COMP2043.GRP Interim Group Report: AI-Powered Digital Signage for Targeted and Personalized Advertisement

TEAM2024.06

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Chapter 1

Introduction

Digital signage is a powerful tool for delivering targeted advertisements to consumers. It is deployed in public spaces for marketing campaigns by displaying advertisement content in the AD pool and cannot be adjusted according to real-time attention. Typically, the effectiveness of advertising may not guarantee accurate delivery to target users (Forsberg, 2024).

Therefore, to address these challenges, this project proposed a new AI-empowered digital signage aimed at delivering targeted and personalized advertisements based on customers' behavior, preferences, and trends by using artificial intelligence (AI), computer vision, and large language models (LLMs). This chapter discusses the limitations of current digital signage and aligns these challenges with the objectives of the proposed solution.

1.1 Problems in Current System

While a degree of personalized advertising has been achieved in current AI-powered digital signage products, there are still some unresolved challenges. The key areas for improvement identified are as follows:

- **Limited personalization** Few facial analysis technology features lead to less diverse results in personalized pushes (Dimidenko, 2024).

- **Ineffective advertisement copies** Lack of personalized and attractive advertising messages due to the requirement of large investment (Dimidenko, 2024)

- **Real-Time performance tracking** Inability to analyze audience sentiment in real-time and gain feedback from users (Janardhanan, 2024).

- **Data privacy concerns** Consumer privacy can be potentially violated due to facial recognition and data analysis (Wolford, 2024). Stakeholders, especially end-users, worry about the misuse of personal data, which could lead to violations of privacy regulations.

These challenges highlight the need for a system that aligns with both stakeholder goals and user expectations.

1.2 Proposed Solution

The proposed digital signage system aims to address the identified challenges by meeting the specific requirements of the stakeholders. The key objectives are as follows:

- **Enhancing Personalization:** Improve the accuracy of personalized advertisements by using advanced. In addition to age and gender, the user's ethnicity is also detected to refine the classification of the population. This ensures advertisements are tailored effectively to diverse audience groups.

- **Create effective advertisement messages:** Outputting advertising messages through the LLM model, which can generate dynamic and context-sensitive advertisement descriptions.

- **Increase user feedback mechanism:** After the advertisements are played, the users are allowed to give feedback to the system through QR code to improve user satisfaction.

- **Ensuring Data Privacy:** The system employs real-time facial recognition and analysis without storing or transmitting identifiable user data. This is to ensure the compliance with privacy regulations and addresses stakeholder concerns about data security.

These objectives are designed to meet the needs of all stakeholders, including advertisers and end-users. By aligning the system's features with these requirements, the project aims to deliver a reliable, efficient, and user-friendly AI-powered digital signage solution.

Chapter 2

Background and Research

This chapter discusses the background and the related research of the project.

2.1 Literature Research

Digital signage has long been an important part of the advertising landscape, serving as a powerful tool for brand awareness and communication. With the rise of digital signage, it has increasingly been applied in various scenarios such as restaurants, corporate offices, and retail stores(Nick, 2020). According to DL (2022), **71%** of people consciously look at billboards while driving, indicating that billboards can effectively attract attention. In addition, according to Okolo (2024), the return on investment of billboards is as high as **497%**, and its effectiveness is expected to continue to increase by **10%** per year.

There are some digital signage solutions in the market, all capable of dynamically displaying the advertisements videos. However, their solutions have significant limitations. Two representative products are compared, **BrightSign** and **NEC Analytics Learning Platform(ALP)**, to highlight their strengths and weaknesses.

- **BrightSign**

  The product is powered by their own system BrightOS, which would provide the signage a suitable environment display the advertisement videos. Based on the BrightOS system, it may create a screen wall and make a multiple-screen advertisement. According to the data showing on BrightSign official website, over 2.5 million digital signage were sold and more than 130 countries installed BrightOS. However,

it still limited in time audience analysis and personalized content delivery. (Hoh, 2021).

- **NEC ALP**

  NEC ALP is an AI-Driven digital signage that develops AI-based analytics to automatically create recommendations for target customers based on their age and gender (NEC Display Solutions of America, Inc., 2019). Whereas, it cannot generate highly personalized advertisement messages based on the user characteristics. Additionally, Chansky (2023) has mentioned legal frameworks differ across regions, raising concerns that facial recognition technology may violate user privacy.

A comparison of existing digital signage solutions (see Table 2.1) highlights the advantages and gaps of current technologies, demonstrating how the system innovates upon them:

Table 2.1: Comparison of Digital Signage Solutions and the Proposed System

Feature	Static Billboards	Basic Digital Signage	AI-driven Digital Signage	Proposed Solution
Adaptability	✗	✗	✓	✓
Personalization	✗	✗	✓	✓
Ads Prompt Generation	✗	✗	✗	✓
Advertisement Completion Guarantee	✓	✓	✗	✓
Privacy Protection	✓	✓	✗	✓
User Feedback Integration	✗	✗	✗	✓

2.2 Market Analysis

Personalized ads not only attract the attention of potential customers but also drive product purchase conversions. Studies show that 80 percent of consumers are more likely to buy when they see a personalized shopping experience. This high correlation between personalization of ads and increased sales reflects the effectiveness of personalized push ads as a marketing strategy (Jessica, 2021).

Personalized advertising has a strong link with purchases because, as Blog (2024) points out, showing consumers products and services that match their preferences, personalized advertising creates a more pleasant shopping experience, reduces the annoyance that

customers feel when they see irrelevant ads, and makes users more receptive to the information presented.

Another reason for this strong correlation is that this type of advertising can strengthen customer loyalty and trust in products by promoting related categories of products based on the purchasing habits of customers with the same characteristics. This customer-centric approach fosters trust and encourages repeat purchases (Milano, 2024). Moreover, by continuously providing relevant content, product brands can cultivate long-term relationships with customers (Leung, 2024).

Chapter 3

Requirements Engineering

Requirements engineering is the process of identifying, analyzing, documenting, and validating the capabilities and constraints of a system to ensure it meets the needs of stakeholders (Macaulay, 2012). This chapter will illustrate the process of requirements engineering for the AI-empowered digital signage system.

3.1 Requirements Elicitation

Requirements elicitation is the first step in understanding stakeholder needs and ensuring the project aligns with academic and ethical standards. The following methods were used:

- **Academic Literature Review:**

  Relevant literature was reviewed to explore methodologies for delivering targeted and personalized advertisements.

- **Stakeholder Meetings:**

  Face-to-face meetings were conducted with the supervisor. These discussions validated initial requirements and facilitated iterative updates based on feedback. This ensured alignment with stakeholder expectations and project objectives.

3.2 Requirements Specification

Requirements are divided into functional requirements and non-functional requirements. Functional requirements define what the system should do to meet user needs. Non-

functional requirements specify how the system performs its tasks.

3.2.1 Functional Requirements

1. **User**
    - Engage with the digital signage to view personalized advertisement videos.
    - View identified personal demographic data and emotional state.
    - Provide feedback through a QR code-generated questionnaire at the end of the advertisement.
2. **System Administrator**
    - Access a marketing dashboard to monitor advertising performance using key indicators, such as viewer count and advertisement popularity.

3.2.2 Non-Functional Requirements

1. **Computer Vision (CV) Module**
    - Detect and capture the user's face when the user is approaching.
    - Perform classification task on user's demographic data (age, gender, ethnicity).
    - Analyze the user's emotional state (happy, angry, sad, neutral).
2. **LLM Module**
    - Use output from the CV module to formulate a tailored prompt.
    - Generate personalized advertising messages using an integrated LLM.
3. **Advertisement(AD) Pool**
    - Store the advertisement videos.
    - Store the corresponding advertisement brief.
4. **Analytical Module**

- Create a QR code on the screen to gather user feedback.
- Store and retrieve formatted feedback data from the user.
- Provide a dashboard for system administrators to monitor marketing effectiveness.

5. **Privacy Protection**
   - Delete captured face images immediately after processing to comply with GDPR and ensure user privacy (Wolford, 2024).
6. **Performance**
   - Process user data and deliver ads within 2 seconds to ensure timeliness.
7. **User Interface**
   - Display demographic analysis and personalized advertisement messages alongside the advertisement video.
8. **Maintainability**
   - The codebase should meet key software engineering development standards for later maintenance.

3.3 Requirements Validation

During the project, the team members made the following changes to the project requirements based on the supervisor's communication:

1. Equipment purchase requests were removed to optimize project expenses and focus on core features.
2. System usage by minors under the age of 17 was prohibited to uphold ethical standards.
3. Vocal and touch interaction features were omitted, as per supervisor recommendations during the project bidding stage.

4. The prerequisite for user agreement to ethical terms before face detection was removed to simplify user interaction.

5. The CV Module initially expected 10 face images input per person and output analysis result with the highest probability. Changed CV Module to expect only 1 image input to simplify workflow.

6. Face detection was paused during advertisement playback to reduce computational overhead.

7. Face detection was paused during advertisement playback to reduce computational overhead.

Chapter 4

Design

4.1 Personas

Persona is a user description that describes the user's characteristics and how they would interact with the system. It is intended to mock real user conditions to help the team predict user needs (Marshall et al., 2019).

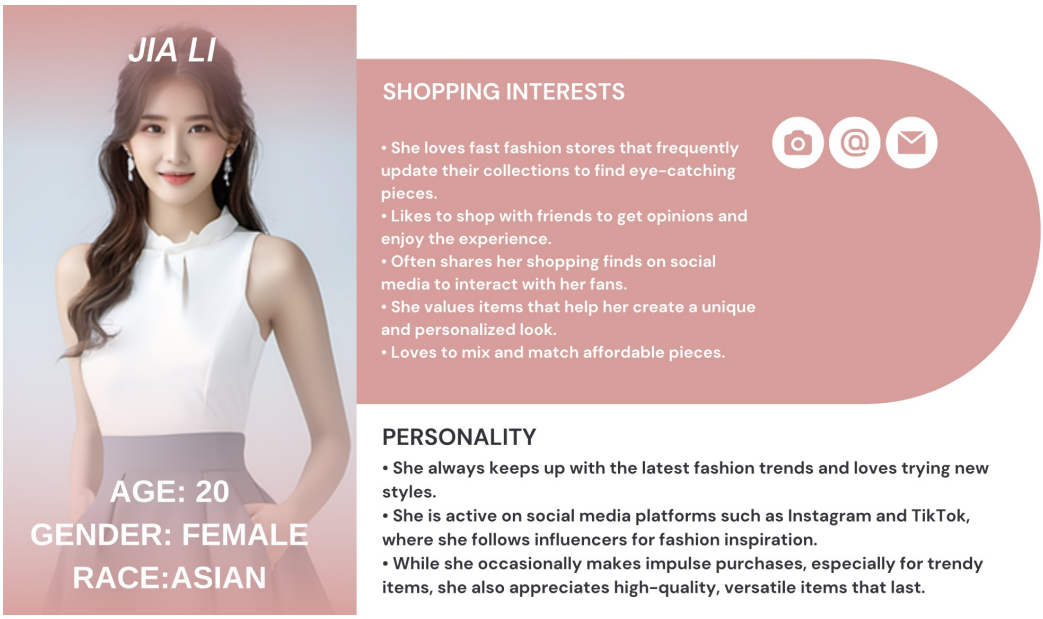


Figure 4.1: Persona 1

According to the JIA's shopping interests and personality as shown in Figure 4.1, the system would tend to recommend popular fast fashion items and cosmetics.

4.2 Pseudocode

Pseudocode is a tool for designing program logic and computational algorithms that limits the programmer's flexibility by specifying the algorithm in what is essentially a high-level language(Davis, 2019). Click here to visit the Pseudocode in Appendix.

4.3 Diagram Design

4.3.1 Use Case Diagram

Use case diagrams are utilized to capture the requirements of a system, which primarily focus on the system's design aspects. During the analysis of a system to identify its functionalities, use cases are developed, and the corresponding actors are determined Mule et al. (2015).

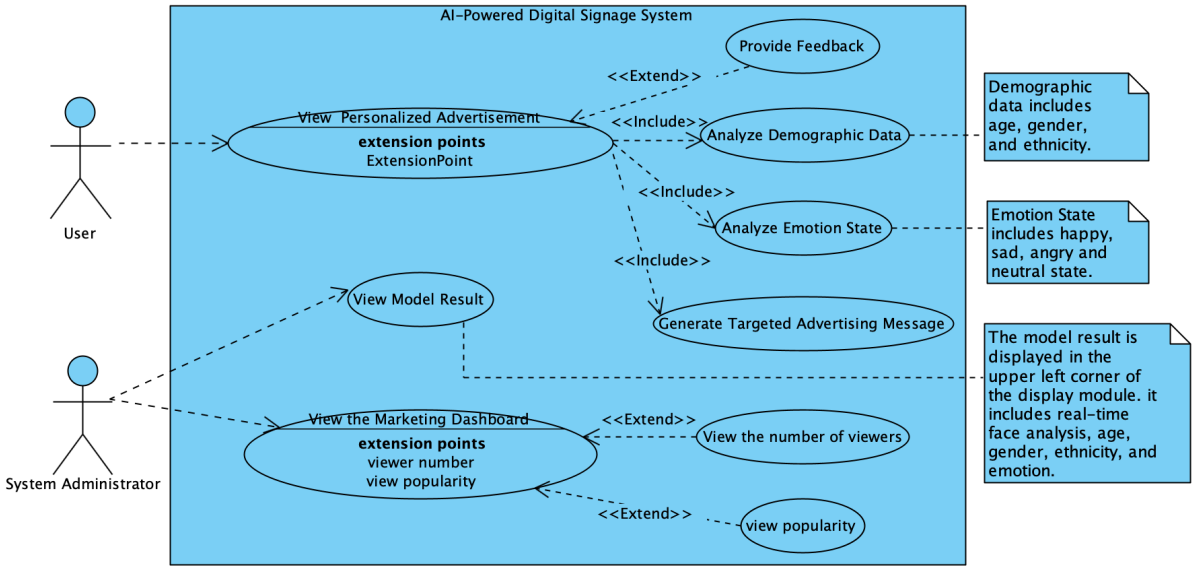


Figure 4.2: Use case Diagram

For the proposed AI-powered digital signage system, the use case diagram highlights its main functions and the interactions between two primary actors: users and system administrators.

Key Information

- This project introduces an AI-Powered Digital Signage System for targeted and personalized advertisements. Users can interact with the system by viewing personalized advertisements and provide feedback to improve and personalization.
- The system uses the CV Module to analyze real-time demographics and emotion data. In addition, LLM Module is employed generate targeted messages to for personalized advertisements.
- The system does not store user facial data in any database, ensuring full compliance with privacy regulations.

Description

Actors:

- User: The primary users who interact with AI-powered digital signage.
- System Administrator: Technical users responsible for monitoring and managing the system.

Use Cases:

1. **View Personalized Advertisements:** Users view personalized advertisements tailored to their real-time demographic and emotional data. Once users have viewed the advertisements, they can scan the QR code to provide feedback to improve personalization and targeting.
2. **View model result:** The system displays facial demographics such as age, gender and ethnicity, as well as emotions. This information is visible to system administrator as part of the interaction.
3. **Monitor Marketing Dashboard:** The system administrator accesses the marketing dashboard to review the number of viewers and popularity to optimize personalized advertisements.

4.3.2 Sequence Diagram

Sequence diagrams define interactions between objects in sequential order, bridging use cases and system design. They help developers detail object behavior, aid business staff in understanding workflows, and refine requirements into formal designs Unhelkar (2005).

View Personalized Advertisements

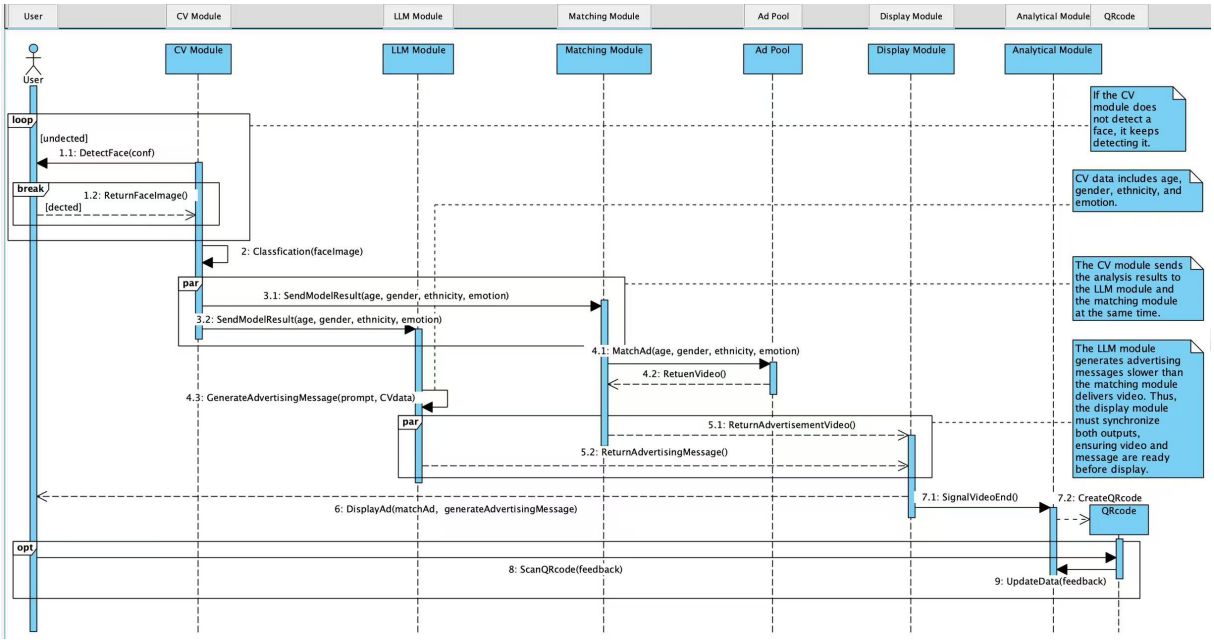


Figure 4.3: Sequence Diagram 1

Key Information

- The sequence diagram shows the functions of the system through the collaboration between modules. The loosely coupled design method is used to enable each module to work independently and interact through a clear data for efficient integration.

Description

- **CV (Computer Vision) Module:** The CV module is responsible for analyzing facial features of the face, such as age, gender, ethnicity, and emotion. The CV module sends the analysis results to the LLM module and the matching module. It does not participate directly in ad generation or matching logic.

- **LLM (Large Language) Module:** The LLM module generates personalized advertising messages based on the analysis results.
- **Matching Module:** The matching module selects ads from the advertising pool based on the inputs received.
- **Display Module:** This module displays personalized advertisements to the users. After the advertisement is displayed, a QR code will appears to collect user feedback.
- **Analysis Module:** Gathers feedback from users and generates a dashboard containing metrics such as viewer count and ad popularity.

View the Marketing Dashboard

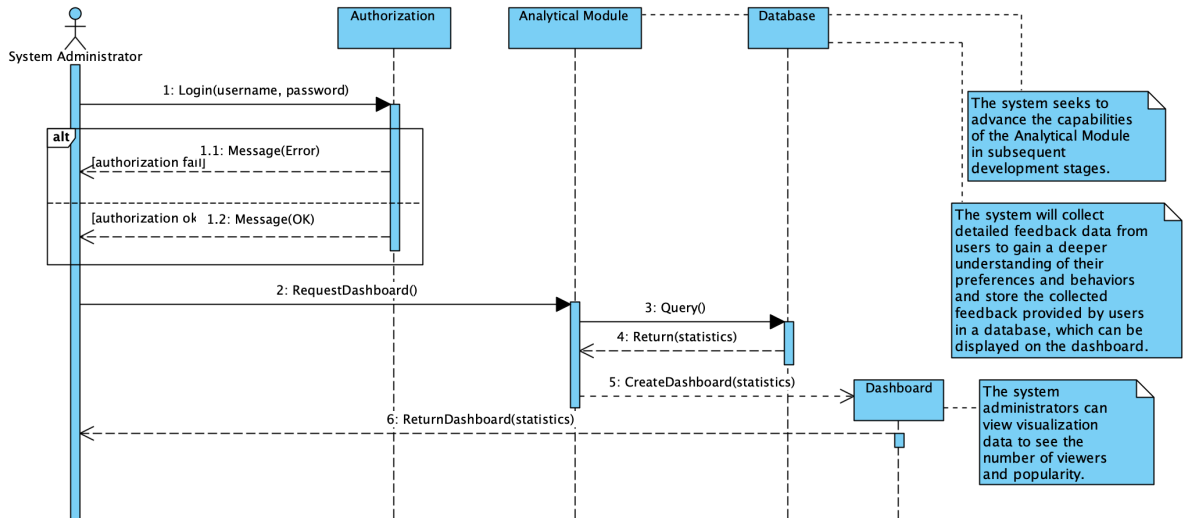


Figure 4.4: Sequence Diagram 2

Key Information

- This sequence diagram illustrates the content of the marketing dashboard in the use case diagram.

Description

- **Authorization:** The system administrator logs in by using a username and password, and the process is allowed to proceed upon successful authentication.

- **Analytical Module:** After successful authentication, the system administrator sends a request to the analytical module to generate the dashboard.

- **Dashboard:** The analytical module responds with dashboard data, which includes additional optional metrics such as the number of viewers and ad popularity.

View Model Result

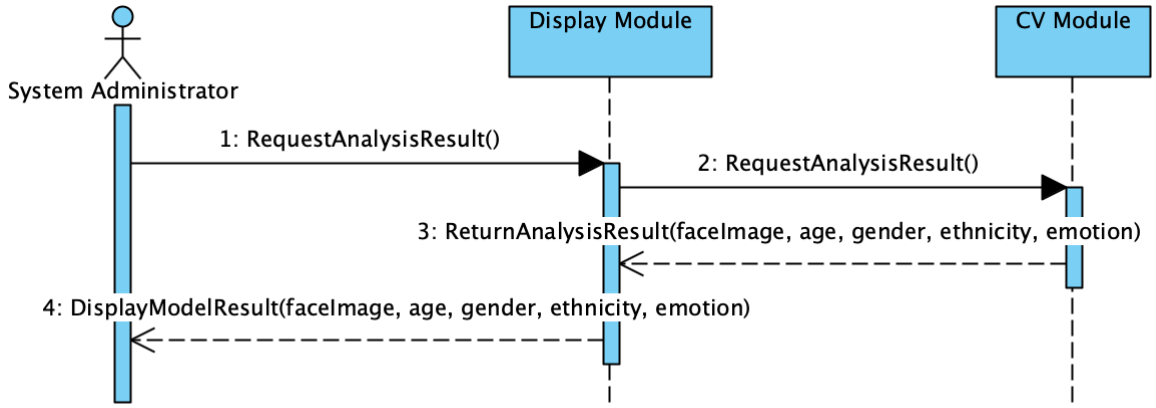


Figure 4.5: Sequence Diagram 3

Key Information

- The sequence diagram shows the process of system administrator view model results.

Description

- **Display Module:** The system administrator requests the display module to view the analysis result.

- **CV Module:** The display module requests the CV module to view the analysis result. The CV module displays the analysis result to display module, including the face image, age, gender, ethnicity, and emotion.

- **Display Module:** The display module displays the analysis results from the CV module, including age, gender, race, and emotion, to the system administrator.

4.3.3 State Diagram

Key Information

- The State Diagram shows transitions between various states in the system.

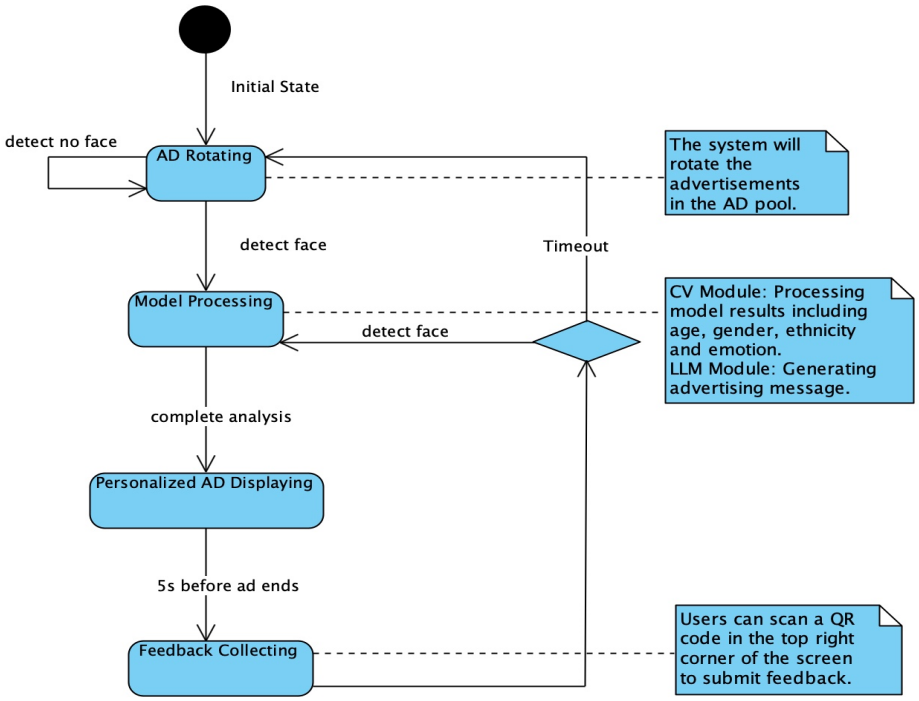


Figure 4.6: State Diagram

Description

- **AD Rotating:** The system starts in the Ad Rotating state. In this state, it cycles through advertisements from the ad pool while continuously detecting faces.
- **Model Processing:** When a face is detected, it enters the Model Processing state.
- **Personalized AD Displaying:** After the analysis is completed, the system enters the personalized ad displaying state, pauses the ad rotation, and displays personalized ads.
- **Feedback Collecting:** Five seconds before the advertisement ends, the system transitions to the Feedback Collecting state. A QR code is displayed for users to

submit their feedback. If a face is detected during this state, the system returns to the Model Processing state for further analysis. If no face is detected, the system transitions back to the Ad Rotating state to resume cycling through advertisements.

Chapter 5

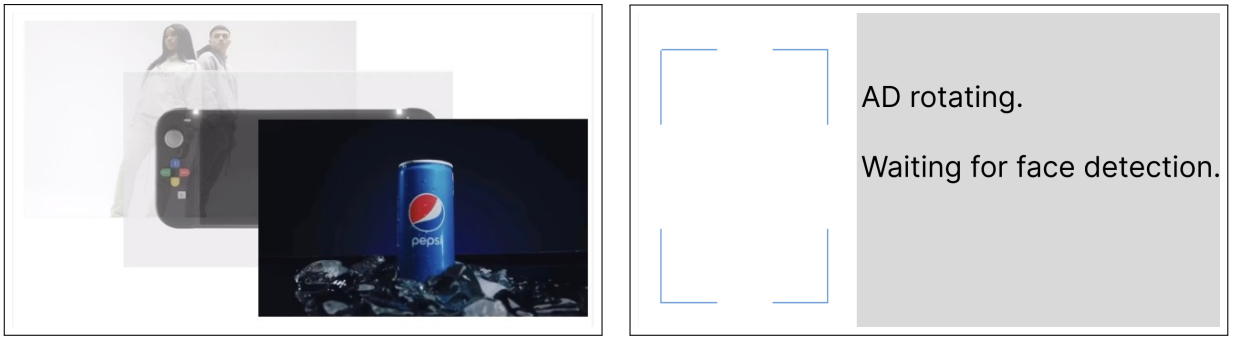
User Interface

5.1 User Interface Per State

This section will depict the user interface for each state and interactions in State Diagram. In all figures shown below, sub-figure (a) represents for User Screen where advertisements are displayed for User, and (b) represents for Backend of the system where system states are monitored by System Administrator.

State: AD Rotating

When no face is detected by the CV Module, the system is in AD rotating state. The User Screen continuously displays a predefined sequence of advertisements in the AD pool, ensuring constant screen utilization. The CV module continues to monitor a face while ads are playing.

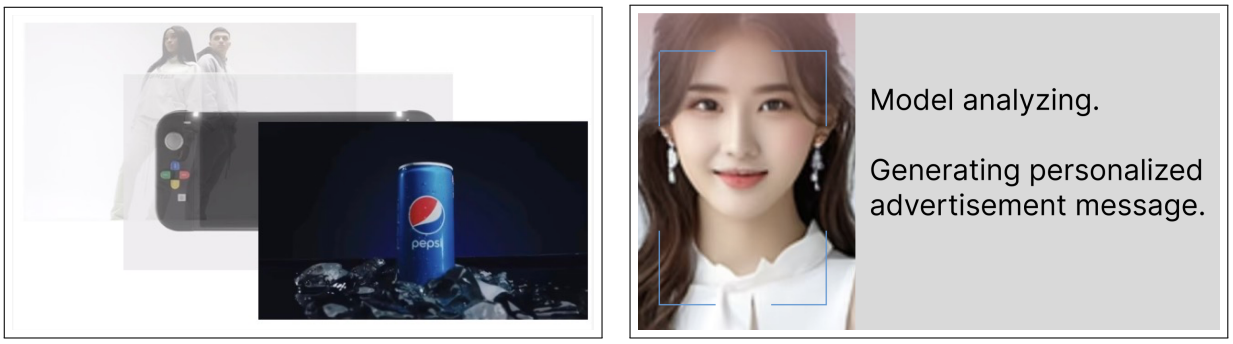


(a) User Screen (b) Backend

Figure 5.1: AD Rotating

State: Model Processing

When any face is detected by the CV Module, the system switches to the Model Processing state. CV and LLM Module start to perform respective tasks. AD from the last state still displays in User Screen.

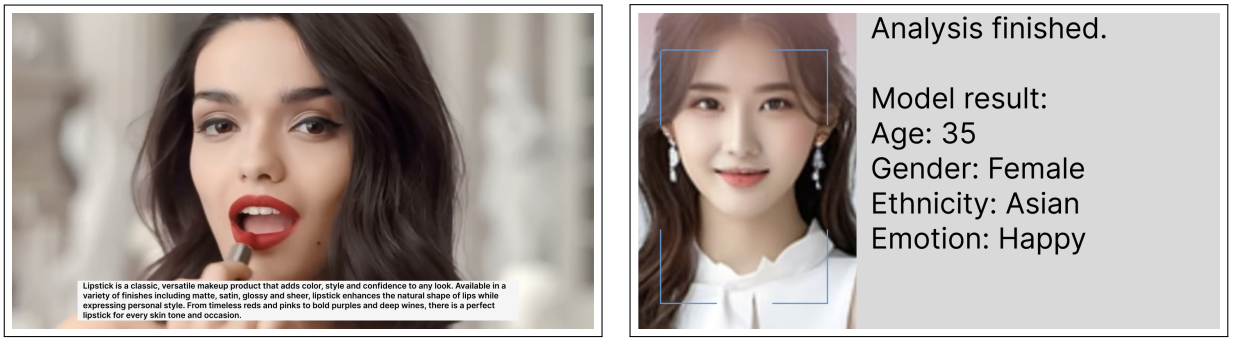


(a) User Screen (b) Backend

Figure 5.2: Model Processing

State: Personalized AD Displaying

Once the model process is complete, the system immediately replace the advertisement rotation on User Screen by matched video from AD Pool. The personalized message generated by LLM is shown at the bottom identical to a subtitle. The analysis results are shown in Backend.



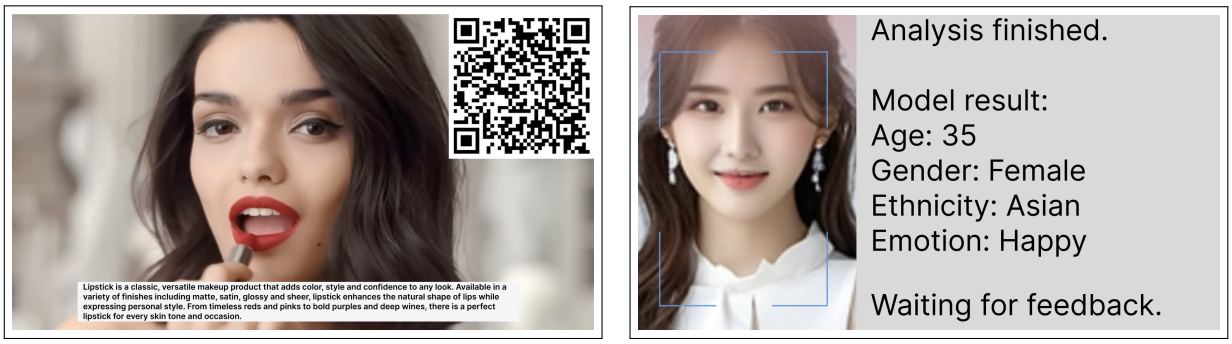
(a) User Screen (b) Backend

Figure 5.3: Personalized AD Displaying

State: Feedback Collecting

Once the personalized AD is about to end in 5 seconds, the system will enter the Feedback Collecting state while continuing to display the AD. Analytical Module would generate a

QR code to be popped up on the upper-right corner of User Screen. User are capable of scanning the code and adding their feedback to in external questionnaire.



(a) User Screen (b) Backend

Figure 5.4: Feedback Collecting

5.2 Dashboard

Dashboard is created by Analytical Module for System Administrator to review Advertising effectiveness with two important metrics: popularity and number of viewers.

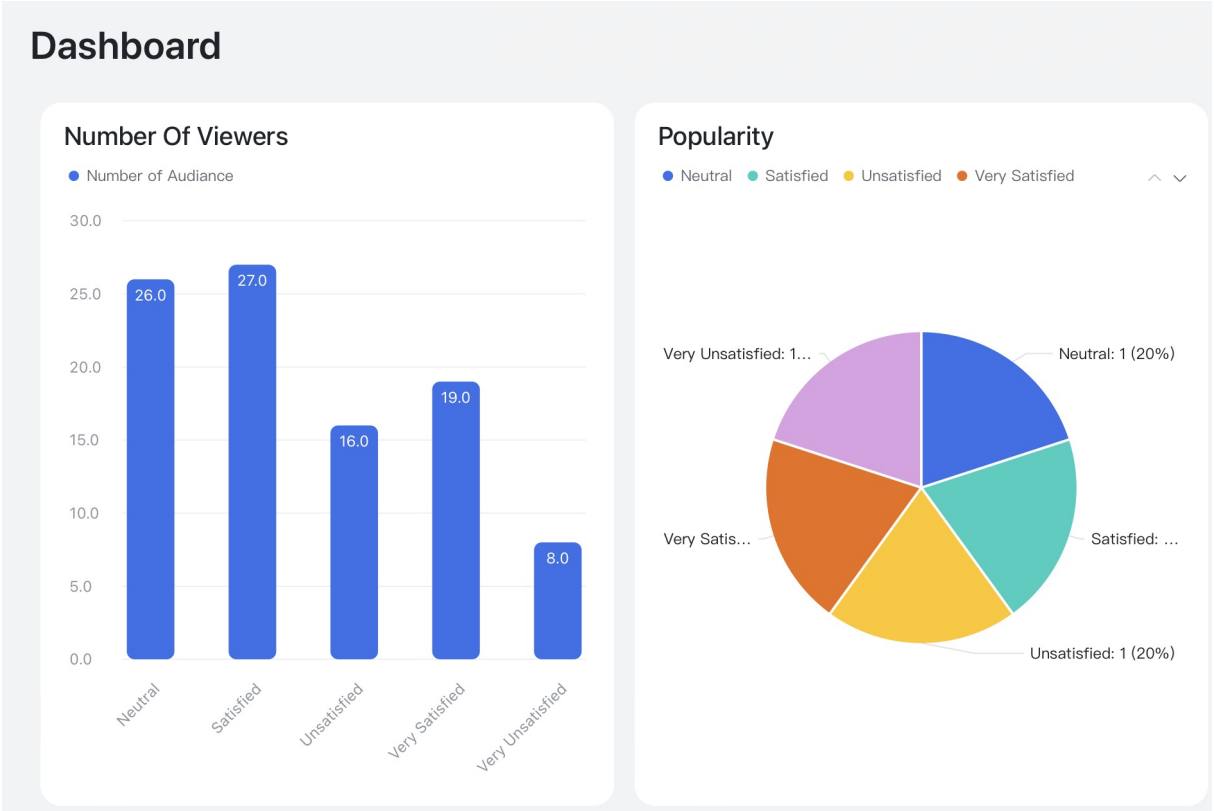


Figure 5.5: Dashboard

Chapter 6

Implementation

This chapter outlines the progress made in system implementation and prototypes development.

6.1 Key Technology Stack

- Python – Base programming language
- PyTorch – Machine learning framework
- OpenCV – Image Capture tool
- YOLOv11 – Face detection
- ResNet18 – Backbone for emotion classification task
- ResNet50 – Backbone for demographic data classification task
- Llama-3.2-1b-Instruct – Pretrained LLM for personalized advertisement message generation

6.2 Iterative Development Process

6.2.1 Initial Research

Description

At the beginning of this project, the team decided to research on available public dataset for demographic and emotional analysis. In addition, CV Module is scheduled to be implemented first.

Achievement

Team members chose open source dataset UTKFace for demographic model training and FER2013 for emotional analysis model training.

Feedback

The datasets were deemed sufficient. Stakeholders suggested parallel development of the CV and LLM modules.

Improvement

The team decided to focus on CV Module first while assigning 1 team member to explore pre-trained LLM models in parallel.

6.2.2 CV Module Development

Description

The CV Module needs to perform tasks on:

- face detection
- demographic classification
- emotion analysis

Literature research was conducted to identify the best approaches for training these models.

Achievement

1. YOLOv8 is leveraged to perform the face detection due to its effectiveness and efficiency. However, it occasionally misclassified incomplete faces which caused negative effects on downstream tasks.

2. ResNet is selected to be the backbone for both demographic and emotion classification due to its accuracy.

3. All models have been trained using Adam Optimizer with learning rate of 0.0001 together with a weight decay of $1e-5$.

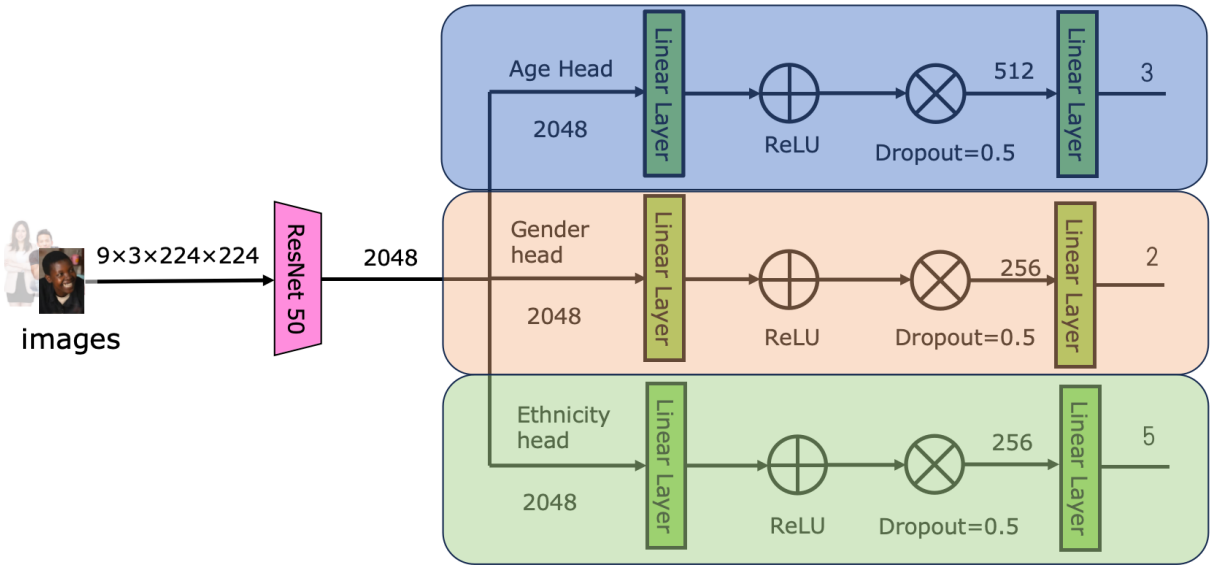


Figure 6.1: Proposed ResNet50 backbone model training on UTKFaces for classification on demographic data. The age head classifies for "17-30", "30-55", "55+". The ethnicity head classifies for "Asia", "India", "Middle East", "White" and "Black". Gender heads classifies for "men" and "women".

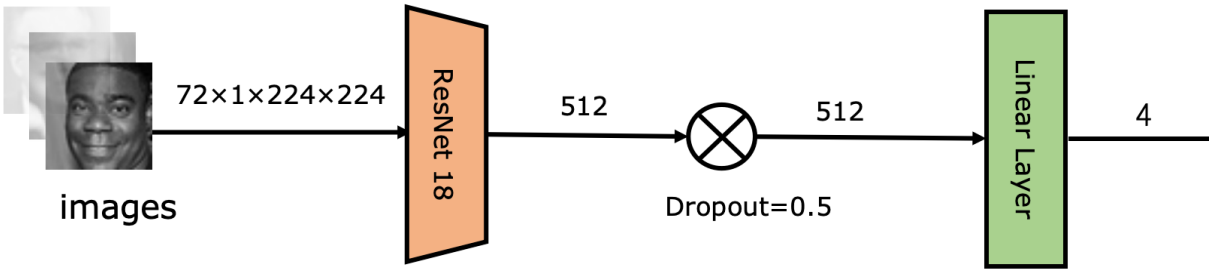


Figure 6.2: Proposed ResNet18 backbone model training on FER2013 for emotional analysis. The model classifies for "happy", "angry", "neutral", "sad".

Feedback

Stakeholder suggested replacing YOLOv8 with a simpler model if system performance was hindered. In addition, ResNet is suitable for the classification tasks. The team members were also encouraged to explore ways to improve model accuracy.

Improvement

1. Upgraded to YOLOv11 for faster and more accurate face detection. Set confidence threshold to 0.86 to ensure full-face detection.

2. Data augmentation techniques (random cutting, color jitter, random flip, randomly adjusted crop, random rotation) are applied on both datasets.

3. UTKFace has more than 20,000 images while FER2013 has only about 2,000 images. After changing ResNet50 to ResNet18 as backbone and adding dropout layer on emotion analysis task to handle identified over-fitting problem started from epoch 8, the accuracy on validation set is increased from 61.43% to 66.52%. The team also tried a VGG type model as a backbone but it is less effective.

4. In FER2013, the emotions were divided into 7 classes, but there were few opportunities for the emergence of "fear", "surprise" and "disgust", so the team decided to reduce it to 4 classes (happy, angry, neutral, sad). The accuracy has increased to 69.04%.

Accuracy of each model (acc@1)	**RenNet50**	**Resnet18**	**VGG50**
UTKFace	80.13%	73.68%	78.92%
FER2013	61.43%	69.04%	66.82%

Table 6.1: Accuracies of Different Models and Datasets

6.2.3 AD Pool Development

Description

An advertisement pool was constructed to store videos and accompanying background information.

Achievement

The AD pool was populated with advertisements video and mock data.

Feedback

The stakeholder suggested to search for more copyright free AD videos on video platforms such as YouTube. Moreover, categorized them into different groups complying with output from CV Module.

Improvement

Done as requested.

6.2.4 LLM Module Development

Description

The LLM Module should be capable to generate personalized advertising message for selected AD video from AD Pool using demographic and emotional data identified from the CV module. White et al. (2023) stated that demographic information collected provides an essential contextual background for the LLM model. Thus, the team attempt to leverage the user's demographic and emotional data to improve user viewing experience and satisfaction.

Achievement

Llama-3.2-1B-Instruct was chosen for its efficiency and compatibility with personal laptops.
Currently, it is capable to output structured message in the following format:
[Advertising Information]
[Personalized advertising message]

Feedback

The stakeholder recommended refining the LLM module for a controllable and targeted output in later stage of the project.

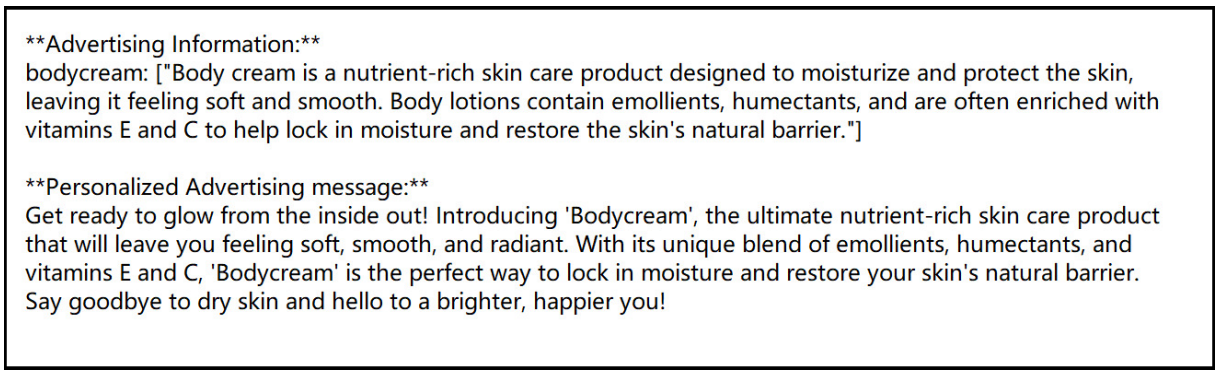


Figure 6.3: Screenshot of current LLM output for Persona 1, ('17-30', 'female', 'Asian', 'Happy'), encompassing both AD background information and personalized advertisement.

6.2.5 Matching Module Development

Description

Matching module should select proper advertisement videos from AD Pool for different age group, gender and ethnicity.

Achievement

Simple selection logic was successfully implemented using a Python dictionary structure.

Feedback

Pending evaluation in future stages.

6.2.6 Analytical Module

Description

The effectiveness of the selected ads should be evaluated by analyzing user engagement and satisfaction.

Achievement

A detailed questionnaire was designed to encourage viewers who use the digital signage to fill out feedback. The survey will cover a number of areas to comprehensively evaluate the effectiveness and user experience of the ad recommendation system.

Feedback

Stakeholder suggested implementing the eye-tracking model or exploring alternative evaluation methods.

6.2.7 Integration

Description

Integrate CV Module, LLM Module, Analytical Module into a unified application.

Achievement

CV and LLM Module are integrated into a unified application, running the way shown in pseudocode.

Feedback

Continue to integrate the remaining Modules in future.

6.3 Team Management Tools

1. **Feishu**
    - Manage personnel by establishing different chat groups to make it easier for team members to communicate respective tasks.
    - Record and summarize members' work in stages through shared documents.
    - File transfer is convenient and will not be automatically cleaned.
2. **GitHub**
    - Version control tool used in system developing.
    - GitHub link: https://github.com/RockYYY888/ai-digital-signage

Chapter 7

Problem Encountered

7.1 Technical

Face Detection Model

- **Problem**

  At the beginning, the team members tried to use YOLOv11 to perform both the face detection and demographic classification tasks. Due to the incompatible format of the dataset and YOLO's expected input, they could not be used. Therefore, the team needed to reconsider the dataset and model selection

- **Remedial action**

  The team decided to switch to ResNet backbone models. They developed a custom Dataset class in PyTorch to generate standard labels suitable for ResNet. To decrease the collapse caused by incompatibility of the input form, the team optimized the input form. By doing so, it leads to a 25% accuracy improvement. The improved dataset and label generate method increased the stability of the face detection model, which may provide the emotional analysis model with a stable and reliable data input.

Emotional Analysis Model

- **Problem**

  Initially, the team used three-channel color pictures, but the accuracy of the model

was low due to more interference noise. Subsequently, team members tried to convert the data into single-channel grayscale images and used the ResNet50 model for training. Converting to single-channel grayscale images improved accuracy by 3%. However, training the ResNet50 model caused overfitting by epoch 8, and the accuracy remained below expectations.

- **Remedial Action**

  To reduce the overfitting problem, the team chose the ResNet18 model, achieving 69 % accuracy(a 9 % improvement), the accuracy has improved 9%. At the same time, team members used techniques like random cut, normalization and reduced learning rate to 0.0001 to enhance the model performance.

- **Problem**

  The model has difficulty distinguishing between "sad" and "neutral" emotions. The training set for "neutral" is smaller, and the similarity between the two datasets causes the model to prioritize "sad".

- **Remedial Action**

  Shrinking the "sad" dataset improved accuracy in distinguishing between the two sentiments.

Face Detection

- **Problem**

  The YOLO model suffers from incomplete detection of some sample regions when dealing with the face analysis task, leading to occasional missing face region analysis, which affects the accuracy of sentiment analysis.

- **Remedial Action**

  The team set a confidence threshold of 0.86 for YOLO, increasing the likelihood of capturing full facial images.

7.2 Interpersonal

Misunderstanding About Equipment Procurement

- **Problem**

  At the beginning of the process of determining the required equipment, we had a misunderstanding about the equipment procurement of the GRP course, and we mistakenly thought that the required equipment could be purchased by the school.

- **Remedial action**

  We decided to use our computer in the development and testing stage, and in the final demonstration stage, we planned to borrow the display equipment from the IT service.

Advertisement Selection

- **Problem**

  The initial search of advertisements without clear classification criteria and insufficient research on the literature, led to a narrow and unfocused selection of advertisements.

- **Remedial action**

  The team conducted a literature review to establish clear classification criteria. The new classification standard increased the types of advertising from **6** to **30**, and the coverage was greatly improved. This improved the system's adaptability and aligned content with user preferences.

Git Usage Issues

- **Problem**

  When using Git, there is no standardized operation process, which leads to unclear submission information and chaotic branch management. When uploading files, it is difficult to track changes and their purpose without including the correct submission information. In addition, improper branch management leads to file conflicts when

merging branches.

- **Remedial action**

  Clear specifications for branch management and commit messages are established, which reduces branch conflicts, facilitates understanding, improves code maintenance efficiency, and contributes to a more effective and organized development process.

7.3 Management

Time Management Issue

- **Problem**

  Our primary focus in November was on training the models, leaving limited time for revising the interim report.

- **Remedial action**

  As a result, we had to work collaboratively and efficiently to make quick adjustments to the report before the deadline.

Code Collaboration Issues

- **Problem**

  The allocation of coding tasks to multiple team members resulted in conflicts, primarily due to differences in implementation approaches and simultaneous modifications to shared components, which complicated integration and slowed progress.

- **Remedial action**

  Pair program tasks and avoid modifying shared components simultaneously. Additionally, ownership of specific components is clarified, ensuring that each team member is responsible for a designated area of integration.

7.4 General Improvement

To improve team performance, collaboration, we proposed to apply two main methods:

Peer Review

To evaluate our team's work, the team used a structured peer review approach to assess the work, where team members check each other's work and provide feedback and suggestions to improve the quality of the deliverables. This process highlights the strengths of teamwork and mutual support, points out areas for improvement, and provides guidance for individual and team development throughout the project.

Reflexive Thinking

In addition to peer review, we have reflection sessions at each meeting to promote reflection on what the team had worked on and the decision-making process. At the end of each project phase, the team collectively discussed what went well, challenges encountered, and possible improvements for the next phase. These can be based on individual expertise for effective task allocation and good communication practices, as well as areas for improvement. By addressing these issues, the team implemented strategies such as setting clearer goals for meetings, which led to significant improvements in efficiency and productivity. Reflective thinking fostered a culture of continuous learning and adaptation, ensuring continued progress throughout the project.

Chapter 8

Time plan

Time Allocation

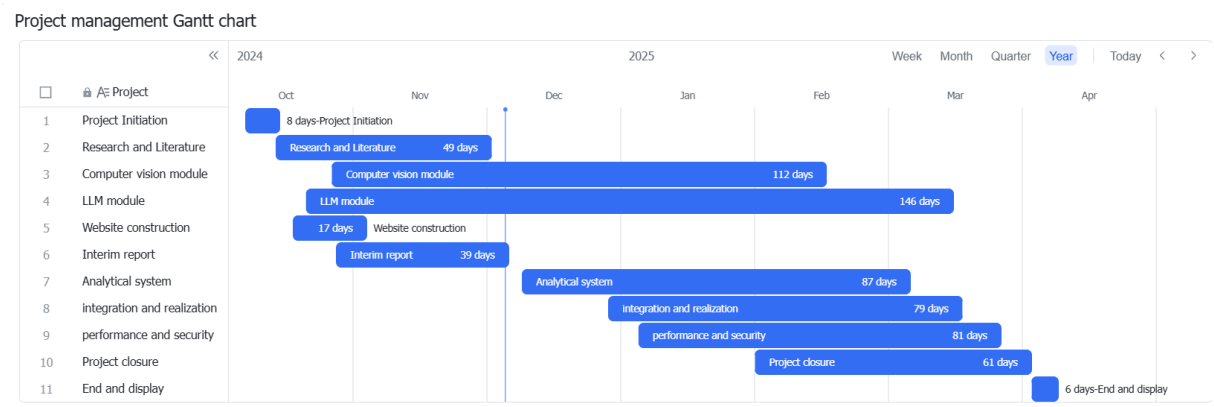


Figure 8.1: current timeline

This Gantt chart illustrates the time allocation from October 2024 to early December 2025 and plans for subsequent tasks until April 2025. Each phase is designed to ensure systematic progress towards the project objectives. Below are the key tasks and milestones:

- In **October 2024**, the team focused on understanding project requirements, adhering to ethical principles, and establishing a foundational knowledge base. This phase included studying the project scope and developing an initial website to describe this project.
- In **November 2024**, this phase prioritized implementing and integrating critical functionalities, including the advertisement selection module and the LLM-based

recommendation system. The team conducted preliminary testing to ensure compatibility and system stability.

- From **November to early December**, the focus shifted to integrating completed modules, preparing the interim report, and addressing feedback from preliminary evaluations.

Future Time Plan

From early December 2024 to April 2025, the team will focus on the following tasks to complete this project:

1. Analysis Module Development
    - Design and advanced analysis module to collect and process system output data.
    - Optimize system performance and improve the accuracy of advertisement delivery through real-time data analysis.
2. Eye-Tracking Model Training
    - Train and integrate eye-tracking models to detect the attractiveness of ads to users and evaluate the effectiveness of ads.
3. final Integration and Deployment
    - Complete the final integration to ensure that all system components can be interconnected to complete the functionality of this project.
    - Conduct deployment testing to verify system stability and readiness for real-world use.
4. Performance and Security Optimization
    - Refine system performance by optimizing resource allocation and processing speed.
    - Strengthen security protocols to mitigate vulnerabilities and enhance the system's robustness.

Reflection

This section presents a comparative analysis between the original and current timelines, highlighting accomplishments, areas of improvement, and unfulfilled goals. A visual representation of the original project Gantt chart is provided to facilitate this comparison.

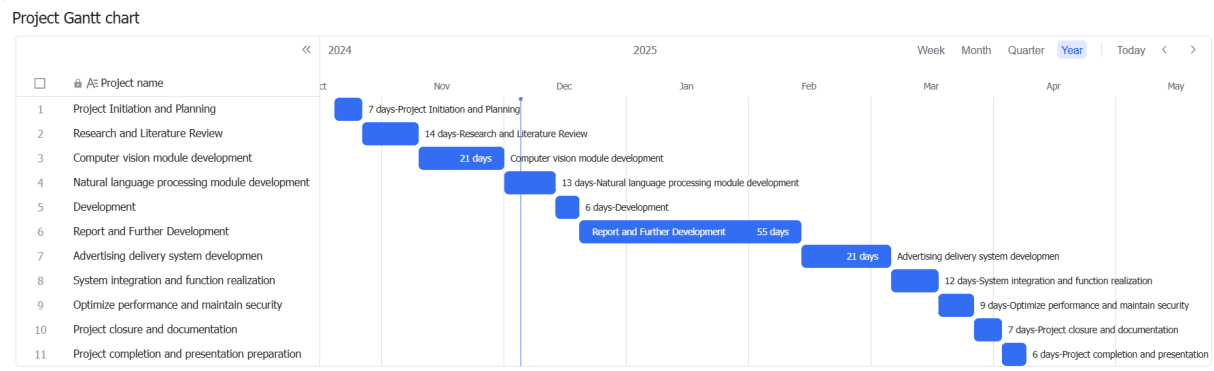


Figure 8.2: original Gantt chart

1. Identified Shortcomings of the Original Timeline

    - Resource Imbalance: Concurrent work on a single module often led to uneven distribution of tasks among team members.
    - Early Development Challenges: In the initial stages, assigning fewer people to module development proved more effective, highlighting inefficiencies in the initial resource allocation.
    - Inactivity Periods: Extended periods of inactivity on certain modules caused memory lapses and increased uncertainty, hindering overall progress.

2. Reasons for Timeline Modification

    - Optimized Resource Allocation: Responsibilities were reassigned based on team members' expertise, ensuring a more balanced workload and efficient task execution.
    - Reduced Task Overlaps: Adjustments were made to minimize inefficiencies caused by overlapping tasks and miscommunication within the team.

- Ensured Consistency: Continuous progress was prioritized by avoiding prolonged inactivity on specific modules, reducing delays and misunderstandings.
- Improved Workflow: The updated timeline better aligns with the complexity and inter-dependencies of the modules, enhancing overall project efficiency.

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Appendix A

Meeting Minutes

Week 3.1

Meeting Overview

- **Time:** 2024.10.14 12:00 PM
- **Chairperson & Secretary:** Kian Ming Lim & Xinna Su
- **Present Members:** Supervisor & All Team Members

Meeting Content

1. **Brief Self-Introduction**
2. **Discuss Project Purpose.**
3. **Project Outline**
    - **Data Collection:** Open-source dataset (Asian version).
    - **Computer Vision:** Automated recognition.
    - **LLM:** Online API for language model integration.
    - **Advertising Delivery:** Demo online video for testing.
    - **Interaction & Optimization:** User interaction and system optimization.
    - **Analytics:** Dashboard for analytics and optimization.

4. **Additional Information**
    - Confirm necessity of mentioned functions.
    - Ethics form submission (Deadline: Before 10.31).
    - Complete functionalities before interim report.

To-Do List

1. Confirm purchase list – Zhitong GUO, Xinna SU
2. Choose dataset – Yiwei LI, Ang LI
3. Complete ethics form – Yuyang ZHANG, Zelin XIA
4. Identify learning needs and plan – Yiwei Zelin Ang

Week 4.1

Meeting Overview

- **Time:** 2024.10.21 12:00 PM
- **Chairperson & Secretary:** Yiwei Li & Xinna Su
- **Present Members:** Supervisor & All Team Members

Meeting Content

1. **Review Minutes**
2. **Recap and outline remaining tasks.**
3. **Model Presentation**
    - Software development.
    - Recognition of age, gender, and emotion.
    - Eye-tracking for engagement.
    - Dashboard for data analysis.

- Focus on CV and LLM.

4. **Equipment Adjustment:** Borrow a big screen instead of buying one.

To-Do List

1. Device Request – Xinna SU
2. LaTeX Notes – Xinna SU, Zelin XIA
3. Website Development – Zhitong GUO, Ang LI
4. YOLO Model – Zelin XIA, Yiwei LI
5. Feedback System – Yuyang ZHANG, Xinna SU
6. Diagram Check – Yiwei LI

Week 5.1

Meeting Overview

- **Time:** 2024.10.28 12:00 PM
- **Chairperson & Secretary:** Zhitong GUO & Zelin Xia
- **Present Members:** Supervisor & All Team Members

Meeting Content

1. **Completed & submitted the Project site.**
2. **Learnd and utilized a pretrained face detection YOLOv11 model.**
3. **Show better model we found and outline the product development plan:**
    - Additional features for gender and age recognition.
    - Potential for racial recognition.
4. **Website review and recommendations:**
    - Streamline content to highlight key attributes.
    - Add images and rearrange them for better aesthetics.
    - Deploy the updated website to the server.

To-Do List

1. Complete & Submit the site – Ang LI, Zhitong GUO, Yuyang ZHANG, Yiwei LI
2. Train & learn the YOLO model – Zelin XIA, Yiwei LI, Ang LI
3. Find suitable ads for different people. – Yuyang ZHANG
4. Starting doing the interim report – Xinna SU, Zhitong GUO, Yuyang ZHANG
5. Recheck the criteria and requirements in the handbook – Yiwei LI, Yuyang ZHANG, Xinna SU

Week 6.1

Meeting Overview

- **Time:** 2024.11.04 12:00 PM
- **Chairperson & Secretary:** Xinna SU& Zhitong GUO
- **Present Members:** Supervisor & All Team Members

Meeting Content

1. **Completed & Submitted the Project site**
2. **Learned and utilized a pretrained face detection YOLOv1 model.**
3. **Trained a Resnet18 for demographic data classification with UTK dataset:**
    - **Gender:** Male/Female
    - **Age Group:** 16- (Young)/17-45 (Young)/46+ (Senior)
    - **Ethnicity:** White/Black/Asian/Indian/Other
4. **Find suitable ads (10s) for different people:**
    - Find reasonable advertisements for each group.

To-Do List

1. Continue with the interim report –Xinna SU, Zhitong GUO
2. Emotional Analysis model training and integrating –Ang Li, Zelin Xia
3. Laptop runnable LLM exploring & prompt engine – Ang Li, Yiwei Li
4. Look for articles on age division & consumption customs –Yuyang ZHANG, Xinna SU
5. Keep training CV part –Yiwei LI
6. UML diagram –Zelin XIA

Week 7.1

Meeting Overview

- **Time:** 2024.11.11 12:00 PM
- **Chairperson & Secretary:** Zelin XIA & Yiwei LI
- **Present Members:** Supervisor & All Team Members

Meeting Content

1. **Update CV models**
    - Adjusted all CV models to process only one picture at a time, reducing the input size from 10 pictures to 1 for better performance and efficiency.
2. **Improving User Experience**
    - Revised the video display logic to ensure a smoother and more seamless experience for users.

To-Do List

1. Continue with the interim report – Xinna SU, Zhitong GUO
2. Training the CV part model – Ang LI, Yiwei LI
3. Prompt engineering – Zelin XIA
4. Fix the AD folder in the new age group – Yuyang ZHANG
5. Set up GitHub – Ang LI, Yiwei LI

Week 8.1

Meeting Overview

- **Time:** 2024.11.18 12:00 PM
- **Chairperson & Secretary:** Yuyang Zhang & Ang LI
- **Present Members:** Supervisor & All Team Members

Meeting Content

1. **Combine LLM MOdel**
    - Combine LLM models and demographic-emotion model and produce it.
2. **Automatic Search**
    - LLM Model will search advertisements from advertisement pool automatically
3. **Softw Engineering**
    - Very Important for the project.
4. **Interim Report**
    - Our model may show in the report.

To-Do List

1. Complete the interim report – Xinna SU, Zhitong GUO
2. Implement a matching algorithm for demographic-based ad selection – Yiwei LI, Ang LI
3. Integrate LLM with CV data and matched text files – Zelin XIA, Yuyang ZHANG
4. Combine and debug code for parts 2 and 3 – Yiwei LI, Ang LI
5. Submit the final code to the Git repository.

Week 9.1

Meeting Overview

- **Time:** 2024.11.28 15:00 PM
- **Chairperson & Secretary:** Yuyang Zhang & Ang LI
- **Present Members:** Supervisor & All Team Members

Meeting Content

1. **Interim Report**
    - The interim report was completed and sent to the supervisor for comments.
2. **Comments for interim report**
    - Correct the interim report according to the marking criteria provided.
3. **Comments for Background and Research**
    - Identify and highlight how the actual needs of the market and the shortcomings of existing technology drive the development of the project.
    - Strengthen arguments with references to industry statistics and literature.
4. **Lack of statistics**
    - Develop a comparison table that lists the functions of different types of signage.
5. **Include additional diagrams**
    - Ensure the following diagrams are included:
        - Use Case Diagram: To showcase user interaction with the system.
        - Activity Diagram: To visualize the workflow of key processes.
        - Sequence Diagram: To detail the interactions between system modules.

To-Do List

1. Continue developing our interim report. – Xinna SU, Zhitong GUO
2. Initial plan after interim report DDL.
3. Add thread control that lets the CV model wait for LLM model to deliver the result, then do the next detection.

Appendix B

User Evaluation Questionnaire

This is the evaluation questionnaire.

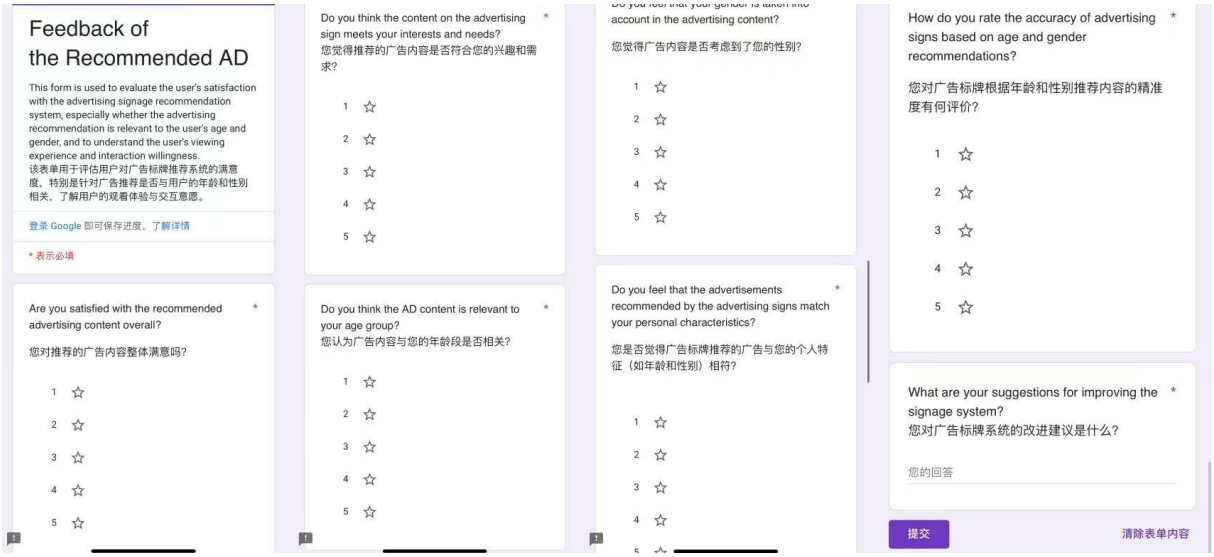


Figure B.1: The contents of questionnaire

Appendix C

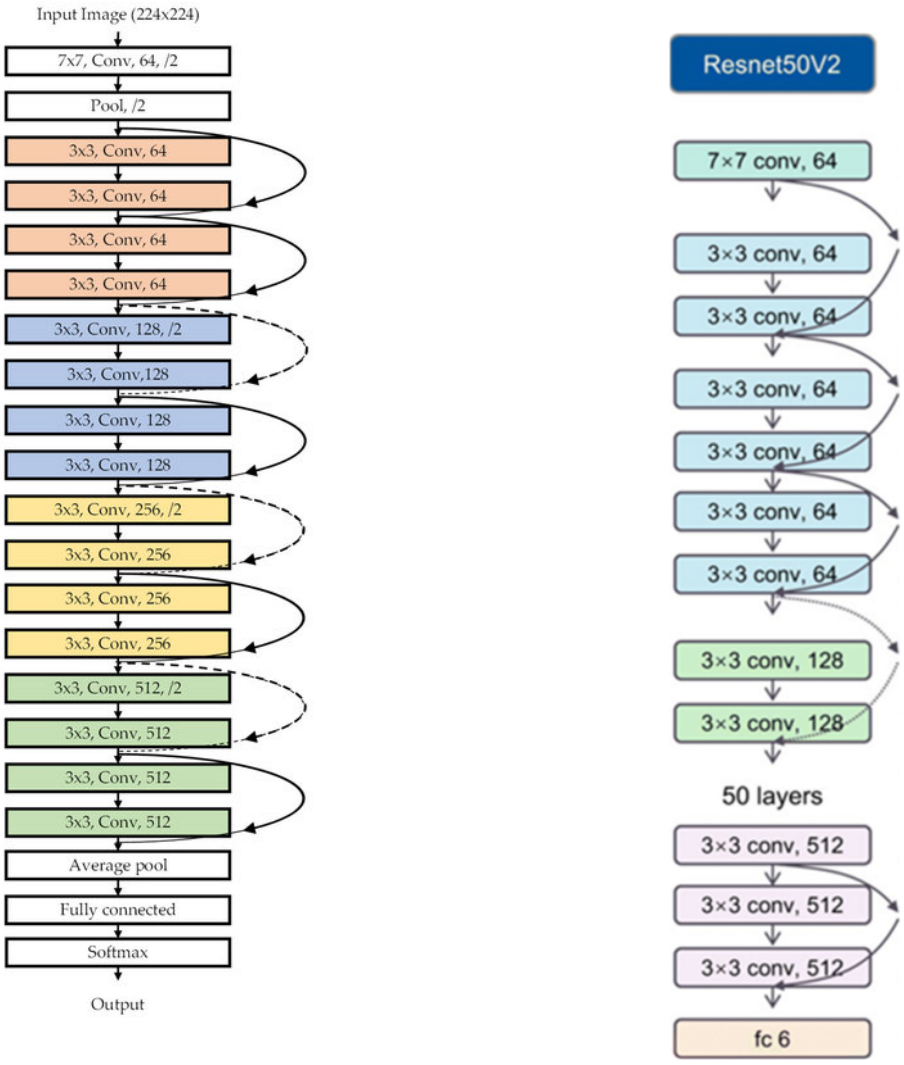
Pseudocode

```
# Pseudocode for Face Detection, Model Inference, and Text Generation Process
Begin Program
While (Video Stream Active):
    # Capture a frame from the webcam
    frame = webcam.capture()

    # Wait for previous detection and processing tasks to complete
    Wait for detection_done_event

    # Perform face detection using YOLOv11
    faces = YOLO.detect_faces(frame)

    # If faces are detected in the frame
    If faces detected:
        # Crop the detected face from the frame
        face_region = crop(frame, face)

        # Predict demographic features (age, gender, race)
        demographic_predictions = DemographicModel.predict(face_region)

        # Predict the emotion of the detected face
        emotion_predictions = EmotionModel.predict(face_region)

        # Combine the demographic and emotion predictions
        combined_predictions = Combine(demographic_predictions,
emotion_predictions)

        # Initiate text generation for personalized advertisement based on
predictions
        Start new_thread(generate_personalized_text, combined_predictions)

        # Wait until the advertisement text generation is complete
        Wait for text_generation_done_event

        # Output the combined predictions and the generated advertisement
message
        output(combined_predictions, personalized_message)

        # Display the advertising message/video
        display(advertising_video)

    # Allow processing of the next frame
    continue
End Program
```

Figure C.1: Pseudocode

Appendix D

Backbone Structure



(a) The structure of ResNet18 (b) The structure of ResNet50

Figure D.1: ResNet50 is more capable for larger dataset and complex task while increasing risk of overfitting compared to ResNet18.