computer interaction and communication in a device.

AI:Artificial intelligence refers to the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions.

1.4 Overview

The Third Eye is a smart surveillance app to enforce social distancing and collect customer data. *The Third Eye* uses deep learning technologies and computer vision. It is innovative in the sense that there are no commercial products that do smart surveillance alongside social distancing enforcing(mainly because social distancing itself is a new thing). Currently, there are no ways to give warnings to enforce social distancing other than an employee giving warnings manually.

Advanced models and techniques such as neural-networks, artificial intelligence, and jetson nano will constitute the backbone of Autoshop. The software will mainly revolve around the topics: Deep Learning and Computer vision. *The Third Eye* will demonstrate that such advanced technologies can be useful for our problem.

The Third Eye software will have one version which works on desktops. Since the software is intended for shop/market owners there was no need for a mobile version.

2. Current Software Architecture

Although Opencv has open-sourced methods for pedestrian detection and is widely used in smart surveillance systems, there is no commercial product that combines smart surveillance with social distance enforcers. There are products to check the distance between two pedestrians however these are not specialized for the pandemic that we are going through right now and therefore are not very useful for enforcing social distancing.

3. Proposed Software Architecture

3.1 Overview

Software architecture is one of the key parts of *the Third Eye* project while the expectation from the project is providing a pure and sophisticated environment to its users. The aim of the subsystem decomposition of the software architecture part is to reduce the complexity of the project by breaking the project into the pieces. 3-tier architecture which includes the presentation, application, and data tiers is determined as the best choice for *the Third Eye* project. The reason is that it is more reliable, faster, and scalable. Project decomposed into parts, thus, every group member can do the implementation of the individual parts faster and clearer. Any undesirable errors can be easily detected. Also, any improvements of the intended part can be easily implemented to the project because of the decomposed architecture. The details of the subsystem decomposition and other software architecture requirements like hardware/software mapping or software controls of the project will be explained in detail.

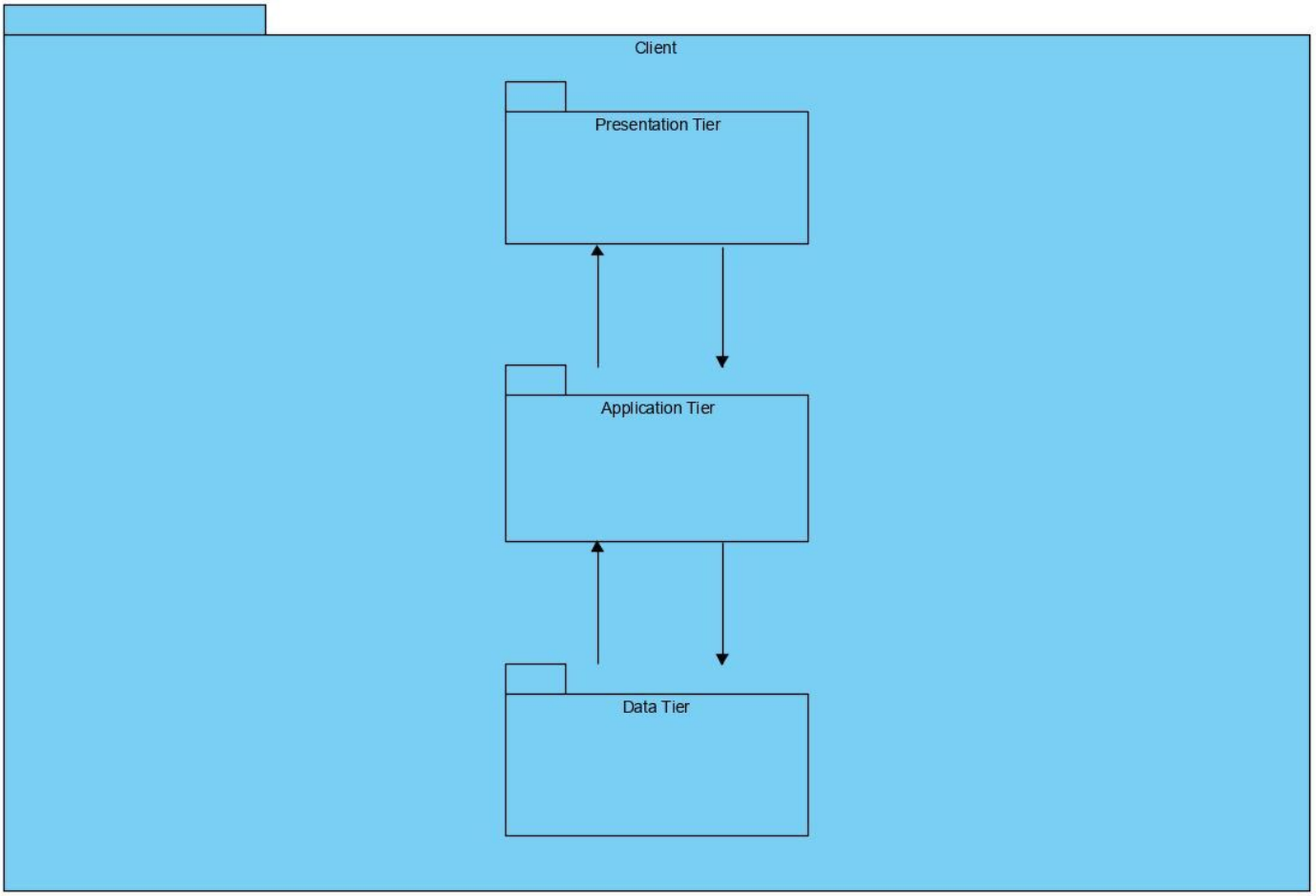

Figure 1: Subsystem Decomposition

3.2 Subsystem decomposition

The Third Eye has the three-layered subsystem decomposition as shown in Figure 2. *The Third Eye* client subsystem has 3 tiers of Application Tier, Data-Tier and Presentation Tier. All of these tiers will run on the client device. The device will be able to analyze both live video feed and recorded footage.

The Presentation Tier will be the connection between the users and the application tier itself. It will control the composition and navigation of the user interfaces. This subsystem will have GUI implementations with practical functionalities and page designs. Every page will have a class to operate its functions. The presentation Tier will be connected to the Application Tier in order to perform the actions desired by the client.

The Application Tier will be responsible for the functionalities of the system. MainManager will be the main controller. It will manage the general selections of the client. CameraManager will handle the camera footage. It will be able to connect to the live camera feed or reach recorded footage. SocialDistancingManager will be responsible for the analysis of the data. DetectionSystem will play the role in the detection of social distancing violations while AlertSystem will be responsible for alerting the violations. StatisticsManager will analyze and manage the results of crowd movement and accumulation. The Application Tier will be the connection between The Presentation Tier and The Data tier.

The Data Tier will be the collection subsystem. CameraFeed will be responsible for managing the live video feed while DataManager will manage the data flow of statistics, maps, images, and alerts.

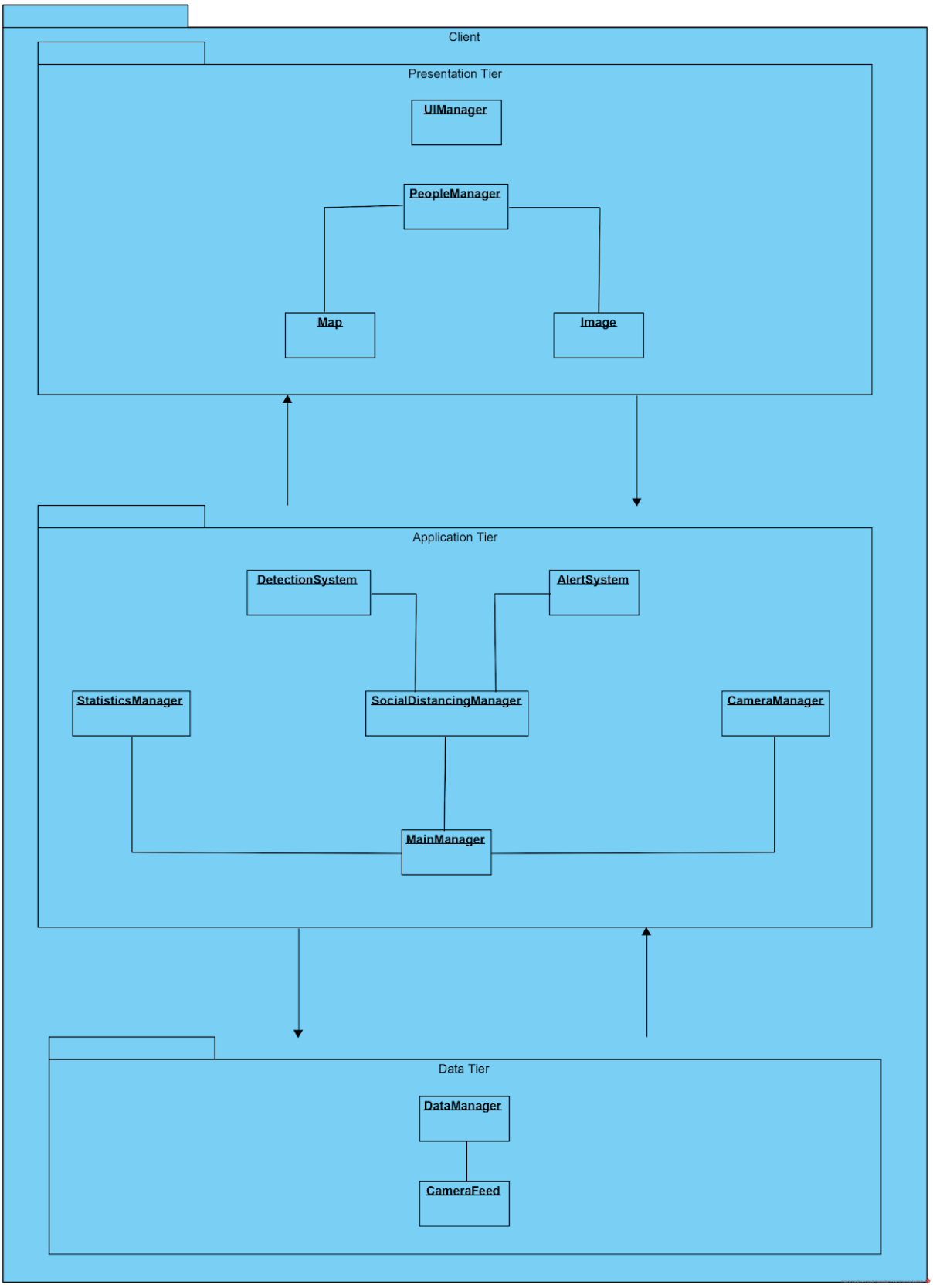

Figure 2: Detailed Subsystem Decomposition

3.3 Hardware/software mapping

The Third Eye project is a desktop application. It will process the real-time camera feeds and give appropriate results to its users. It does not require any internet or server connection. The backend parts of the software are planned to be written in python. UI part of the project will be done with Tkinter close program or "PySimpleGUI". In order to determine the relation between people, some AI algorithms can be used in the software part of the project. The actual project plan is to use Jetson Nano hardware tool for AI algorithms, but as an alternative "OpenCV" can be used for human detection which is a software based component. The project is planned to be working on Windows, MacOS, and Linux.

The data will be received from the real-time camera feeds. Therefore, cameras can be considered as a part of the hardware for this project. Also, NVIDIA Jetson Nano developer kit is planned to be used as the hardware tool in order to make more professional and consistent AI based detections. This means that some useful NVIDIA libraries should be also used in the project.

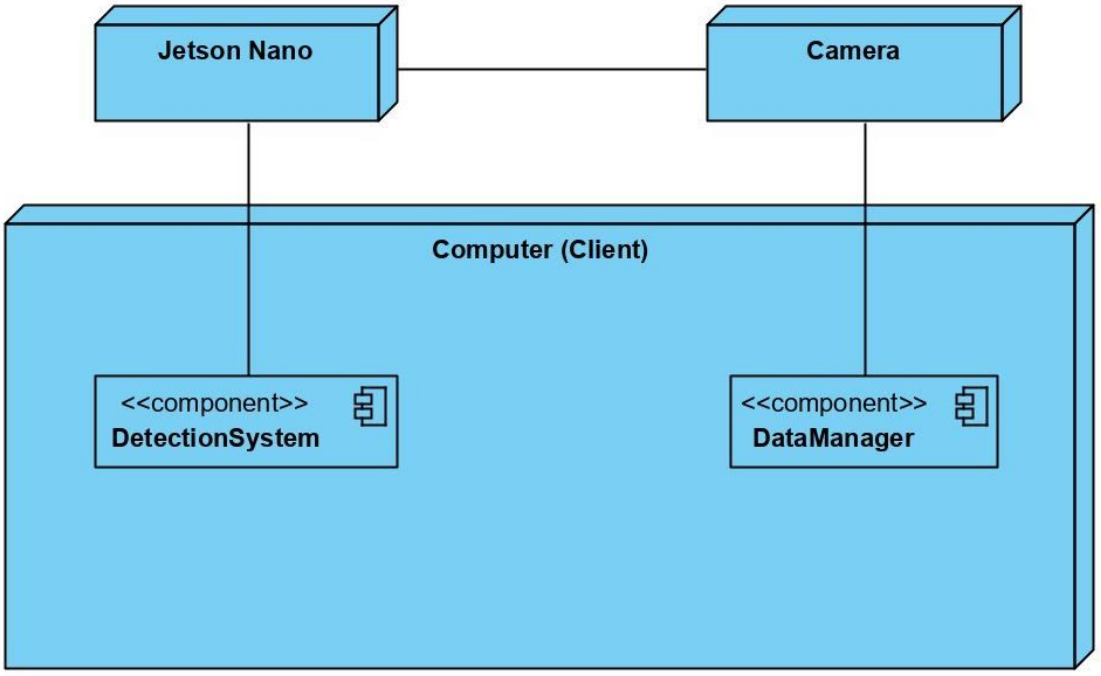

Figure 3: Deployment Diagram

3.4 Persistent data management

Persistent data management is an important part of *the Third Eye* project. The data will be received by the computer in order to process and give proper feedback to users. The cameras in the public places will provide the data to the application. The data taken from those camera records should be uninterrupted.

Any database program like MySQL is not required for this project. *The Third Eye* considers the data and user privacy; therefore, it does not store any taken camera records.

Only data stored will be about the statistics for commercial concerns. This specification will not give any private information about people in public. The system will only incorporate the numeric data for statistical reasons.

3.5 Access control and security

Control and security of the information has been put to great emphasis as *the Third Eye* relies heavily on user information (even though it is anonymous data). Thus, it uses an authentication system for the initial user to gain access to the program and the data that is relevant for the application. Then again, we would like to point out that this precaution was taken for external threats such as malwares, rather than from an in-system user.

In order to achieve this authentication, the program will take a username and a password (a strong password would be mandatory for the sake of the data). The user will be checked regularly as multiple security constraints will be used during the usage of *the Third Eye.* In order to prevent any data leaks and increase the chance of a data breach, we have decided not to store the data in an external database or any other storage. In addition, the application will not include any type of identification such as names or faces. With these precautions, we will make sure that the data is safeguarded and secure, while keeping the boundaries of public information ethics. As a side note, *the Third Eye* is designed to be in accordance with the General Data Privacy Regulation [12].

3.6 Global software control

In *the Third Eye,* the operation of work uses live feed, and thus, synchronization is of utmost importance. *The Third Eye* uses a "3-Tier Architecture" which is working as a chain, so that the program takes the data and processes it step-by-step. In this section, we will put a light on how the application handles this problem and discuss the working principles of the concurrency system and how the tiers keep in sync with one another.

Since there is only one subsystem in *the Third Eye,* which is the *Client*, there is no need to check the connection between the subsystems. However, since there are three layers in our subsystem (namely *Data, Application* and *Presentation*), we will need to check their concurrency. Briefly, it can be said that the *Data* tier creates and takes the data and passes it to the *Application* tier, which then proceeds the said data and passes it to the *Presentation* tier, which the statistics will be provided to the user. These three layers will work in a concurrent manner, where the needed data will be transacted to the layer which requires it almost seamlessly. Here are the detailed explanations for our three tiers:

- **Data Tier** will take the input data from the live camera feed, and pass it to the *Application* tier after processing the human images and clearly highlighting the people on the feed.

- **Application Tier** will take the camera data and process it. It will produce many statistics for the user to benefit, and construct a rough list of processed data. It then passes it to the *Presentation* tier for the user to see.

- **Presentation Tier** will take the rough data and construct various graphs using it and present them to the user. It will also inform the user in case of any violations of the social distancing measurements, making it effectively the most important step of *the Third Eye.*

Please note that the investigated systems will be working in accordance, and continue to do so. Since our application will process live feed, all of these steps will be required to work concurrently and in harmony.

3.7 Boundary conditions

The Third Eye will have 5 boundary conditions. These are: setting up the program, initializing the program, terminating the program, the possibility of a critical failure and the possibility of an authentication error. These boundary conditions are discussed in detail in the sections below.

3.7.1 Application Setup

Before starting to use *the Third Eye* it needs to be set up. This will be able to be done using our "User's Manual" that will be provided to the customers. The users will be given authentication codes to register themselves to the system. From our website, they will be able to download the application to their system.

At the first startup of the program, the user will be required to connect the external systems to *the Third Eye*. These will consist of:

- a mandatory camera surveillance system,
- optional alert systems such as
    - a speaker system for audio signals,
    - a lighting system for visual signals.

After verifying the connection of the systems, the application will be ready to use.

3.7.2 Initialization

At every initialization, the users will need to verify their authentications before using the application. Also, *the Third Eye* will check the integrity of the loaded systems (the mentioned external systems) and their connection. If there are any problems with the authentication or the connectivity, the user will be prompted with an error message and be required to take the related procedures.

3.7.3 Termination

The users can terminate the program by simply clicking the *Exit* button and quit through the main menu, or just terminate the application from their devices processes list. When the user decides to terminate the application, any running processes will be

closed down and terminated. The related data (statistics etc.) will be stored on the local disk of the user's device. Unlike the statistical data, the camera feed will not be stored as a security measurement.

3.7.4 Critical Failure

There may occur problems that might lead to critical failures due to unexpected reasons (such as bugs). As a precaution for such scenarios, *the Third Eye* will periodically store the statistical data on a local disk. This will enable the program to have a safeguard for any kind of failure situations. The program will also store backups for the statistical information, so that in the case of a data corruption, it will be able to restore the corrupted data with the backed-up version. Please note that this data does not include the live camera feed that is being used during the usage of the application.

3.7.5 Authentication Error

Whether it is a potential data breach or a simple authentication problem with the user (forgetting one of the constraints, passwords e.g.), there may occur some problems regarding the authentication of the user. We will provide a "User's Manual", so that in the case of such scenarios, the user will be able to reset its access and create a new one from scratch. Although it is being recoverable, the stored data will be deleted to prevent any form of data leaks. This is a clear indication that the authentication process is emphasized heavily.

4. Subsystem Services

In this section, we will describe the major components of our system. Our main system is the client layer and it has 3 subsystems under it.

4.1 Presentation Tier

The Presentation Tier will be responsible for managing the user interface operations.

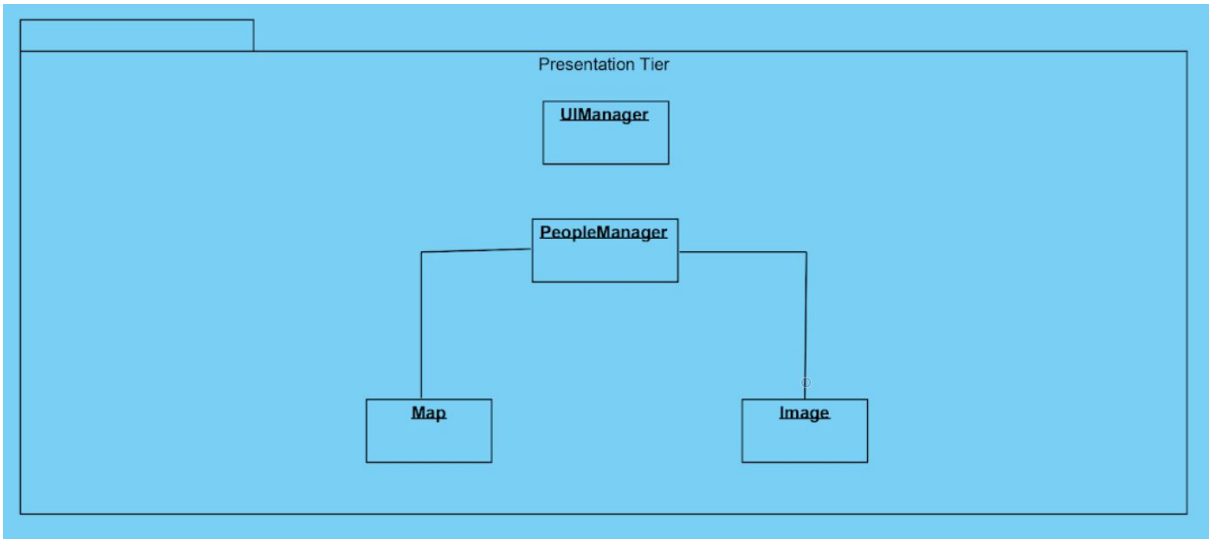

Figure 4: System Decomposition of Presentation Tier

UIManager

This view is responsible for the main page and the settings of *the Third Eye*.

PeopleManager

This view is responsible for analyzing people's movements and accumulation either in real-time or from recorded video footage.

Map

This view is responsible for observing the analysis statistics on top of the map created by the system.

Image

This view is responsible for observing the analysis statistics on top of the stabilized image from the area of the video.

4.2 Application Tier

The Application Tier will be responsible for handling the user's requests and performing the necessary actions.

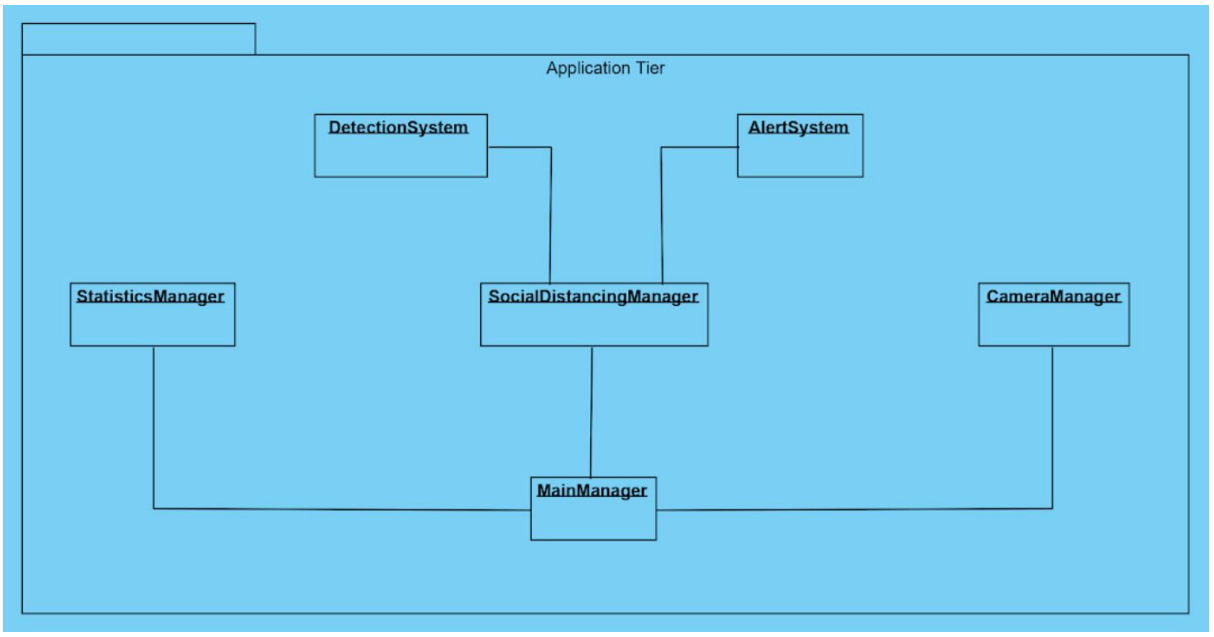

Figure 5: System Decomposition of Application Tier

MainManager

This class is responsible for starting the application and handling user's requests. It controls the application's functions.

CameraManager

This class is responsible for retrieving the footage. It allows people to choose a video from already recorded footage. It is also able to connect to a live camera feed and do analysis.

SocailDistancingManager

This class is responsible for setting up the social distancing system and changing its settings.

DetectionSystem

This class is responsible for analyzing the crowd under the social distancing rules of the client. It can access the footage and detect violations of the regulations.

AlertSystem

This class is responsible for informing the clients about the findings of *DetectionSystem*.

StatisticsManager

This class is responsible for creating crowd statistics on top of the stabilized image or the map of the area.

4.3 Data Tier

The Data Tier is the collections subsystem of *the Third Eye*. It will handle the storage of footage, images, maps, and analysis results.

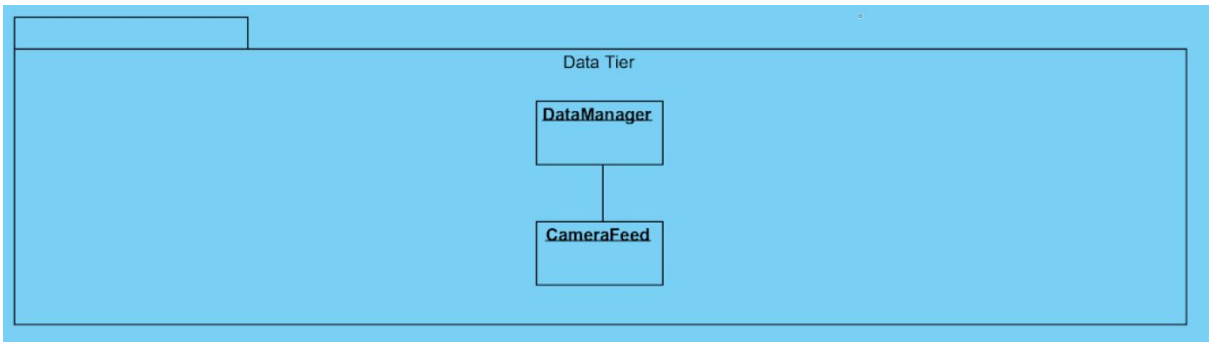

Figure 6: System Decomposition of Data Tier

DataManager

This class is responsible for storing the results of the analysis in desired form, i.e. on top of the image of the area from the video or in the map. It will also be responsible for storing other user information and desired settings for the Application Tier.

CameraFeed

This class is responsible for storing the address for the live feed of recorded footage.

5. 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 *the Third Eye* to public safety. While it gives a warning to the people closer than 1.5 meters, 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

The 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, *the 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 that 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

The 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 *the 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,

the 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 *the 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	The project will be a solution to the global issue such as COVID-19 virus
Public Welfare	5/10	*The Third Eye* can be built into any system free of charge.
Social Factors	4/10	*The 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

6. Teamwork Details

6.1 Contributing and functioning effectively on the team

Teamwork is critical in the development process of a product, and ensuring that it is done properly is a must. Correct teamwork can provide more successful project outcomes and higher profits with perfect timing. 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 we will be doing our project in the quarantine period the distribution of the work became even more important for us.

We assign a leader role for the different parts of the project to each member in the project plan so that it increases team members contributing and functioning effectively on the team. For contributing and functioning effectively on the team, team members are trained before and during the implementation process. Each team member is trained for their corresponding position specifically for the project. The training includes the research of algorithms and methods specifically designed to solve problems that are in the scope of this project. After training, every team member contributed the project and function effectively on their part. If any team member had an issue with his part we set up a meeting and did collaborative work.

6.2 Helping to create a collaborative and inclusive environment

In order to create a collaborative and inclusive environment, 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 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.

6.3 Taking lead role and sharing leadership on the team

Project leaders are responsible for setting the expectations for their team members, their team performance and act as a problem solver. Taking a lead role in a team will make the leader to be more motivated in that team and taking that responsibility will increase the leader's commitment to the project. For increasing every team member's commitment to the project, we decided to share the leadership on the team. Sharing leadership on a team prevents in team problems and increases progress so that 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. Below is our sharing leadership on the team table.

Work Package	Leader	Members	Deliverables
1	-	-	Project Specification Report
2	-	-	Website
3.1	Alkım	Goktug, Eren	Analysis Report
3.2	Berke	Alperen, Alkım	Analysis Report
3.2	Goktug	Eren,Berke	Analysis Report
3.3	Eren	Alperen, Goktug	Analysis Report
3.4	Alperen	Alkım,Berke	Analysis Report
4.1	Alkım	Goktug, Eren	Jetson Nano
4.2	Berke	Alperen, Alkım	Python libraries
5.1	Goktug	Eren,Berke	High Level Report
5.2	Eren	Alperen, Goktug	High Level Report
6.3	Alperen	Alkım,Berke	Human detection on still images
6.4	Alkım	Goktug, Eren	Human detection on still images
7.1	Berke	Alperen, Alkım	Select a camera
8.1	Goktug	Eren,Berke	Real time human detection

8.2	Eren	Alperen, Goktug	Real time human detection
9.1	Alperen	Alkım,Berke	Demo
9.2	Alkım	Goktug, Eren	Demo
10.1	Berke	Alperen, Alkım	Low level Report
10.2	Goktug	Eren,Berke	Low level Report
11.1	Eren	Alperen, Goktug	GUI
11.2	Alperen	Alkım,Berke	GUI
12.1	Alkım	Goktug, Eren	Check distance
12.2	Berke	Alperen, Alkım	Check distance
13.1	Goktug	Eren,Berke	Collect info
14.1	Eren	Alperen, Goktug	Working Project
14.2	Alperen	Alkım,Berke	Working Project
15.1	Alkım	Goktug, Eren	Optimize Project
15.2	Berke	Alperen, Alkım	Optimize Project
16.1	Goktug	Eren,Berke	Deliver last demo
16.2	Eren	Alperen, Goktug	Deliver last demo
16.3	Alperen	Alkım,Berke	Deliver last demo

Table 2: Sharing Leadership On Team Table

7. 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].

Computer Vision: Computer vision is a field of artificial intelligence that trains computers to interpret and understand the visual world.

Tkinter: It is a standard Python interface to the Tk GUI toolkit.

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