COMSATS University Islamabad,
Abbottabad Campus

SOFTWARE DESIGN DESCRIPTION

(SDD DOCUMENT)

for

Treasure Hunt Adventure

Version 1.0

By

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Table Of Content

Revision History

Name	Date	Reason for changes	Version

Application Evaluation History

Comments (by committee) ***include the ones given at scope time both in doc and presentation**	**Action Taken**

Supervised by

<Supervisor's Name>

Signature_____

Introduction

Treasure Hunt Adventures is an interactive mobile game that blends Augmented Reality (AR) with real-world exploration, designed to offer players a gamified treasure-hunting experience using their smartphones. The game leverages Unity with AR Foundation to place virtual treasures in physical environments, requiring players to move, scan, and interact with AR objects. As they explore different locations, players solve engaging puzzles, collect digital rewards, and compete on a real-time leaderboard.

The project scope completed so far includes the design and partial development of several key modules. These modules include:

- **User Interface Module**: Handles sign-in, registration, onboarding tutorial, and settings.
- **AR Engine Module**: Utilizes ARCore/ARKit and GPS to detect flat surfaces and anchor virtual content.
- **Puzzle & Clue System**: Generates and validates puzzles such as riddles, symbol-matching, and memory challenges.
- **Treasure Collection Module**: Allows users to interact with AR-placed objects to collect virtual treasures.
- **Leaderboard System**: Maintains live rankings based on player performance, synced through Firebase.
- **Rewards & Achievement System**: Tracks progress and awards digital badges, coins, and bonuses to encourage continued play.

The system also integrates with Firebase for user authentication, real-time database storage, and cloud sync. These foundational components lay the groundwork for a robust, engaging, and scalable AR-based mobile game experience.

Design methodology and software process model

Design Methodology – Object-Oriented Programming (OOP)

The Treasure Hunt Adventures system is being developed using the Object-Oriented Programming (OOP) methodology. OOP is most appropriate for this project due to its modular structure and the need for clear abstraction between game components such as the AR Engine, Puzzle System, Treasure Collection, and Leaderboard Module. OOP allows us to define classes and objects that represent real-world entities like players, treasures, and puzzles, supporting better code reuse, scalability, and maintainability.

Each module in the game—such as the User Interface, AR functionality, and Firebase integration—is encapsulated within distinct classes with defined responsibilities and interactions. This design ensures that updates, enhancements, or debugging can be carried out without affecting unrelated parts of the system. Moreover, object-oriented principles like inheritance and polymorphism will help in extending game features like additional puzzle types or reward mechanisms in future iterations.

Software Process Model – Iterative Incremental Model

The development of this project follows the Iterative Incremental Process Model. This model is chosen due to the dynamic and exploratory nature of AR-based mobile games, where user feedback, testing, and gradual integration play a crucial role. The project is divided into multiple manageable iterations, with each increment adding functionality—starting with core modules such as user authentication and AR scanning, followed by puzzle integration, reward systems, and leaderboard functionality.

This approach allows the development team to build a functional baseline early in the process, test it thoroughly, and improve upon it in each cycle. It also facilitates continuous user validation and minimizes risk by allowing early detection and resolution of issues. The model aligns well with the mobile game development life cycle, especially when deploying modules like Firebase authentication, AR surface detection, and puzzle logic in stages.

System overview

Treasure Hunt Adventures is a mobile-based augmented reality (AR) game that transforms real-world exploration into an interactive treasure hunting experience. Designed for Android and iOS platforms using Unity and AR Foundation, the game overlays virtual treasure elements in real-world environments by utilizing GPS, camera input, and AR surface detection technologies. Players navigate their surroundings, solve engaging puzzles, collect treasures, and climb the leaderboard—all while interacting with virtual content seamlessly blended into their physical environment.

The system is built with a modular design, featuring distinct components such as User Authentication, AR Engine, Puzzle & Clue Management, Treasure Collection, Leaderboard Tracking, and Rewards & Achievements. Firebase serves as the backend for authentication, real-time data storage, and leaderboard synchronization. The AR Engine leverages ARCore (for Android) or ARKit (for iOS) to detect flat surfaces, place AR objects, and respond to user gestures.

From a functional perspective, the system guides users through a simple onboarding and login process, then transitions them into AR-based gameplay where they explore nearby areas, detect virtual clues, solve memory and logic-based puzzles, and earn digital rewards. The system ensures real-time syncing of game progress and achievements while providing engaging feedback through the UI and animations.

By merging physical activity with cognitive challenges and immersive technology, *Treasure Hunt Adventures* aims to create a playful, educational, and rewarding experience that promotes both mental and physical engagement. Its scalable design and backend integration make it suitable for solo play, with future potential for multiplayer enhancements and commercial partnerships (e.g., branded treasure hunts).

Architectural design

Onion Architecture:

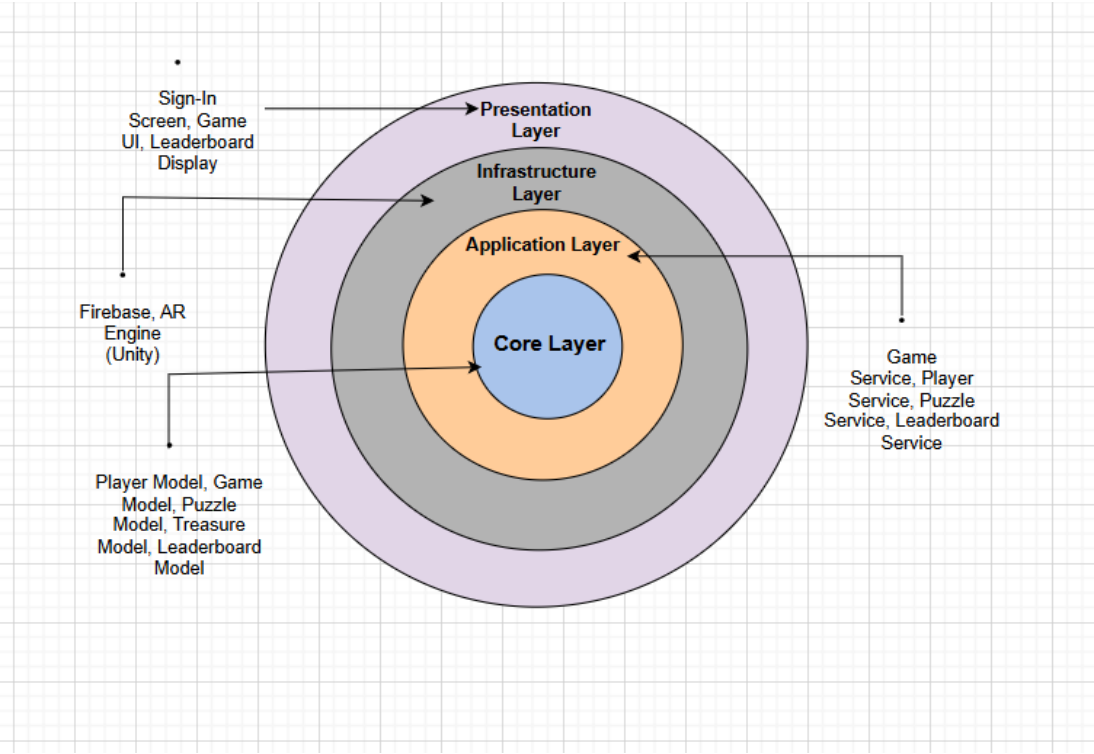


Fig 1.1 Onion Architecture for Treasure Hunt Adventure

Process flow/Representation

The activity diagram of *Treasure Hunt Adventure* outlines the complete gameplay flow and system interaction from the player's perspective. The process begins when the player launches the game on their Android device, initiating the AR environment and backend services. The user is then presented with a login or registration interface. If the user is new, they must register by creating an account; otherwise, existing users can log in. Post-authentication, the user has the option to update their profile, such as adding a username or avatar.

Once authenticated, the player starts a new game session. The AR Manager component activates and detects real-world planes using AR Foundation technology. Once a surface is found, virtual treasure clues are spawned within the environment. The user then transitions into the game session phase where they are required to solve a puzzle tied to each treasure. Successful puzzle completion allows the player to collect the treasure.

After collecting the treasure, the system verifies the collection and rewards the player with points or virtual items. The user's score is updated accordingly, and if certain criteria are met, achievements are unlocked. The game session can be ended by the player at any time, after which the user is allowed to view the leaderboard and compare scores with other players globally. Finally, the player can log out of the application, completing the gameplay cycle. This diagram encapsulates authentication, AR interaction, reward progression, and leaderboard integration in a streamlined, user-centric flow.

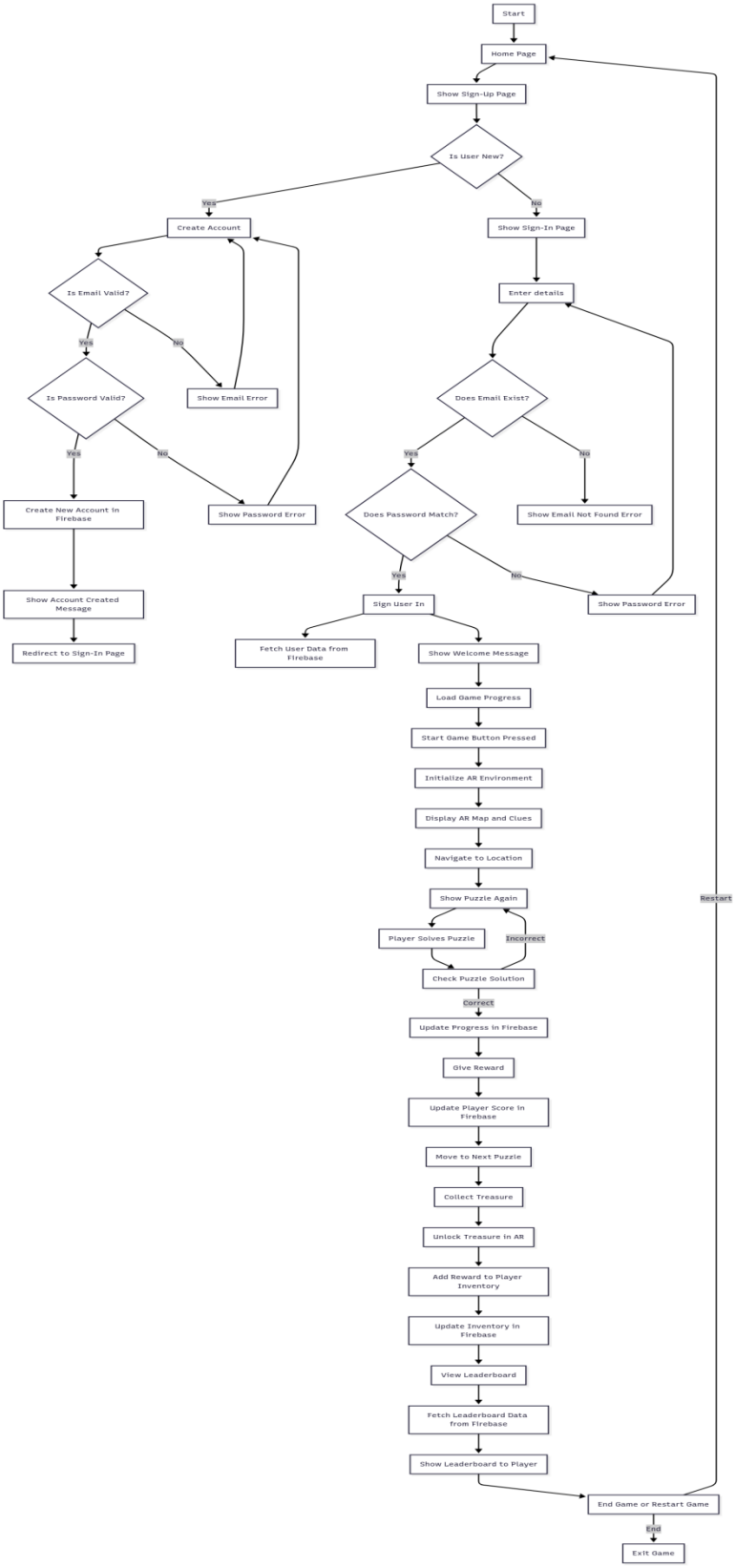


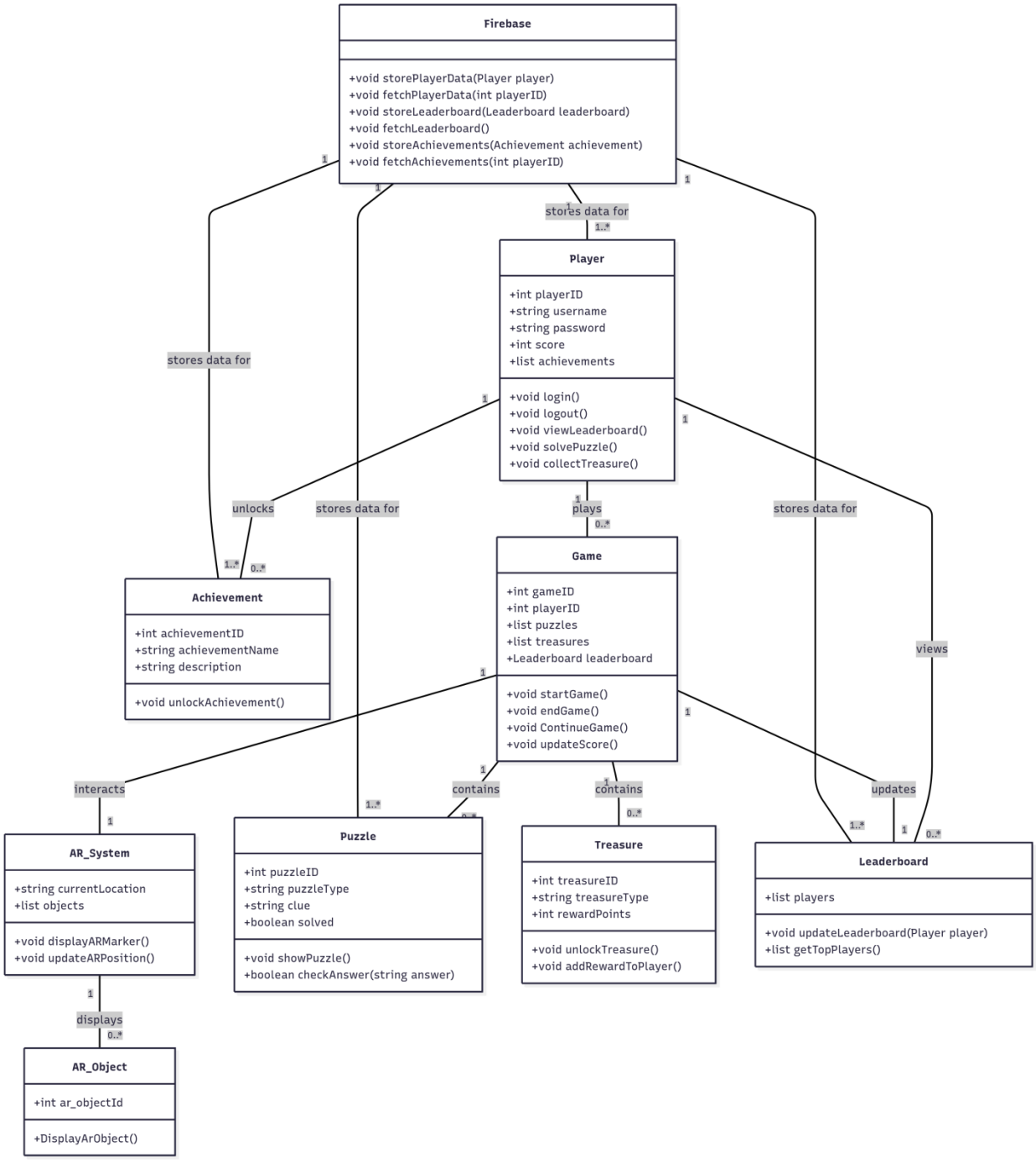
Fig 1.2 Activity Diagram for Treasure Hunt Adventure

Design models

The applicable models may include:

- **Class Diagram**

  This class diagram represents the object-oriented structure of the *Treasure Hunt Adventure* mobile AR game. The central entity is the Player class, which holds user credentials, score, and achievements. Each player can initiate multiple GameSession instances, which manage the gameplay timeline, score, and status.
  Within a game session, the system aggregates multiple Puzzle and Treasure objects. Puzzles include challenge-specific data like type, question, and difficulty, while treasures are defined by GPS location, collection status, and reward points. The ARManager handles real-world plane detection and virtual object spawning for AR interaction.
  Players receive Reward instances based on performance and can unlock Achievements during gameplay. Both are linked back to the player with one-to-many associations. The AuthManager manages sign-up, sign-in, and OTP verification, while the FirebaseManager handles data synchronization, loading, and saving through Firebase.
  This architecture ensures modularity, data persistence, and a robust connection between real-world interaction and in-game logic.


Firebase
+void storePlayerData(Player player)
+void fetchPlayerData(int playerID)
+void storeLeaderboard(Leaderboard leaderboard)
+void fetchLeaderboard()
+void storeAchievements(Achievement achievement)
+void fetchAchievements(int playerID)
stores data for
Player
+int playerID
+string username
+string password
+int score
+list achievements
+void login()
+void logout()
+void viewLeaderboard()
+void solvePuzzle()
+void collectTreasure()
stores data for
unlocks
stores data for
plays
stores data for
Achievement
+int achievementID
+string achievementName
+string description
+void unlockAchievement()
Game
+int gameID
+int playerID
+list puzzles
+list treasures
+Leaderboard leaderboard
+void startGame()
+void endGame()
+void ContinueGame()
+void updateScore()
views
interacts
contains
contains
updates
AR_System
+string currentLocation
+list objects
+void displayARMarker()
+void updateARPosition()
Puzzle
+int puzzleID
+string puzzleType
+string clue
+boolean solved
+void showPuzzle()
+boolean checkAnswer(string answer)
Treasure
+int treasureID
+string treasureType
+int rewardPoints
+void unlockTreasure()
+void addRewardToPlayer()
Leaderboard
+list players
+void updateLeaderboard(Player player)
+list getTopPlayers()
displays
AR_Object
+int ar_objectId
+DisplayArObject()

System Sequence Diagram

The system sequence diagram illustrates the complete user interaction flow within the Treasure Hunt Adventure game. It begins with the registration and login process, where the player submits their credentials through the AuthManager, which communicates with FirebaseManager to save and load user data. Upon successful authentication, the user initiates a game session via GameSession, which logs the start time and session details.

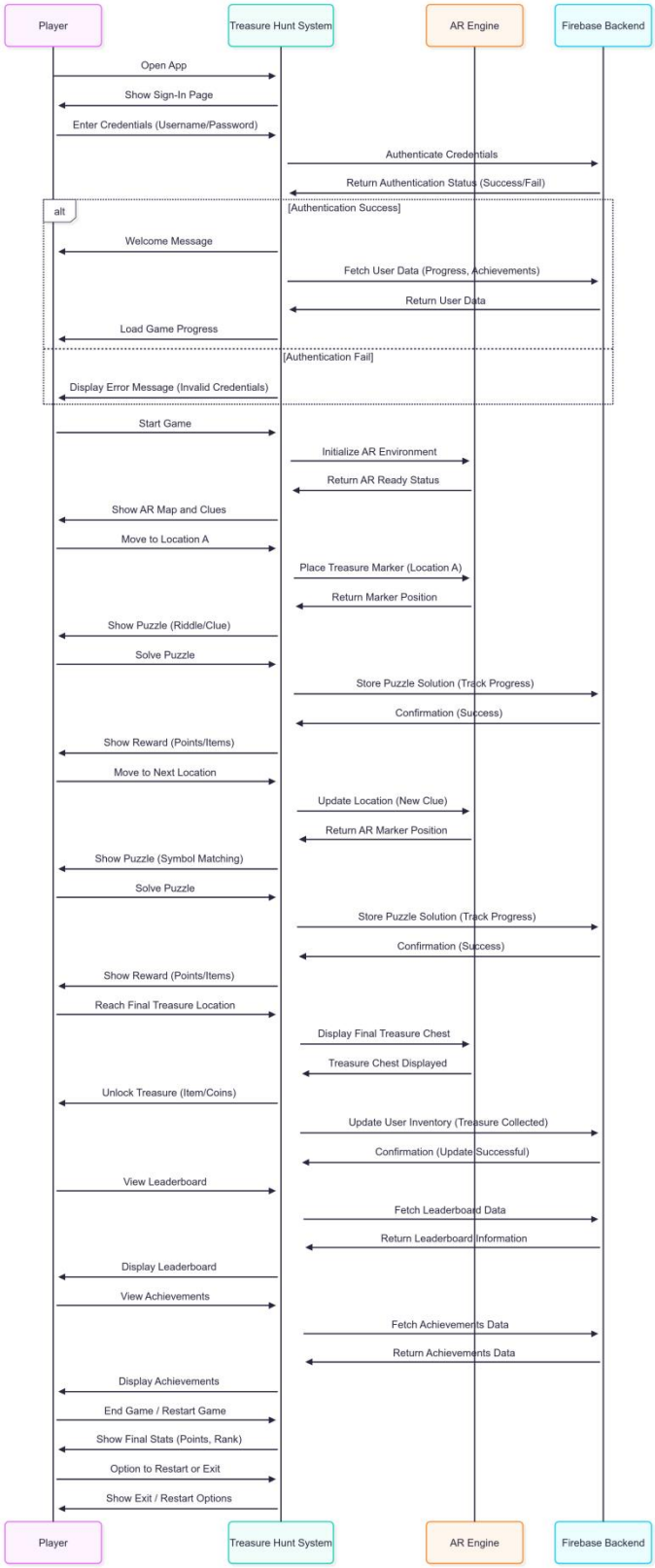


Fig 1.4 System Sequence Diagram for Treasure Hunt Adventure

Sequence Diagram

The following diagrams shows the process sequence of our system.

User Sign-In Sequence Diagram

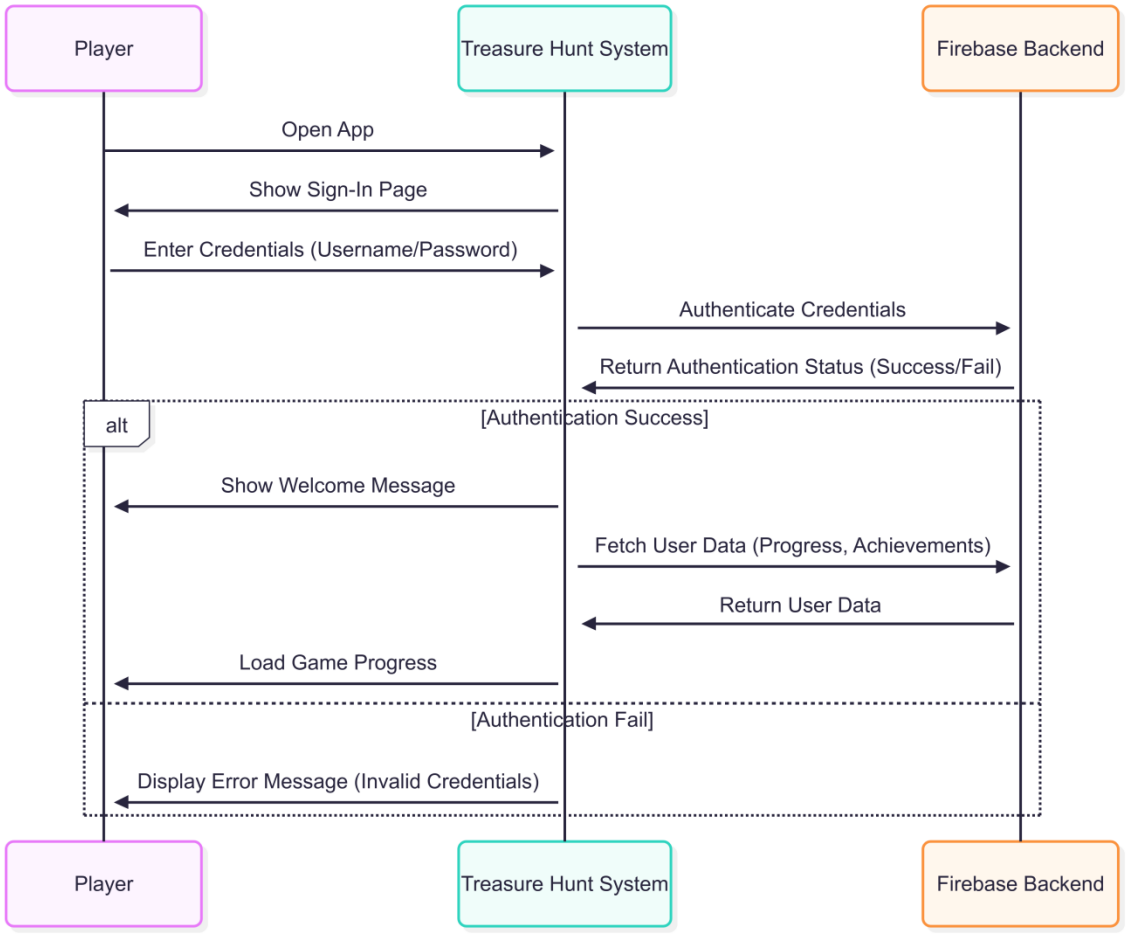


Fig 1.5 system sequence diagram for User sign-in

AR Navigation (Treasure Hunt) Sequence Diagram

Fig. 1.6 shows the process sequence for Login Account

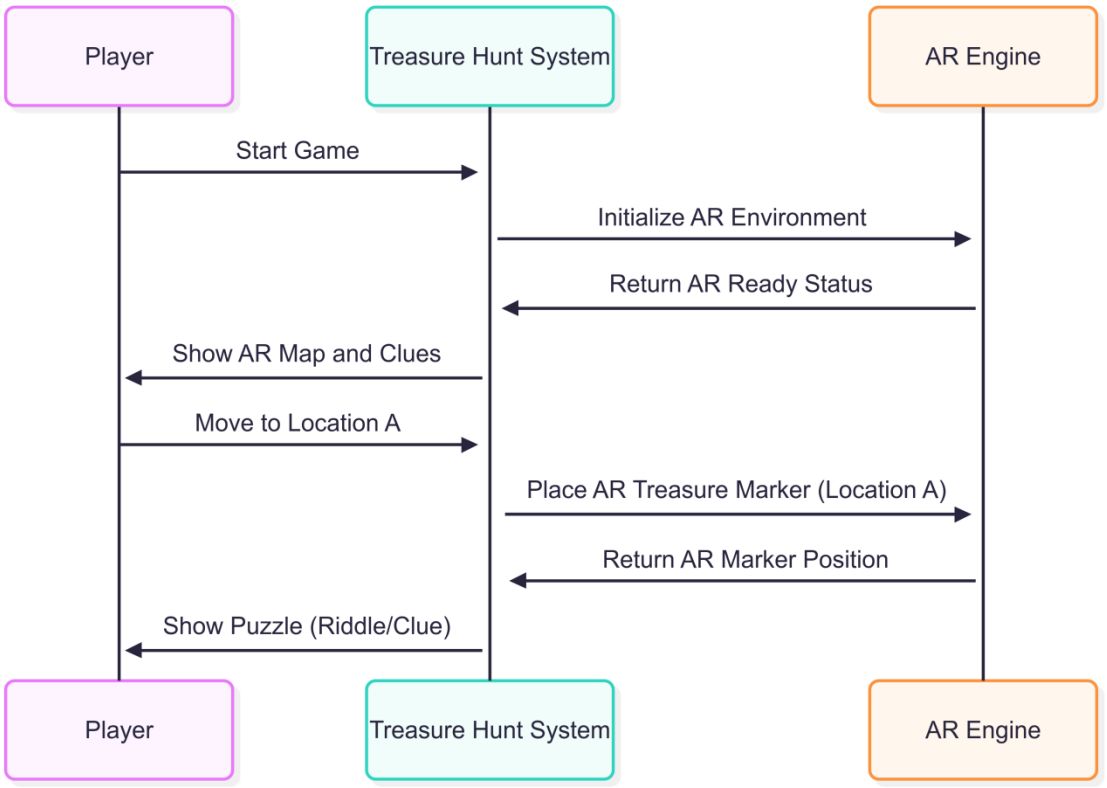


Fig 1.6 system sequence diagram for AR navigation

Puzzle Solving Sequence Diagram

Fig. 1.7 shows the process sequence for Reset Password

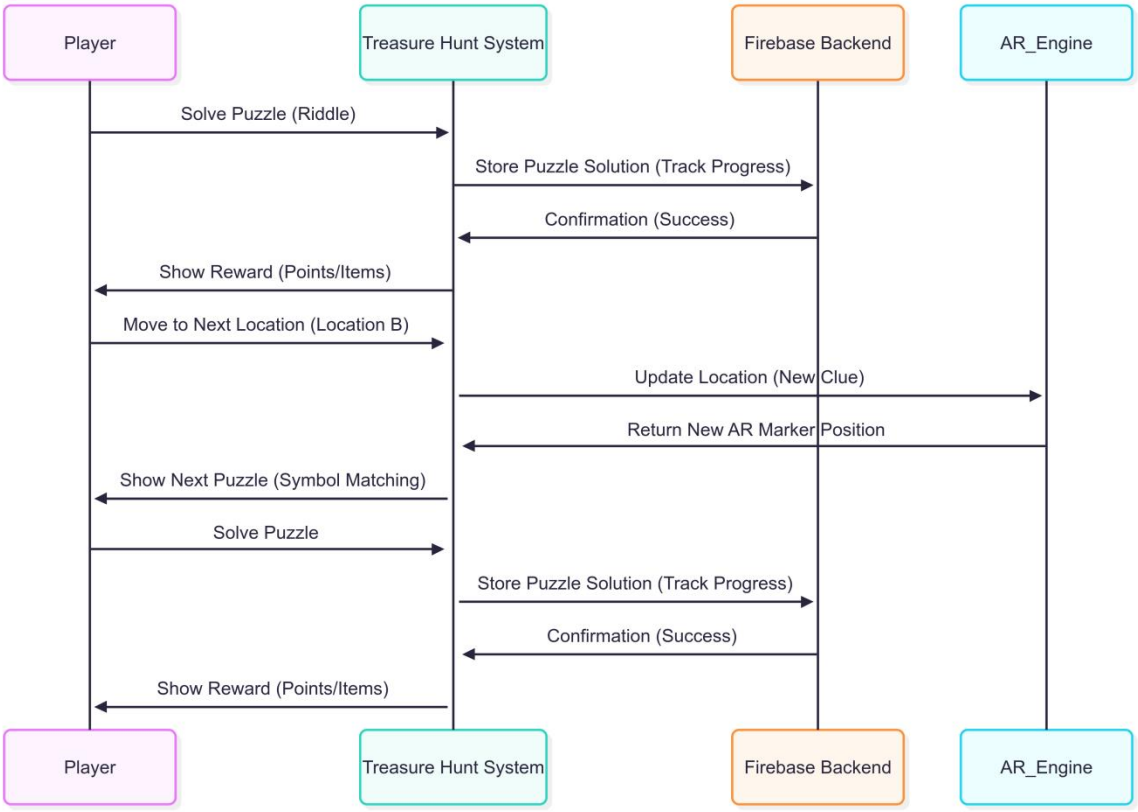


Fig 1.7 system sequence diagram for puzzle solving

Treasure Collection Sequence Diagram

Fig. 1.8 shows the process sequence for Update Profile

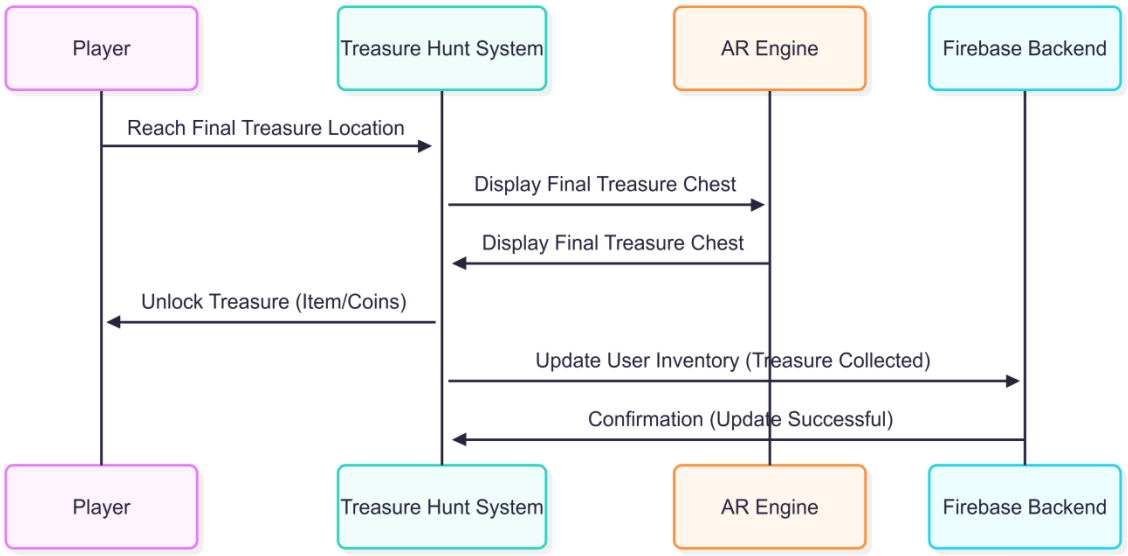


Fig 1.8 system sequence diagram for treausre collection

Leaderboard and Reward System Sequence Diagram

Fig. 1.9 shows the process sequence for Start New Game

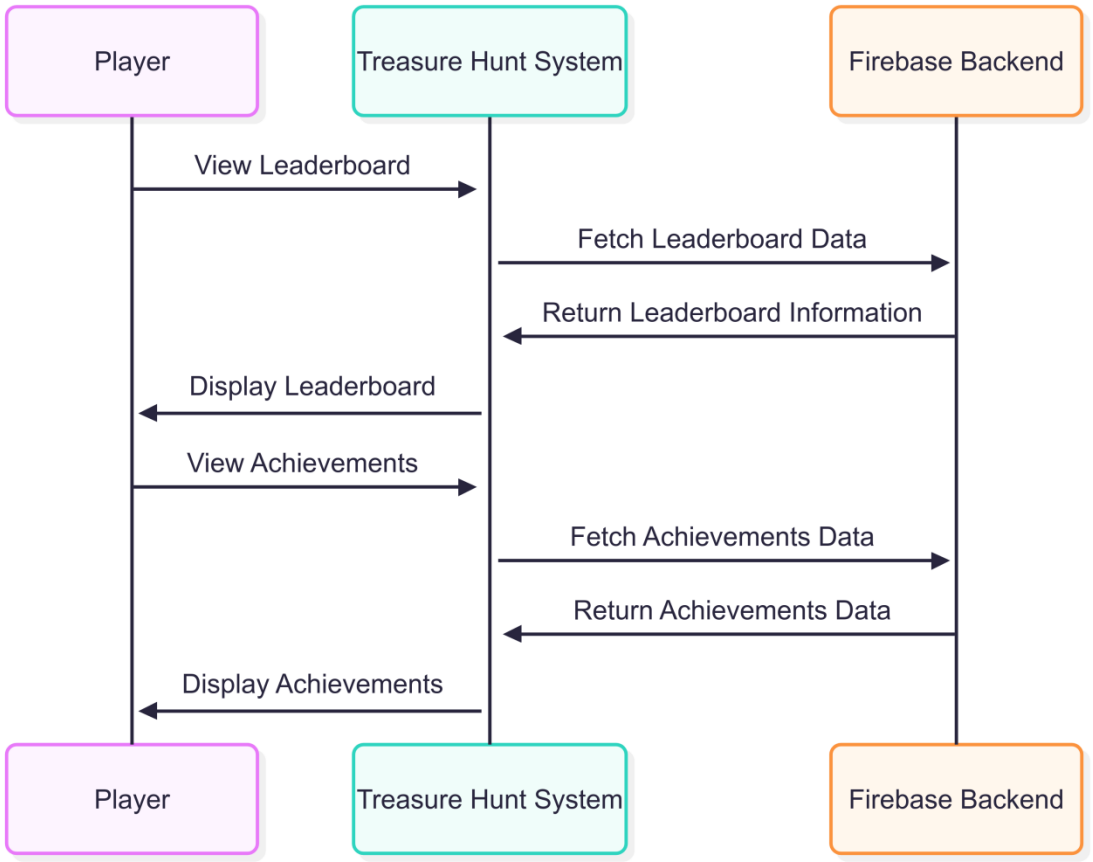


Fig 1.9 system sequence diagram for leaderboard and reward

JSON Tree

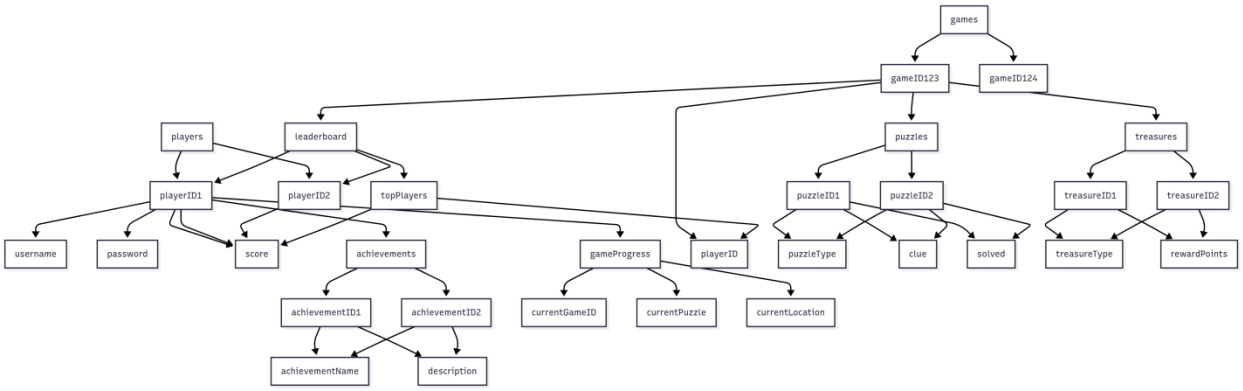


Fig 1.10 system sequence diagram for JSON tree

Data design

The data design of *Treasure Hunt Adventures* focuses on organizing and managing the game's dynamic information such as user data, AR elements, puzzles, rewards, and gameplay progress. The system uses **Firebase** as the primary backend, utilizing its Authentication, Firestore Database services to handle real-time data processing and synchronization across devices.

4.1 Data Organization and Entities

The system transforms the information domain (players, treasures, puzzles, etc.) into well-structured data entities, each with defined attributes and relationships:

- **Player Entity**: Contains attributes like PlayerID, Username, Email, Score, Avatar, AchievementsUnlocked, and GameProgress.
- **Treasure Entity**: Includes TreasureID, Location (GPS coordinates), Type, IsCollected, and AssociatedReward.
- **Puzzle Entity**: Stores PuzzleID, PuzzleType, Difficulty, ClueText, Solution, and Status.
- **Leaderboard Entry**: Includes PlayerID, Rank, Score, Timestamp.
- **Achievement Entity**: Contains AchievementID, Title, Description, IsUnlocked, and UnlockDate.

These entities are stored in a **NoSQL structure** within Firebase Firestore, allowing flexible and scalable access patterns suitable for mobile AR applications.

4.2 Data Storage Technologies

4.3 Data Processing and Flow

During gameplay, data is continuously read and written between the client (Unity AR App) and Firebase. For example:

- When a player collects a treasure, the system updates the Treasure Entity and unlocks a corresponding Achievement, which is then pushed to the Leaderboard.
- Puzzle-solving triggers a validation process, and upon success, the Player Entity is updated with reward information.
- Sync operations ensure all gameplay data is persisted, even when switching devices.

The data design prioritizes real-time responsiveness, data integrity, and minimal latency, all critical for ensuring a seamless AR gaming experience.

Data Storage	Purpose
Firebase Firestore	Stores player profiles, puzzle data, treasure status, rewards, and leaderboard records in real time.
Firebase Authentication	Manages user accounts, login credentials, and secure access control.
Firebase Cloud Storage	Used for storing heavy media files like AR assets, puzzle images, and 3D models.
Local Device Storage	Temporarily holds session data and offline progress, which is synced when online.

Data dictionary

This section lists the major objects (entities) used in the system, along with their attributes, data types, and brief descriptions, followed by relevant methods and parameters where applicable. The dictionary is alphabetically ordered for clarity.

Achievement

Attribute	Type	Description
achievementID	String	Unique identifier for each achievement.
title	String	Name of the achievement (e.g., “Puzzle Master”).
description	String	Description of how the achievement is earned.
isUnlocked	Boolean	Indicates whether the player has unlocked the achievement.
unlockDate	Timestamp	The date/time the achievement was earned.

LeaderboardEntry

Attribute	Type	Description
playerID	String	Unique reference to the Player.
rank	Integer	The position of the player in the leaderboard.
score	Integer	Total score of the player.
timestamp	Timestamp	Time when the score was recorded.

Player

Attribute	Type	Description
playerID	String	Unique identifier for the player.
username	String	Player's display name.
email	String	Registered email address.
avatar	String (URL)	Link to the profile picture/avatar.
score	Integer	Cumulative score earned.
achievementsUnlocked	List	List of unlocked achievements.
gameProgress	JSON/Object	Snapshot of last known progress.

Puzzle

Attribute	Type	Description
puzzleID	String	Unique identifier for each puzzle.
puzzleType	String	Type of puzzle (e.g., riddle, memory).
difficulty	String	Difficulty level (easy, medium, hard).
clueText	String	The hint or description for the puzzle.
solution	String	Correct answer to the puzzle.
status	String	Solved / Unsolved status.

Treasure

Attribute	Type	Description
treasureID	String	Unique ID for the treasure.
location	GeoPoint (lat, long)	GPS coordinates of the treasure.
type	String	Type of treasure (chest, scroll, gem).
isCollected	Boolean	Whether it has been collected by the player.

associatedReward	String	Reward/achievement unlocked upon collection.

Method	Parameters	Description
spawn()	location: GeoPoint	Places treasure in AR world.
scollect()	–	Marks the treasure as collected and triggers reward.

Algorithm & Implementation

This section outlines the core functionality of the system's major object-oriented components using Procedural Description Language (PDL) or pseudocode. It reflects the internal behaviour of objects like Player, Puzzle, Treasure, and others, based on their responsibilities.

Class: Player

Function: login(email, password)

```
IF Firebase.Authenticate(email, password) == SUCCESS THEN
   Load player profile from Firestore
   Set session status to ACTIVE
ELSE
   Display error message to user
END IF
```

Function: updateProfile(username, avatar)

```
pseudocode
CopyEdit
Update local user data with new username and avatar
Push updated data to Firebase Firestore
Notify user of success or failure
```

Function: logout()

```
pseudocode
CopyEdit
Clear local session data
Sign out from Firebase Auth
Redirect user to Login screen
```

Class: Puzzle

Function: checkAnswer(input)

```
pseudocode
CopyEdit
IF input == solution THEN
   status = "Solved"
   RETURN true
ELSE
   RETURN false
END IF
```

Function: generatePuzzle()

```
pseudocode
```

CopyEdit
SELECT random puzzle from Firebase WHERE difficulty == current level
SET currentPuzzle = selected puzzle
DISPLAY clueText to user

Class: Treasure
Function: spawn(location)
pseudocode
CopyEdit
IF ARSurfaceFound(location) THEN
  Instantiate virtual treasure model at detected plane
  Store treasure metadata locally
ELSE
  Prompt player to move or scan again
END IF

Function: collect()
pseudocode
CopyEdit
IF Player is within collection radius THEN
  Mark treasure as collected
  Trigger reward system
  Sync treasure status with Firebase
ELSE
  Show message: “Get closer to collect treasure”
END IF

Class: Leaderboard
Function: updateScore(playerID, score)
pseudocode
CopyEdit
FETCH current score from Firestore
ADD new score to existing score
UPDATE Firestore with new total
REFRESH leaderboard UI

Function: getTopPlayers()
pseudocode
CopyEdit
QUERY Firestore for top 10 players ORDER BY score DESC
RETURN list of usernames and scores
DISPLAY in leaderboard screen

Class: Achievement
Function: unlock(achievementID)
pseudocode
CopyEdit
IF achievementID NOT IN player.achievementsUnlocked THEN
  ADD achievementID to unlocked list
  SHOW notification to player
  SAVE progress to Firebase
END IF

Human interface design

The *Treasure Hunt Adventures* system is designed with a user-centric interface that provides an intuitive and seamless experience, particularly for mobile users engaged in real-world exploration. The application interface follows mobile design best practices, with a clear layout, consistent navigation, minimal taps to access core features, and engaging feedback through visual cues, animations, and sound.

User Interaction Overview

Upon launching the application, the user is greeted with a clean and interactive login or sign-up screen powered by Firebase Authentication. After successful authentication, the user is navigated to the **Main Menu**, where they can access:

- **Start AR Hunt** – Initiates the augmented reality gameplay session.
- **Achievements** – View earned badges and progress stats.
- **Inventory** – Check collected treasures or puzzle items.
- **Leaderboard** – View top players and their ranks.
- **Settings** – Manage sound, difficulty, profile info, and logout.

Each button in the UI is clearly labeled with icons and text, making navigation simple even for first-time users.

AR Gameplay Interface

When the AR session starts, the system activates the device's camera and overlays virtual content on the real environment using ARCore or ARKit. Players will see:

- **On-screen indicators** for detected planes.
- **Interactive treasure objects** placed on flat surfaces.
- A **puzzle popup** when reaching a treasure spot, allowing players to solve a challenge.

Touch-based interactions such as tap, drag, or double-tap are used to collect items or interact with the environment. Players receive immediate feedback through visual animations, sound effects, and real-time score updates.

Feedback and Notifications

The system provides constant feedback through:

- **Popup messages** for success/failure in puzzles.
- **Progress bars** showing game advancement.
- **Toasts and alerts** for actions like treasure collection or AR errors.
- **Achievement unlocks** displayed with badge animations.
- **Firebase sync confirmations** ensuring data is safely stored.

Additionally, session data such as score, collected treasures, and completed puzzles are visually reflected in the player's profile and leaderboard in real-time.

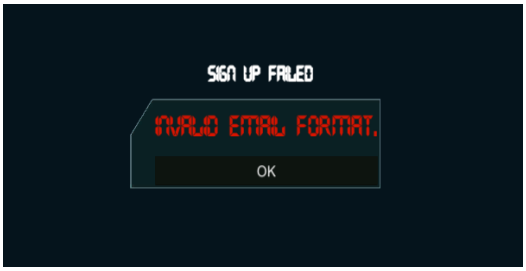
Screen images

Display screenshots showing the interface from the user's perspective. These can be hand-drawn, or you can use an automated drawing tool. Just make them as accurate as possible. (Graph paper works well.)

8.2 Screen objects and actions

A discussion of screen objects and actions associated with those objects


SIGN UP FAILED
EMAIL CANNOT START WITH A NUMBER.
OK

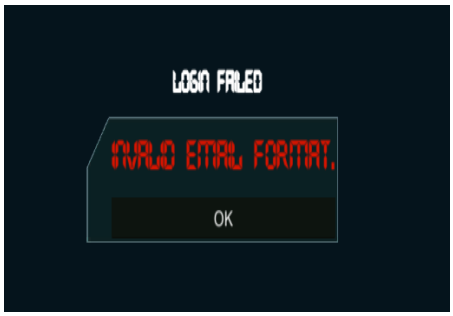

SIGN UP FAILED
INVALID EMAIL FORMAT.
OK

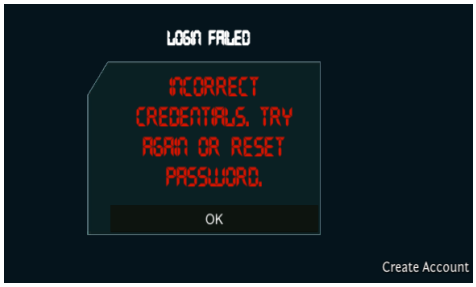

SIGN UP FAILED
PASSWORDS DO NOT MATCH.
OK

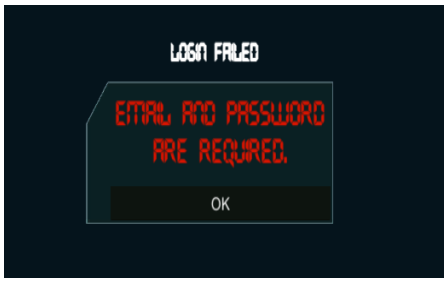

ENTER OTP
Enter 6-digit OTP
Verify

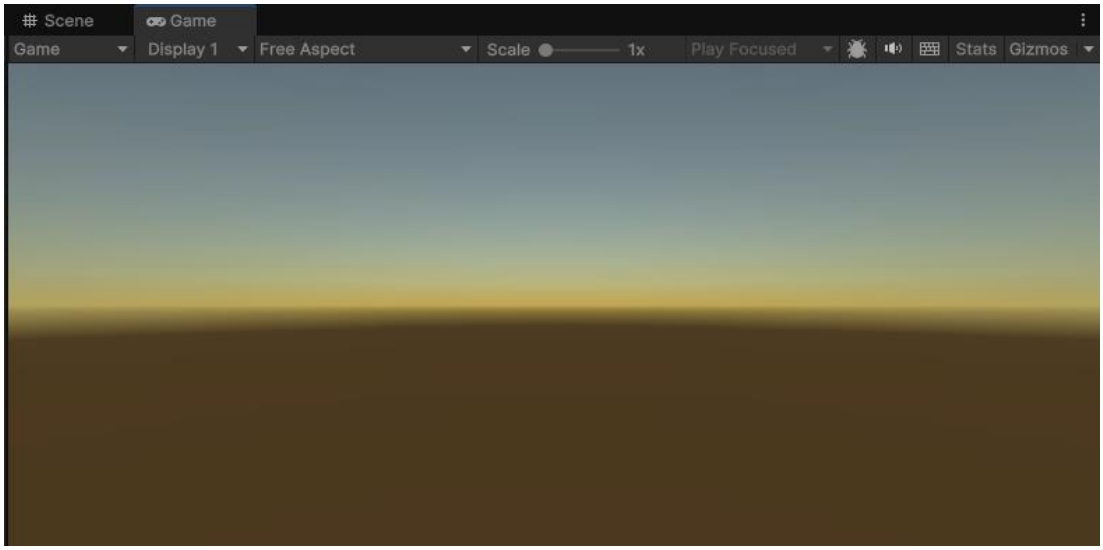

SIGN UP SUCCESS
NO OTP FOUND FOR THIS EMAIL.
OK


LOGIN
Username:
Password:
Remember Me
Login
Create Account


LOGIN FAILED
INVALID EMAIL FORMAT.
OK


LOGIN FAILED
INCORRECT CREDENTIALS. TRY AGAIN OR RESET PASSWORD.
OK
Create Account


LOGIN FAILED
EMAIL AND PASSWORD ARE REQUIRED.
OK


Scene
Game
Game
Display 1
Free Aspect
Scale
1x
Play Focused
Stats
Gizmos

Appendix I

- How to design using UML (OOP): For guidance please follow the instructions mentioned in the link: http://agilemodeling.com/artifacts/

- How and when to design ER diagrams: For guidance please follow the instructions mentioned in the link:
  http://people.inf.elte.hu/nikovits/DB2/Ullman_The_Complete_Book.pdf

- Data flow diagrams: For guidance please follow the instructions mentioned in the link and book:
  - http://www.agilemodeling.com/artifacts/dataFlowDiagram.htm
  - Software Engineering –A Practitioner's approach by Roger Pressman
- Architecture diagram: For guidance please follow the instructions mentioned in the link and book:
  - Ian Sommerville – Software Engineering 9th Edition– Chapter 6