VIRTUAL 3D TOUR

Project Team

Dabeer Ul Haq Qureshi	21I-1518
Senan Faisal	21I-1546
Saad Ahsan	21I-2965

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Supervised by

Mr Zeshan Khan

Co-Supervised by

Mr./ Ms./ Dr. Supervisor Name

Department of Computer Science

National University of Computer and Emerging Sciences
Islamabad, Pakistan

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Chapter 1

Introduction

The purpose of this project proposal document is to outline the objectives and approach for the "Virtual 3D Tour" project, which aims to enhance tourism in Pakistan's northern areas by converting 2D images into immersive 3D visualizations. The project leverages advanced technologies like Convolutional Neural Networks (CNN), Large Language Models (LLM), and Neural Radiance Fields (NeRF) to create photorealistic 3D models from 2D images, providing users with an interactive and realistic virtual tour experience through a mobile app. This project seeks to boost tourism, promote the region's beauty, and set a new standard for virtual tourism.[11]. [1].

1.1 Problem Statement

The Virtual 3D Tour project aims to address the challenge of limited accessibility to Pakistan's northern areas due to geographical constraints and lack of awareness about their natural beauty and cultural significance. By converting 2D images into immersive 3D visualizations, this project seeks to provide a virtual tour experience that allows users to explore these regions from the comfort of their homes, overcoming geographical barriers and fostering a deeper appreciation for their unique attractions. This virtual platform will not only promote tourism but also serve as an educational tool, showcasing the diverse landscapes, historical sites, and local traditions of Pakistan's northern areas to a wider audience.

1.2 Scope

The Virtual 3D Tour project aims to create an immersive and interactive experience for users to explore Pakistan's northern areas. The scope of the project encompasses the

following key functionalities:

Data Collection and Processing: Gathering a comprehensive dataset of high-quality 2D images from various tourist destinations in the northern areas, followed by preprocessing and cleaning the images to ensure optimal quality for 3D model generation.

3D Model Generation: Utilizing advanced technologies like Convolutional Neural Networks (CNN) and Neural Radiance Fields (NeRF) to reconstruct photorealistic 3D models from the collected images, capturing the intricate details and unique characteristics of each destination.

Mobile App Development: Creating a user-friendly mobile app that allows users to seamlessly navigate and interact with the generated 3D models. The app will incorporate features such as zooming, panning, and rotation, providing a realistic and immersive virtual tour experience.

Informative Content Integration: Incorporating informative descriptions, captions, and historical context for each destination, generated using Large Language Models (LLM), to enhance the user's understanding and appreciation of the region's cultural heritage and natural beauty.

User Interface Design: Designing an intuitive and visually appealing user interface that is easy to navigate and provides a seamless user experience.

Testing and Refinement: Thoroughly testing the mobile app to ensure its functionality, performance, and compatibility with various devices. Gathering user feedback to identify areas for improvement and make necessary refinements to enhance the overall user experience.

Scalability: Designing the system to accommodate future expansion and updates, allowing for the addition of new destinations and features as the project evolves.

By focusing on these key functionalities, the Virtual 3D Tour project will provide a valuable and engaging tool for promoting tourism in Pakistan's northern areas, showcasing their natural beauty and cultural heritage to a wider audience.

1.3 Modules

1.3.1 Module 1

Data Acquisition and Processing

1. Collect a diverse dataset of high-quality 2D images from various tourist destinations in Pakistan's northern areas.

2. Clean and preprocess the images to ensure optimal quality for 3D model generation.

1.3.2 Module 2

3D Model Generation

1. Utilize advanced technologies to create photorealistic 3D models from the processed images.
2. Capture the intricate details and unique characteristics of each destination.

1.3.3 Module 3

Mobile App Development

1. Design an intuitive and visually appealing user interface for the mobile app.
2. Incorporate interactive features to provide a realistic and engaging virtual tour experience.

1.3.4 Module 4

Content Integration

1. Generate informative descriptions and captions for each destination using Large Language Models (LLM).
2. Include relevant historical and cultural information to enrich the user's understanding.

1.3.5 Module 5

Testing and Refinement

1. Conduct thorough testing to identify and address any bugs or issues.
2. Gather user feedback to improve the app's performance and user experience.

1.4 User Classes and Characteristics

User Class	Description
Tourists/End Users	A tourist or end user interacts with the 3D virtual tour system to explore different tourist locations. They are expected to have minimal technical skills and require a user-friendly interface to navigate, zoom, and interact with the immersive 3D scenes. They expect high-quality visuals and real-time performance.
Tourism Operators/Businesses	Tourism operators include travel agencies, hotels, and other businesses that promote tourist spots through the virtual tour platform. They manage content and listings, offering services to users. These users require tools to upload and update relevant information and track user engagement.
System Administrators/Developers	System administrators or developers are responsible for maintaining and optimizing the 3D tour platform. Their tasks include fixing bugs, enhancing performance, and ensuring that the backend infrastructure works smoothly. They possess high technical skills, especially in handling machine learning models, databases, and 3D rendering systems.
Tourism Authorities/Policy Makers	These users represent government or tourism departments who use the platform to monitor tourist trends and make decisions based on the engagement data. They require access to dashboards and reports for analyzing the popularity of locations and making policy or development decisions.

Table 1.1: User Classes and Characteristics

Chapter 2

Project Requirements

This chapter describes the functional and non-functional requirements of the project.

2.1 Use-Case, Event-Response Table, and Storyboarding

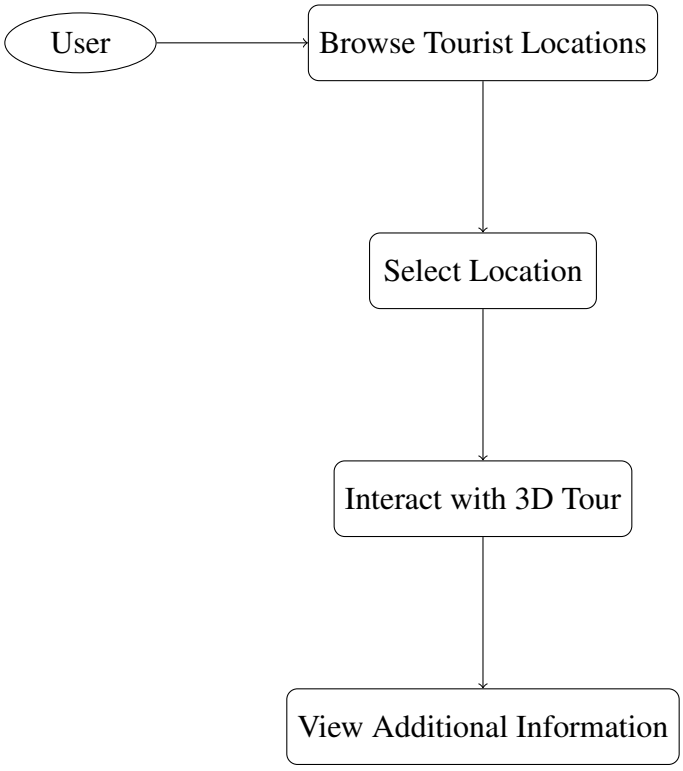


Figure 2.1: Use-Case Diagram for the 3D Virtual Tour Application

Event	Response
User selects a tourist location	System displays 3D tour of the location.
User interacts with the 3D model	System updates view based on user input (zoom, rotate).
User requests additional information	System retrieves and displays relevant details about the location.
User exits the application	System saves the session and logs the user out.

Table 2.2: Event-Response Table for the 3D Virtual Tour Application

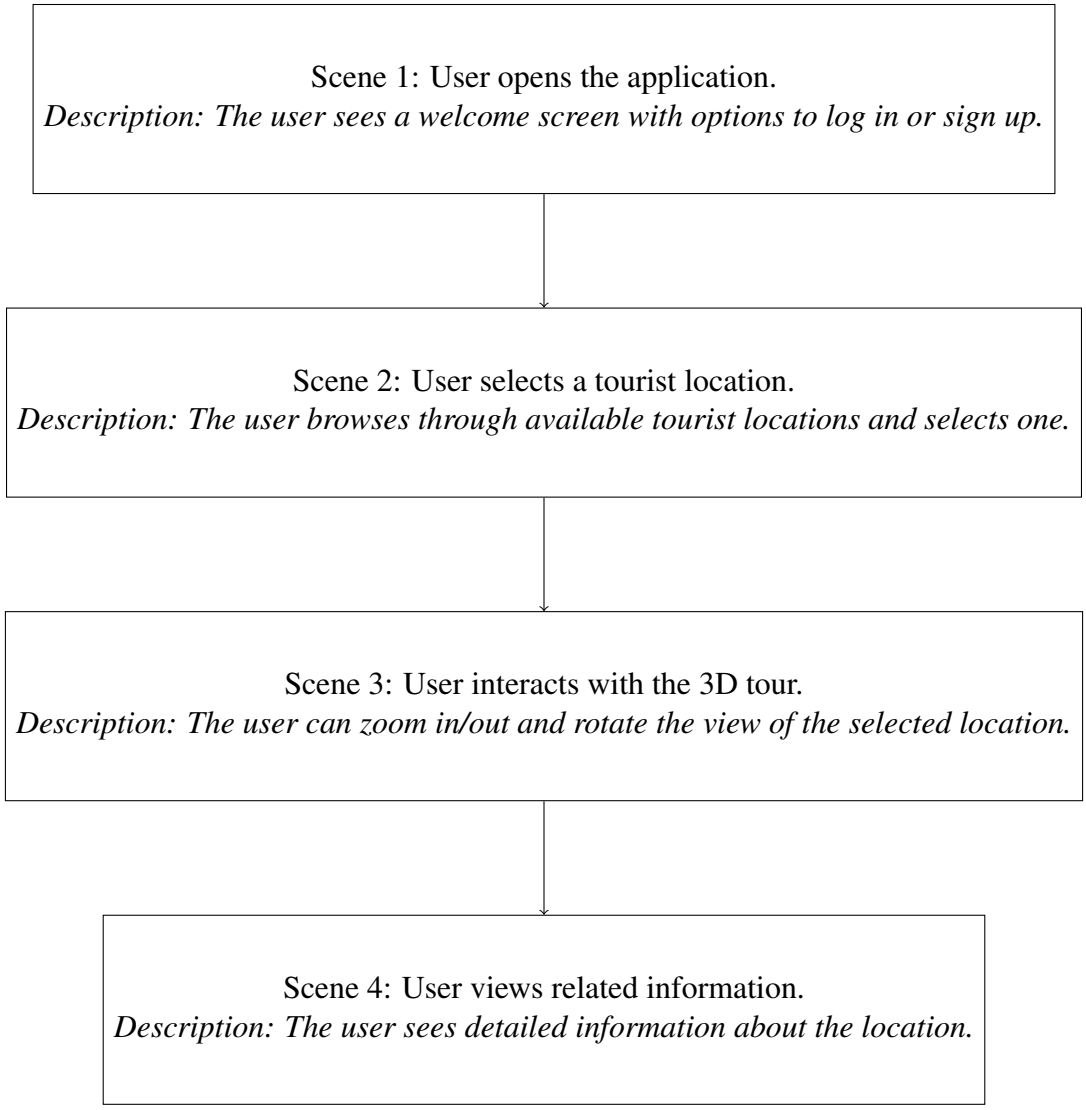


Figure 2.2: Storyboard for the 3D Virtual Tour Application

2.2 Functional Requirements

This section describes the functional requirements of the system expressed in the natural language style. This section is typically organized by features of the system. For the

Virtual 3D Tour Project, the functional requirements are divided into different modules, each addressing specific system functionalities.

2.2.1 Module 1: User Authentication and Profile Management

Following are the requirements for the User Authentication and Profile Management module:

1. The system shall allow users to create a new account by providing a username, email, and password.
2. The system shall allow users to log in using their credentials (username and password).
3. The system shall allow users to reset their password if they forget it.
4. The system shall store and manage user profiles, including saving their 3D tour preferences and viewing history.
5. The system shall log users out after a period of inactivity for security purposes.

2.2.2 Module 2: Tourist Location Browsing and Selection

Following are the requirements for the Tourist Location Browsing and Selection module:

1. The system shall allow users to browse a list of tourist locations from different categories (e.g., Mountains, Beaches, Historical Sites).
2. The system shall allow users to filter and sort the list of tourist locations based on attributes like popularity, rating, or proximity.
3. The system shall allow users to view detailed descriptions, images, and ratings for each tourist location.
4. The system shall allow users to select a specific location to start the 3D tour.

2.2.3 Module 3: 3D Virtual Tour Interaction

Following are the requirements for the 3D Virtual Tour Interaction module:

1. The system shall allow users to interact with the 3D virtual tour of a selected tourist location.

2. The system shall provide navigation controls for zooming, panning, and rotating within the 3D virtual environment.

3. The system shall display tourist landmarks and points of interest during the tour.

4. The system shall allow users to pause and resume the 3D tour at any point.

5. The system shall provide real-time updates to the 3D view based on user inputs (e.g., zooming, rotating).

2.2.4 Module 4: Information Retrieval and Display

Following are the requirements for the Information Retrieval and Display module:

1. The system shall retrieve and display additional information related to specific landmarks or locations in the 3D tour.

2. The system shall display pop-up information, including historical facts, tips, and recommendations, when a user clicks on an object in the 3D view.

3. The system shall provide detailed information about the location, such as nearby attractions and local guides.

2.2.5 Module 5: Feedback and Ratings

Following are the requirements for the Feedback and Ratings module:

1. The system shall allow users to rate the tourist locations they have toured virtually.

2. The system shall allow users to provide feedback and comments on their virtual tour experience.

3. The system shall display average ratings and reviews for each location, based on user feedback.

2.3 Non-Functional Requirements

This section specifies the non-functional requirements for the Virtual 3D Tour system. These quality requirements are specific, quantitative, and verifiable.

2.3.1 Reliability

The reliability of the system refers to how often it experiences failures. It should be measured in terms of MTBF (Mean Time Between Failures). A failure in this system is defined as the inability to load or display a 3D tour, or a crash during a user interaction. The consequences of a failure include user dissatisfaction and potential data loss.

- REL-1: The system shall have an MTBF of 10,000 hours of operation.
- REL-2: The system shall detect and log errors in real-time and notify the administrator within 1 minute of an error occurring.
- REL-3: In the event of a system failure, the system shall recover all unsaved user data from the last 5 minutes of interaction.

2.3.2 Usability

Usability is crucial for the user's interaction with the 3D tour. It should be intuitive and easy to use for both first-time users and experienced users, focusing on ease of navigation and interaction within the virtual tour.

- USE-1: The system shall allow users to start interacting with a 3D tour within 5 minutes of first use without needing any external guidance.
- USE-2: The user interface shall support multiple languages, including English and Urdu.
- USE-3: The system shall allow users to rotate, zoom, and pan the 3D view using simple mouse or touch gestures.
- USE-4: The system shall provide accessible features for users with disabilities, including screen reader support for text information and voice commands for navigation.

2.3.3 Performance

Performance refers to how quickly the system responds to user interactions and loads 3D tours. This includes the time it takes to load locations, display additional information, and process user inputs.

- PER-1: 95

- PER-2: The system shall respond to user inputs (such as zoom or rotation) within 0.5 seconds.

- PER-3: The system shall support at least 100 simultaneous users interacting with different 3D tours without any degradation in performance.

2.3.4 Security

Security focuses on protecting the system and user data from unauthorized access or breaches. It addresses data protection and preventing malicious attacks.

- SEC-1: The system shall require users to log in with a secure username and password before accessing any tours.

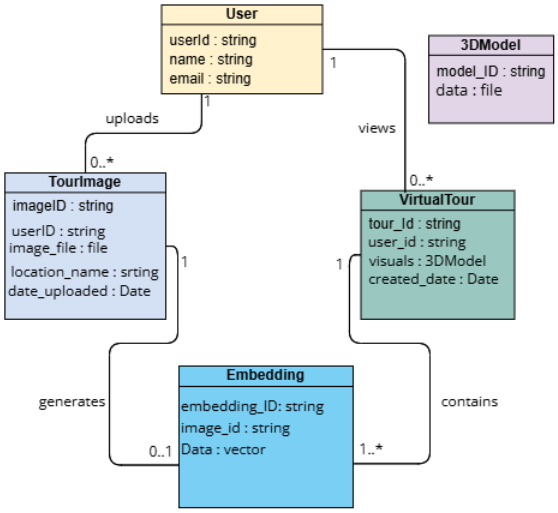
- SEC-2: All user data shall be encrypted using AES-256 encryption when stored in the database.

- SEC-3: The system shall implement role-based access control (RBAC), allowing only authorized users to access certain administrative functionalities.

- SEC-4: The system shall log all login attempts and notify administrators of any suspicious activity, such as 5 failed login attempts within 10 minutes.

2.4 Domain Model

This section presents the domain model for the Virtual 3D Tour project, detailing the various entities involved and their relationships.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userId : string
name : string
email : string
3DModel
model_ID : string
data : file
uploads
views
1
1
0..*
0..*
TourImage
imageID : string
userID : string
image_file : file
location_name : srting
date_uploaded : Date
VirtualTour
tour_Id : string
user_id : string
visuals : 3DModel
created_date : Date
1
1
generates
contains
Embedding
embedding_ID: string
image_id : string
Data : vector
0..1
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Chapter 3

System Overview

The Virtual 3D Tour project aims to transform 2D images of tourist locations into immersive 3D visuals using advanced technologies like CNN (Convolutional Neural Networks), LLM (Large Language Models), and NeRF (Neural Radiance Fields). The system captures intricate details of the location and generates high-quality 3D scenes that enhance the tourism experience. The goal is to create an interactive and scalable system that allows users to explore tourist spots in a more engaging way.

3.1 Architectural Design

The architectural design of the system is based on a modular approach, where each module performs a specific function. The major modules include:

- **Input Module**: Captures the 2D image of a tourist location. - **CNN Embedding Module**: Extracts detailed embeddings from the image using a CNN model. - **Prompt Generation Module**: Uses LLM to generate descriptive prompts from the CNN embeddings. - **NeRF Module**: Converts the prompt and embeddings into a 3D scene. - **Rendering Module**: Displays the final 3D visual to the user.

Box and Line Diagram: Below is the initial design representation of the system using a box and line diagram, which outlines the interactions between different components.

Once the architecture style is finalized, the system will follow a layered pattern, with distinct layers for input, processing, and output.

3.2 Design Models

The following design models are applicable for the **Virtual 3D Tour** system, using an Object-Oriented Development Approach.

Object-Oriented Design Models:

- **Activity Diagram**: Describes the workflow of transforming 2D images into 3D tours.

- **Class Diagram**: Shows the structure of the system, detailing classes like ‘Image-Processor‘, ‘EmbeddingExtractor‘, ‘LLM‘, and ‘NeRFRenderer‘.

- **Class-level Sequence Diagram**: Illustrates the sequence of interactions between major components (CNN, LLM, NeRF).

- **State Transition Diagram**: Represents how the system transitions between states (e.g., from image input to 3D rendering).

Procedural Approach Models:

- **Activity Diagram**: Represents a step-by-step flow of the procedural approach for the image-to-3D process.

- **Data Flow Diagram**: The DFD shows how data (e.g., images and embeddings) flows between different modules of the system.

- **System-level Sequence Diagram**: Displays the sequence of system-level events, from input to 3D rendering.

3.3 Data Design

In this section, we describe how the system transforms the information domain into data structures, and how data is stored, processed, and organized.

The system relies on the following data structures: - **Images**: Raw input 2D images of tourist locations. - **CNN Embeddings**: Detailed embeddings capturing objects and textures from the 2D image. - **Prompts**: Descriptive text generated by the LLM based on CNN embeddings. - **3D Models**: Output of the NeRF process, stored as 3D scenes.

The database schema includes tables for storing: - **Images**: Metadata and path to the original 2D images. - **Embeddings**: Vectorized representations of image features. - **3D Scenes**: Data structure for storing the output NeRF 3D model.

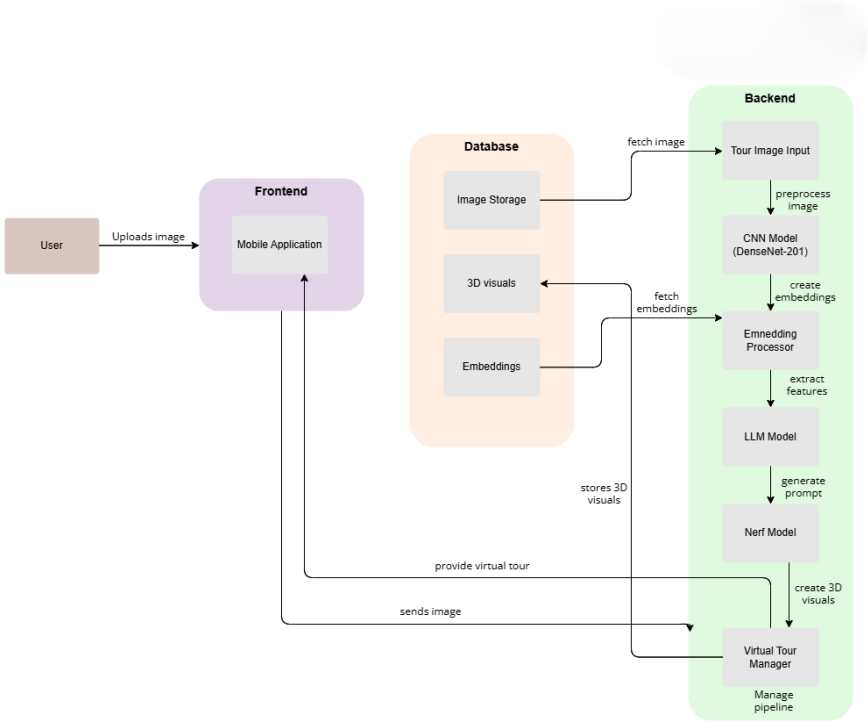

Figure 3.1: Box and Line Diagram of the Virtual 3D Tour Architecture

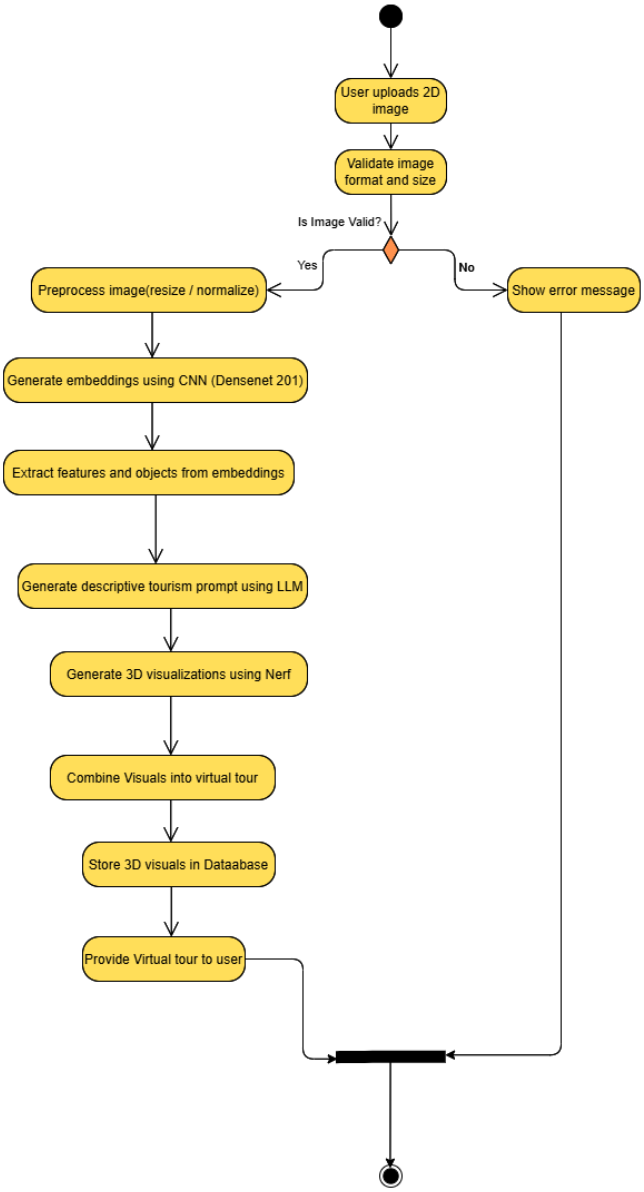

Figure 3.2: Activity Diagram for Image-to-3D Tour Transformation

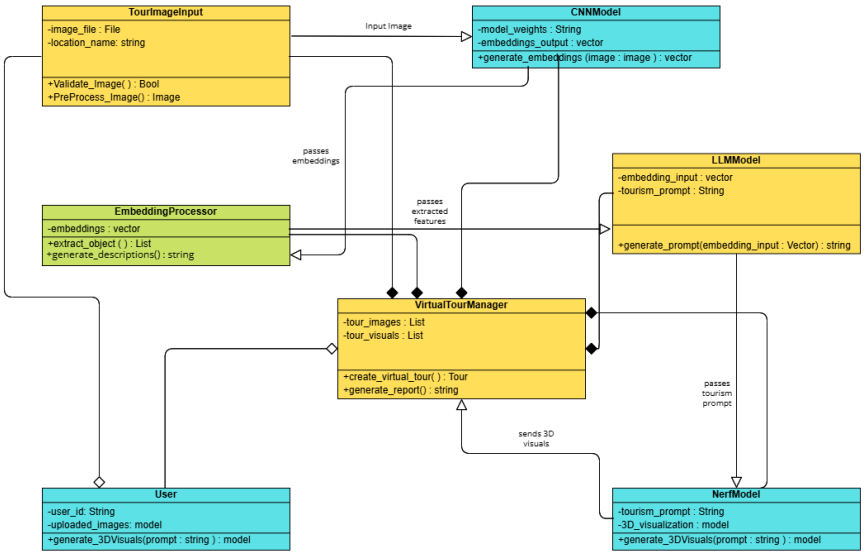

Figure 3.3: Class Diagram of the Virtual 3D Tour System

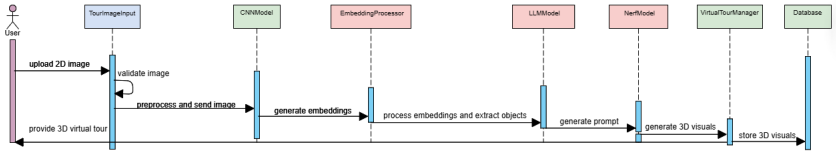

Figure 3.4: Class-Level Sequence Diagram for Virtual 3D Tour

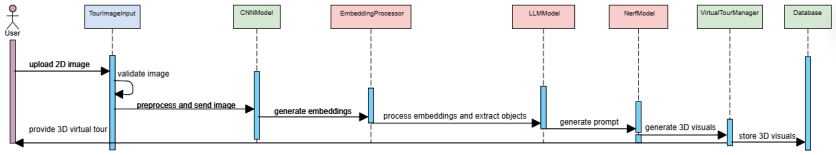

Figure 3.5: State Transition Diagram for Virtual 3D Tour System

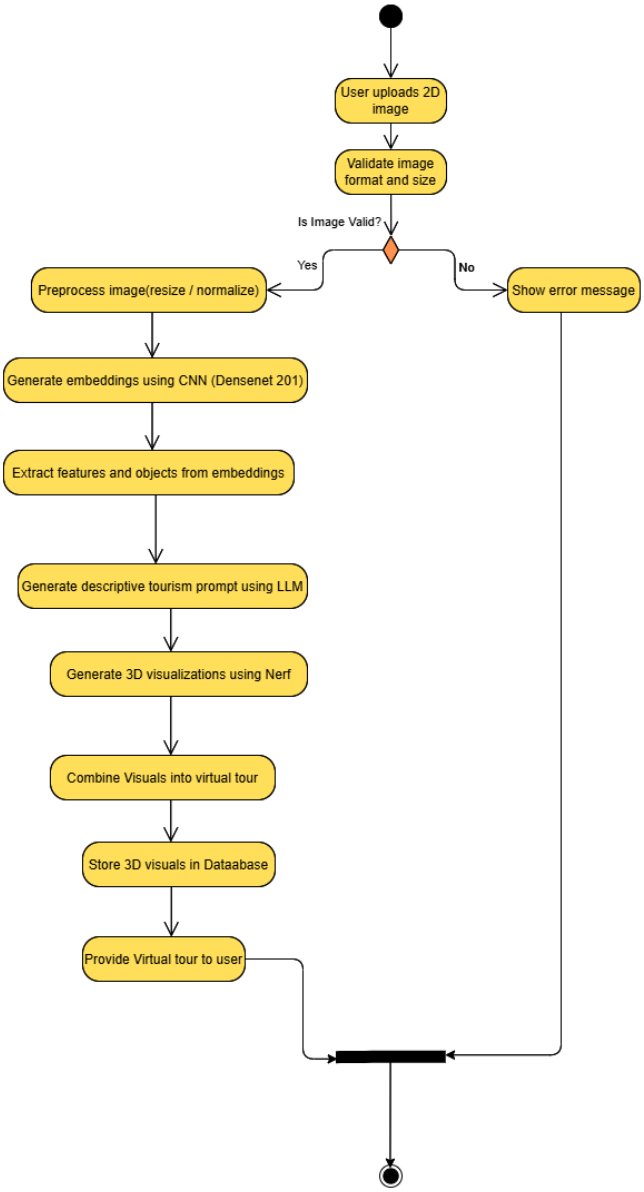

Figure 3.6: Activity Diagram for Procedural Approach

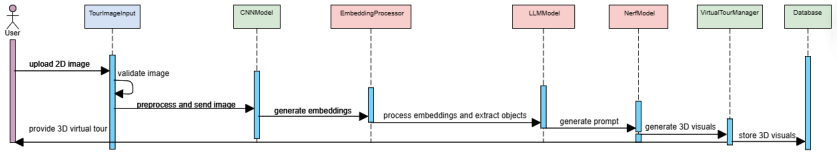

Figure 3.7: Data Flow Diagram (DFD) for Virtual 3D Tour System

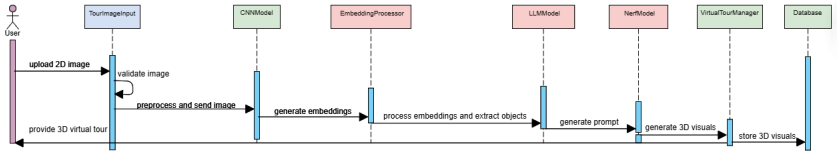

Figure 3.8: System-Level Sequence Diagram for Virtual 3D Tour

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[1] A Kolyshkin and S Nazarovs. Stability of slowly diverging flows in shallow water. *Mathematical Modeling and Analysis*, 2007.