APPLIED INFORMATION TECHNOLOGY AND COMPUTER SCIENCE
e-ISSN: 2773-5141

AITCS

Vol. 6 No. 2 (2025) 1895-1914
https://publisher.uthm.edu.my/periodicals/index.php/aitcs

Room Vision: Development of Mobile Application for Interior Visualization with 3D and AR Technology

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DOI: https://doi.org/10.30880/aitcs.2025.06.02.101

Article Info

Received: 21 July 2025
Accepted: 19 Nov 2025
Available online: 30 Nov 2025

Keywords

Interior Design, Augmented Reality, Room Vision, Three-Dimensional, Agile

Abstract

Interior design plays a crucial role in creating functional and aesthetically pleasing living space, and its demand is steadily increasing. However, many individuals struggles with planning and visualizing home decoration due to the lack of visualization tools. Android-based interior design applications often do not incorporate Augmented Reality (AR) feature, limiting user engagement and spatial awareness. Therefore, this project proposes a mobile application that enable users to design and visualize their room using three-dimensional (3D) manipulation and markerless AR. The application provides users various virtual furniture options, allowing users to design a complete and personalized room layout. It is targeted at individuals who aged 18 to 30 years old and own a room. The Agile methodology is chosen for the development of the Room Vision application. The application has been developed to enable users to experiment with their designs in 3D scenes and visualize them using Markerless AR. It scored 71.88 on the System Usability Scale (SUS), placing it slightly below the "Good" threshold at Grade C, indicating acceptable usability.

1. Introduction

Interior design is the planning and design of man-made spaces, a part of environmental design and closely related to architecture [1]. It plays a crucial role in transforming any space into a functional and aesthetically pleasing environment, encompassing the art and science of enhancing the interiors to ensure that they are not only visually appealing but also serve a purpose [2]. Since the Covid-19 pandemic, working from home has become common, increasing the need for well-designed home interiors.

Despite advances in interior design tools, many individuals still struggle to visualize and plan their spaces effectively. From both the customer's and designer's perspective, replicating a room based on descriptions alone is challenging in the absence of visualizations [3]. For example, furniture does not fit the physical space of a room or mismatch with the theme of the room color.

To address these issues, this project proposes Room Vision, a mobile application that allows users to design their interior spaces in 3D spaces and visualize them using augmented reality (AR). Users can manipulate furniture, experiment with layouts, and preview the final design in real environments. A web-based admin system supports scalability by allowing administrators to manage furniture assets and inspirations.

This project aims to design a user-friendly Room Vision application that is visually appealing and allows for easy navigation within 3D interior design project, develop an interactive Room Vision application with 3D object manipulation that allows users to drag and move furniture, and integration of AR viewing type, and evaluate the usability test on the target users towards Room Vision application. The target users are homeowners, renters,

interior designers, and individuals aged 18 to 30 years old. The application consists of seven modules, which are the authentication module, project management module, furniture catalogue module, profile module, inspiration module, 3D module, and AR module. The admin system includes four modules, which are authentication module, furniture management module, category management module and inspiration management module. The technology used includes 3D and Marker-less augmented reality (MLAR) technology Both the application and admin system are designed in English. This project will follow the Agile methodology, an iterative approach that enables continuous improvement based on user feedback [4].

The rest of the paper is arranged as follows: Section 2 covers the domain of study, the technology used, and the result of the comparative analysis. Section 3 describes the Agile methodology that has been chosen to be used in this project, as well as the output of the analysis and design phases of this project. Furthermore, Section 4 discusses the result and discussion, while Section 5 states the conclusion of the project.

2. Related Work

This section discusses the domain of interior design, AR technology, and the result of comparative analysis.

2.1 Interior Design

Interior design is a fascinating field that allows designers to transform spaces into captivating and functional environments [5]. An experienced designer able to transform the client's idea into a functional environment. Design concepts begin with an inspiration or a specific theme, requiring both designers and clients to visualize how furniture and color schemes will work together within a space. While interior design is often associated with visual appeal, it goes beyond aesthetics. It involves spatial planning, flow, and effective use of space. Common interior design styles include minimalist, classical, futuristic, and more. Subject Matter Expert (SME), Mr. Soh Choon Chai mentioned that minimalist style is currently a popular trend, as people increasingly prefer clean and simple designs. Once a theme is selected, designers and users can more easily choose furniture that aligns with the room's concept. Before the development of computer-aided software, designers relied on hand-drawn sketches and mentally visualized 3D layouts. After the design is done, it will be presented to the client for approval. Then, the client either goes to a furniture retail store to find the furniture or assigns the interior design company to find a manufacturer for producing the designed furniture [6]. Nowadays, advancements in 3D technology and computer-aided design (CAD) software have significantly improved the accuracy and efficiency of interior design. Manual sketching has become a fundamental for designers to equip with. Subject matter experts also emphasize that AutoCAD is often used by designers because it provides accurate visualization by creating a 3D scene of the room design and rendering it into an image. As mixed reality technology matures, it can now offer AR features in interior design, allowing clients to preview the final outcome. This creates an immersive experience for both designers and clients, helping them visualize the design in detail.

2.2 Three-Dimensional (3D) Technology

3D refers to the representation of objects that have width, height, and depth. 3D provides a realistic appearance compared to two-dimensional (2D) due to the inclusion of depth. In computing, a 3D image is a computer-generated graphic that provides the perception of depth like a real-world object [7]. CAD software or 3D modeling software such as Blender or AutoCAD are used to create realistic 3D models. 3D transformation is the process of manipulating the view of a 3D object with respect to its original position through methods such as translation and rotation [8]. It serves as a foundation for AR, enabling the integration of digital models into the real world.

2.3 Augmented Reality (AR) Technology

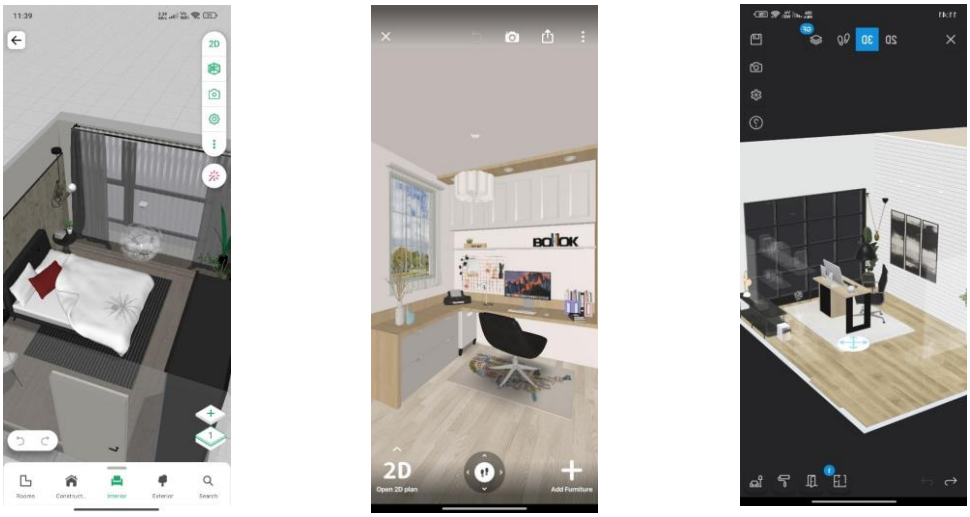
AR technology is a technology that combines virtual information with the real world [9]. It overlays the digital content on a real scene, fusing it with the real scene through a specific display device such as a head-mounted display or the screen of a smartphone [10]. It has been used in various fields such as engineering, games, tourism, medical and interior design itself. Since AR deals with both the virtual and real world, it is suitable for space management in interior design, which requires the simulation of calculated shape and size of the virtual space projected on top of the real world [11]. There are two main types of AR which are marker-based and marker-less. Marker-based AR experiences rely on predefined input into your smartphone or other device [12]. This type of AR guarantees high quality experience and stable tracking, yet it has limited flexibility and issues reflective surfaces. On the other hand, marker-less AR utilizes data provided based on our location and is provided with the help of a digital compass, accelerometer, velocity meter or global positioning system (GPS) [13]. It integrates advanced computer vision algorithms to recognize and track real-world objects and

surfaces. This type of AR provides flexibility that allows users to move around, and the objects remain in their position. However, it reduces tracking stability because it relies on the visual and lighting of the environment.

2.4 Comparative Analysis

Comparative analyses were conducted on three reviewed applications to the proposed application. The three applications are Planner 5D[14], Room Planner[15] and HomeByMe[16], as shown in Fig. 1(a), (b) and (c), respectively. Table 1 shows the result of comparative analysis.

The comparison is based on six criteria which are technology used by the application, cost, android version, language, module and special features. In comparison, Room Vision implements both 3D and AR technologies, positioning itself competitively as an immersive design option. Room Vision is free of charge, unlike the other three applications. Additionally, Room Vision uses Android version 7.1 and above, the minimum version that supports ARCore. Room Vision only provides one language, which is English. Regarding the special features, Room Vision contains AR features and an admin system for scalability of the application.



(a) **(b)** **(c)**

Fig. 1 *3D interface of reviewed application (a) Planner 5D[15]; (b) Room Planner[16]; (c) HomeByMe[17]*

Table 1 *Comparative analysis*

Criteria / Applications	Planner 5D	Room Planner	HomeByMe	Room Vision
Technology	2D, 3D, VR	2D, 3D	2D, 3D	3D, AR
Cost	Freemium	Freemium	Freemium	Free
Android version	Android 7 and above	Android 9 and above	Android 7.1 and above	Android 7.1 and above
Language	English, German, French, Italian, Spanish, Portuguese, Russian, Chinese, Japanese	English, Spanish, French, German, Italian, Portuguese, Arabic, Russian, Chinese, Japanese, Korean	English, French, German, Spanish and Portuguese	English
Module	• 2D • 3D • VR • Project management • Gallery • Contests • Profile • User authentication	• 2D • 3D • Design feed • Project management • Portfolio • Saved ideas • Profile • Bookmark items • User authentication	• 2D • 3D • Inspiration • Catalog • Project management • Collection • Profile • User authentication	• 3D • AR • Furniture catalogue • Project management • Inspiration • Profile • User authentication

Table 1*: (Continued)*

Criteria / Applications	Planner 5D	Room Planner	HomeByMe	Room Vision
Special feature	• Multiple 3D view mode (Flyover, Presentation, First Person, VR) • HD/4K Render • Collaborate function • Layer view mode • AI Designer • Room generates from floor plan • View and like people's design	• 360 / Walk view • Lighting option in photo mode • Export option • Social media design feed • Edit room from design feed • Various options of room creation (Blank, Template, Scan Room, Restyle photo with AI) • Reward badges	• Walk view • Photo and video capturing • HD/4K Render • Floor layer view • Detailed project initiation	• AR view • AR custom room measurement • Admin web system

3. Methodology

Agile methodology is chosen for the development of Room Vision application and system. It is a project management framework that breaks a project down into several dynamic phases, commonly known as sprints [4]. This iterative approach ensures flexibility, incremental development and faster delivery of modules to the stakeholders. Agile methodology consists of six phases, which are Plan, Design, Develop, Test, Deploy, and Review. These six phases will be iterated for every sprint. Fig. 2 illustrates the phases of agile methodology.

Fig. 2 *Agile methodology phases [4]*

3.1 Plan Phase

Plan phase is the most vital phase among the others because the requirements and schedule need to be planned carefully to ensure the project is aligned with requirements. All the essential planning, requirements and analysis are completed during the first sprint. The project idea was initiated, the problem statement, objectives and scope were defined. Several journal articles are researched to gain a deeper understanding of the domain. An online interview had conducted with SME Mr. Soh Choon Chai, an interior designer from Romax Interior Design Batu Pahat. Table 2 shows the user requirements analysis from an interview with SME. Analysis is also conducted during this phase to evaluate the requirements and existing applications. Existing applications are reviewed to understand the strengths and weaknesses of the application, helps to improvise the strengths and avoid the weaknesses in the proposed application. Functional requirements describe the product's functions and feature to achieve the objectives. The functional requirements of the application and system is shown in Table 3 and Table 4 respectively.

Table 2 *User requirements analysis*

Stakeholder Category	Role in Product	Design Implication	Action Needed
SME	Content consultant expert in interior design	Provide multifunctional furniture	• Include multifunctional furniture models in the application, along with detailed descriptions and images. • Highlight multifunctionality in the furniture description using clear labels.
		Provide inspiration guidance	• Include inspiration concepts with accompanying images and detailed descriptions. • Provide step-by-step guidance in inspiration to help users recreate the design.
		Provide latest material and trend	• Include materials and furniture models that reflect the latest trends in design. • Include simple and minimalist color palettes to align with modern trends.

Table 3 *Functional requirements of user application*

Functional Requirements	Module	Description
User Interaction	Authentication	• The application shall provide users with the ability to login and register an account. • The application shall provide users with the ability to reset password by requesting email.
	Project Management	• The application shall provide users with the ability to create a project. • The application shall provide users with the ability to select the room layout and enter the dimensions. • The application shall provide users with the ability to place vertices for custom layouts. • The application shall provide users with the ability to delete a project.
	Furniture Catalog	• The application shall provide users with the ability to search for furniture. • The application shall provide users with the ability to filter by category. • The application shall provide users with the ability to view furniture details.
	3D	• The application shall provide users with the ability to rotate, pan and zoom the camera. • The application shall provide users with the ability to add furniture to the room. • The application shall provide users with the ability to position and rotate the furniture in the room. • The application shall provide users with the ability to select the material for the furniture. • The application shall provide users with the ability to remove furniture from the room. • The application shall provide users with the ability to enable or disable the visibility of the walls. • The application shall provide users with the ability to save the project.
	AR	• The application shall provide users with the ability to project the room on the ground. • The application shall provide users with the ability to reset the view.

Table 3: (*Continued)*

Functional Requirements	Module	Description
	Profile	• The application shall provide users with the ability to edit their profile information • The application shall provide users with the ability to log out.
	Inspiration	• The application shall provide users with the ability to view the inspiration information.
Autonomous System Activities	Authentication	• The application shall be able to validate the credentials. • The application shall be able to display warning messages if invalid input. • The application shall be able to store and retrieve user's credentials from the database. • The application shall be able to redirect users to Home page after successfully login.
	Project Management	• The application shall be able to store and update the project in the database. • The application shall be able to load the project data into 3D scene.
	Furniture Catalog	• The application shall be able to retrieve and display furniture information.
	3D	• The application shall be able to generate a room based on the dimension input. • The application shall be able to save the furniture placement and room data.
	AR	• The application shall be able to ask for camera permission for new users. • The application shall be able to project the room loaded from the 3D scene.
	Profile	• The application shall be able to display the username and email.
	Inspiration	• The application shall be able to retrieve and display the inspiration available in the database.

Table 4 *Functional requirements of admin system*

Functional Requirements	Module	Description
User Interaction	Authentication	• The system shall provide the admin with the ability to login an account. • The system shall provide the admin with the ability to reset password by requesting email
	Furniture Management	• The system shall provide admin with the ability to add, edit or delete furniture.
	Catalog Management	• The system shall provide admin with the ability to add, edit, or delete inspiration.
	Inspiration Management	• The system shall provide admin with the ability to add, edit, or delete category.
Autonomous System Activities	Authentication	• The system shall be able to validate the credentials. • The system cation shall be able to display warning messages if invalid input. • The system shall be able to retrieve admin's credential from the database. • The system shall be able to redirect admin to Home page after successfully login.
	Furniture Management	• The system shall be able to display furniture available in database.

Table 4: (*Continued*)

Functional Requirements	Module	Description
	Catalog Management	• The system shall be able to display inspiration available in database.
	Inspiration Management	• The system shall be able to display category available in database.

3.2 Design Phase

The design phase defines the technical details of the project and preparing the assets for implementation. The navigation structure of this project was established, as illustrated in Fig. 3 and Fig. 4. The user interface was planned during this phase to align with the defined navigation structure. Object-oriented approaches were adopted for both the mobile app and admin system, hence Unified Modelling Language (UML) diagrams were designed to represent the system architecture. Four UML diagrams, use case diagram, sequence diagram, activity diagram and class diagram were illustrated as shown in Appendix A. Use case diagram illustrates the functional requirements of the system boundaries and its interactions with actors, as seen in Fig. 14. The sequence diagram depicts the interaction between objects in sequential order. Two main sequence diagrams, focusing on 3D and AR modules are included in Fig. 15 and Fig.16. The activity diagram designs the flow of control in the system, both admin and user activity diagram are shown in Fig. 17 and Fig. 18 respectively. Class diagram represents the structure and relationships of classes within a system, as seen in Fig. 19. Since the proposed application involves database integration, Data Flow Diagram (DFD) was developed. The DFD consists of a context diagram and level 0 diagram, shown as Fig. 20 and Fig. 21 which include Appendix B. A data dictionary was also created to define the structure and meaning of data elements used in the system.

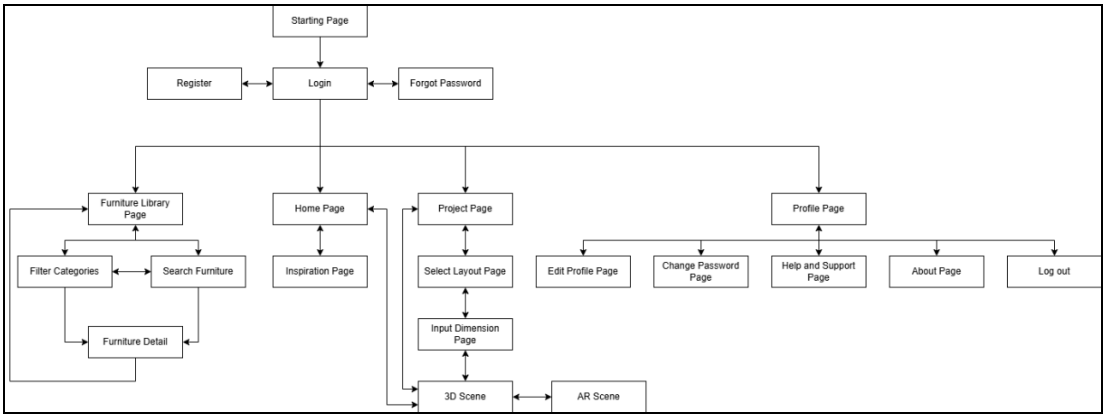


Fig. 3 *User navigation structure*

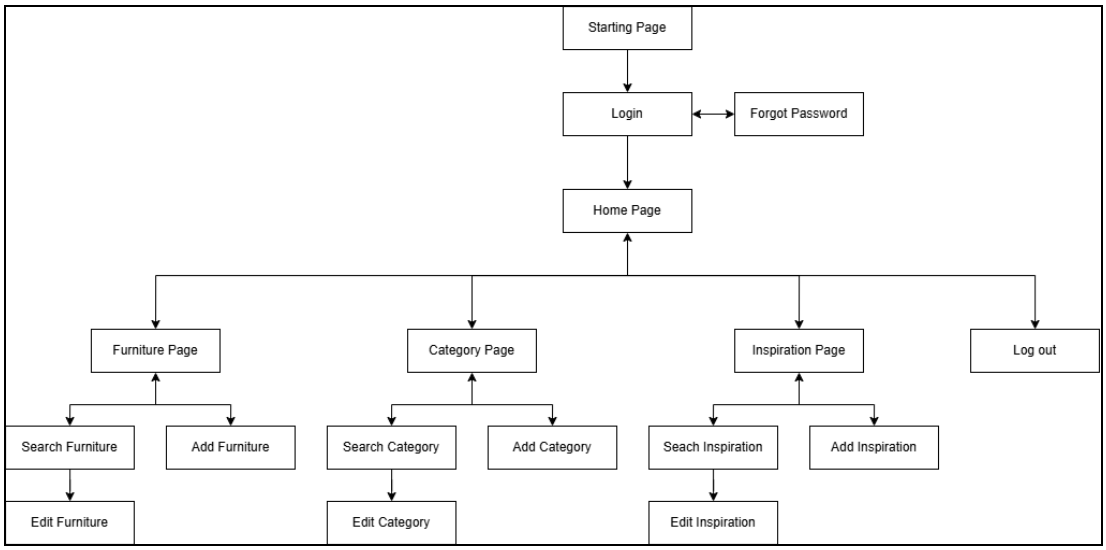


Fig. 4 *Admin navigation structure*

3.3 Develop Phase

This phase involves executing the project plan to achieve the objectives. The requirements and analysis serve as references for developing the application. The assets required for this project were modelled and integrated during development. The furniture 3D models were created referencing product images and observations. The user interface of the application and system follow the design of the storyboard, including the interaction of buttons. Additionally, the database will be integrated into both platforms. During implementation, any bugs encountered were addressed and resolved. Performance optimization was also carried out prior to the application's release. The development of the application using Unity and Visual Studio 2022 for scripting. Visual Studio Code was used to develop the admin system. Firebase, a Backend as a Service (BaaS) was used as the integrated database solution, providing various backend services for mobile and web development. This phase followed an iterative approach, where features were incrementally developed, reviewed, and refined across multiple sprints until the final product was completed.

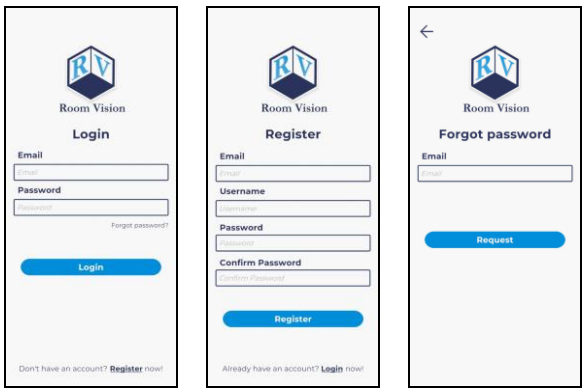


Fig. 5 *User authentication interface (a) Login; (b) Register; (c) Forgot password*

Fig. 5 shows the user authentication module interface. Users can log in using email and password in Fig. 5(a). Invalid credentials trigger an error message. Upon successful login, users are redirect to home page. The registration page, as seen in Fig. 5(b) requires an email, password, and username, with a warning shown for invalid inputs. After registration, users will be redirected back to login page. Fig. 5(c) shows the forgot password page, users request a reset link via email, managed by Firebase.

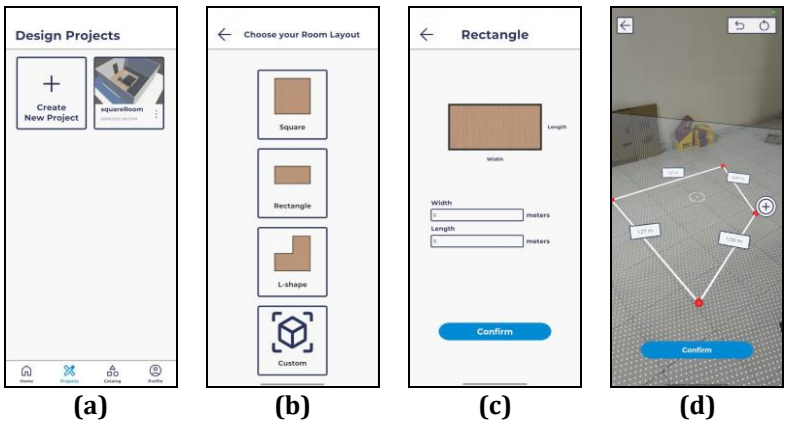


Fig. 6 *Project management interface (a) Projects; (b) Layout selection; (c) Dimensions form; (d) AR custom room*

Fig. 6 shows the project management module interface. The projects page shown in Fig. 6(a), displays all user-created projects. Each project button displays an image, name, last updated time, and a More button. The More button allows users to either rename or delete a project. Renaming opens a pop-up for name input, while deletion triggers a confirmation dialog before removing the project from the database. In Fig. 6(b), users can choose from four types of room layout, which are square, rectangle, l-shape and custom. For the first three layout, users input room dimensions, which then generate the room in 3D upon confirmation as shown in Fig. 6(c). For custom layouts, users scan the floor in AR mode and place vertices to define the room shape, as seen in Fig. 6(d). The system displays vertex connections and distances. A minimum of three vertices is required, else an error message appears.

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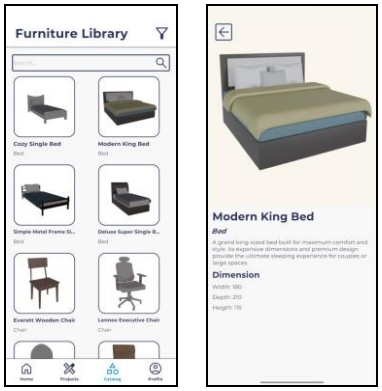
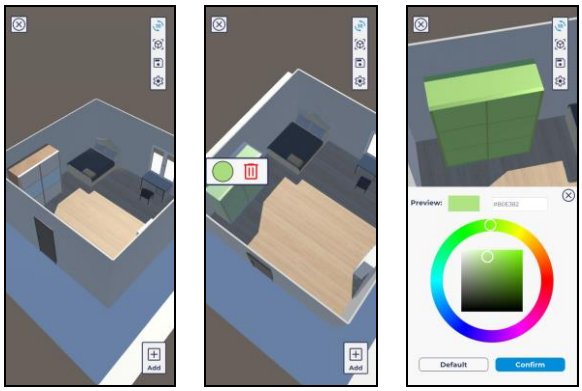


(a) (b)

Fig. 7 *Furniture catalogue interface (a) Furniture catalogue; (b) Furniture detail*

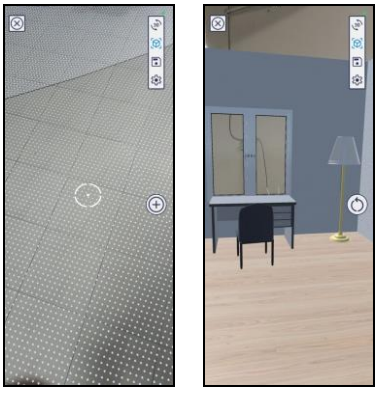
Fig. 7 shows the furniture catalogue and furniture detail interfaces. The catalogue page, shown in Fig. 7(a), displays furniture items as buttons labelled with their name and category. Users can search by keyword or filter items by category using the top-right filter button. Upon selecting a furniture item, a detailed view appears showing the image, name, category, description, and dimensions, as seen in Fig. 7(b).



(a) (b) (c)

Fig. 8 *3D interface (a) 3D view; (b) Furniture option; (c) Material picker*

Fig. 8 shows the 3D module interface. The 3D view, shown in Fig. 8(a), allows users to navigate the room using touch gestures, orbit with one finger, move with two fingers, and zoom via pinch. The Add button at the bottom right lets users browse furniture categories and spawn items into the room. Selecting a furniture opens an option to change its material colour or delete it as shown in Fig. 8(b). Clicking the material button will open the colour picker, enabling users to apply custom material, as seen in Fig. 8(c). Selected furniture can be moved or rotated, and overlapping furniture is indicated by a red selector box. Top-right buttons include AR mode, Save Project, and Settings. The top-left button exits back to the project page.



(a) (b)

Fig. 9 *AR interface (a) Scan Floor; (b) Project Room in AR*

Fig. 9 shows the AR module interface, which closely resembles the 3D interface. Fig. 9(a) shows that users scan the floor before projecting the room. A dotted plane appears upon successful detection and adjusts dynamically with continued scanning. The Add button on the right spawns the room onto the plane. After it is spawned, the button turns into a reset icon for reprojection if needed, as shown in Fig. 9(b).

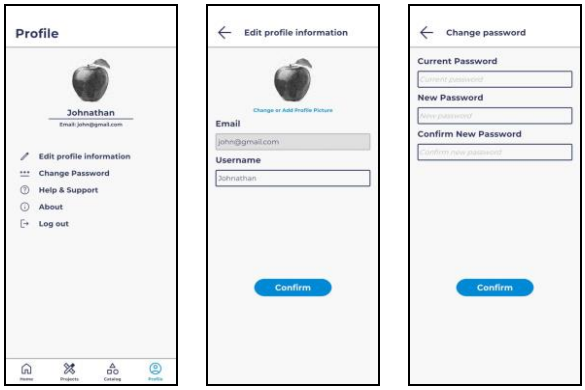


Fig. 10 *Screenshots of (a) Profile; (b) Edit Profile; (c) Change Password interfaces*

Fig. 10 shows the profile module interface, where users can manage their account information, including username, email, profile picture and password. Fig. 10(a) shows the profile page, which have actions such as editing profile info, changing password, accessing help and support, viewing app info, and logging out. Users can update their username and upload a new profile picture in edit profile page as in Fig. 10(b). Besides, password can be changed in the change password page shown in Fig. 10(c), which will authenticate users before updating.

Table 5 *C# Script for Room Vision Mobile Application*

Functions	Source Code	Description

Room Generator	`public void GenerateRoom(){`
	`  switch(dimensions.layout){`
	`  case LayoutTypes.Square:`
	`  case LayoutTypes.Rectangle:`
	`  GenerateBoxFloor(width, length);`
	`  GenerateBoxWall(width, length, height);`
	
	`  break;`
	`  case LayoutTypes.Lshape:`
	`  GenerateLShapeFloor();`
	`  GenerateLShapeWalls(width, length, width2, length2, height);`
	
	`  break;`
	`  case LayoutTypes.Custom:`
	`  List<Vector3> vertices = EnsureClockwise(dimensions.vertices);`
	`  GenerateCustomFloorMesh(vertices);`
	`  GenerateCustomWalls(vertices, height);`
	
	`  break;`
	`  default:`
	`  Debug.LogWarning("Invalid Layout Types!");`
	`  break;`
	`  }`
	`  SetWallStencilRef();`
	`}`
		Generate room based on selected layout and dimension values. Applies wall stencil reference.

Spawn Furniture	`Addressables.LoadAssetAsync<GameObject>(model).Completed += handle =>{`
	`  if (handle.Status == AsyncOperationStatus.Succeeded){`
	`  GameObject prefab = handle.Result;`
	
	`  GameObject furniture = Instantiate(prefab, location, Quaternion.identity);`
	`  }`
	`  else{`
	`  spawnErrorPopup.SetActive(true);`
	`  }`
	`};`
		Fetch furniture asset using Unity Addressables and spawn it into the 3D scene.

Modify Material	`if(ColorUtility.TryParseHtmlString(hexCode, out Color newColor)){`
	`  foreach (var renderer in renderers){`
	`  Material[] mats = renderer.materials;`
	`  for (int i = 0; i < mats.Length; i++)`
	`  mats[i] = new Material(mats[i]) { color = newColor };`
	`  renderer.materials = mats;`
	`  }`
	`}`
		Parse hex color and apply new material to furniture.

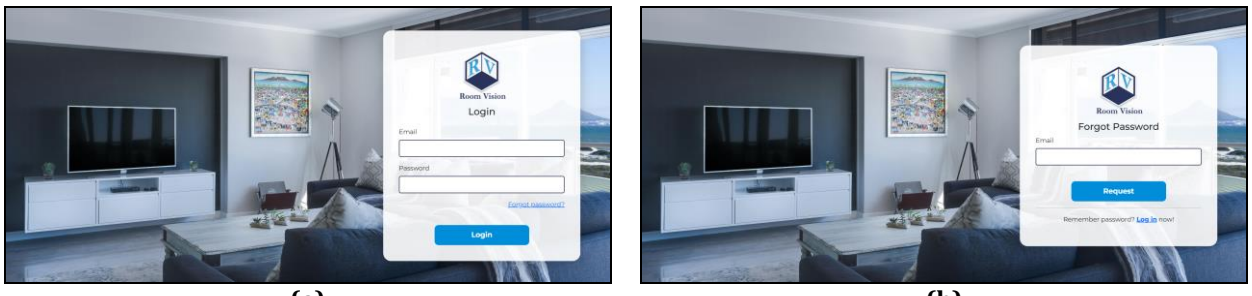
Table 5: (*Continued*)

Functions	Source Code	Description

Camera Control	`if (touchCount.Count > 1){`
	`  var touch1 = onScreen.touches[0];`
	`  var touch2 = onScreen.touches[1];`
	
	`  var initialVector = touch2.startPosition.ReadValue() - touch1.startPosition.ReadValue();`
	`  var currentVector = touch2.position.ReadValue() - touch1.position.ReadValue();`
	
	`  float initialMagnitude = initialVector.magnitude;`
	`  float currentMagnitude = currentVector.magnitude;`
	
	`  float changes = Mathf.Abs(currentMagnitude - initialMagnitude);`
	
	`  if ( changes < 100){`
	`  PanAround(touch1, touch2);`
	`  }else{`
	`  ZoomInOut(touch1, touch2);`
	`  }`
	`}else if (touchCount.Count == 1){`
	`  var touch = onScreen.touches[0];`
	`  OrbitAround(touch);`
	`}`
		Camera orbit, pan, and zoom handled through single- and multi-touch input.

Save Project	`private void ProjectSaved(System.Action onComplete)`
	`{`
	`  var docRef = db.Collection("Project").Document(projectId);`
	
	`  var updates = new Dictionary<string, object>`
	`  {`
	`  { "thumbnail", thumbnailURL },`
	`  { "updatedAt", Timestamp.GetCurrentTimestamp()}`
	`  };`
	
	`  docRef.UpdateAsync(updates).ContinueWithOnMainThread(task =>`
	`  {`
	`  if(task.IsCompleted)`
	`  {`
	`  Debug.Log("Project updated successfully!");`
	`  }`
	`  });`
	`  onComplete?.Invoke();`
	`}`
		Update project in Firestore, including thumbnail URL and last modified time.

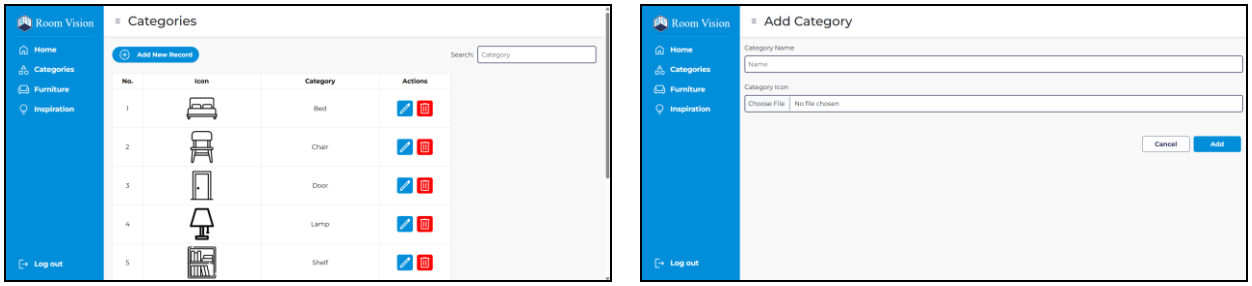
Spawn Room on AR Cursor	`if (!hasSpawned){`
	`  roomGenerator.GenerateRoom();`
	`  _roomParent.transform.position = _cursor.transform.position;`
	`  surfaceManager.ApplyFloorMaterial(floorMat);`
	`  surfaceManager.ApplyWallMaterial(wallMat`
	
	`  if (furniture.Count != 0){`
	`  foreach (string key in furniture.Keys)`
	`  spawner.SpawnFurniture(key, position, rotation, material);`
	`  }`
	`  _hasSpawned = true;`
	`}else{`
	`  Destroy(_roomParent);`
	`  _hasSpawned = false;`
	`}`
		Spawn or reset the 3D room, apply materials, and load furniture items on AR cursor.



(a) **(b)**

Fig. 11 *Admin authentication interface for (a) Login; (b) Forgot password*

Fig. 11 shows the admin authentication module interface. Fig. 11(a) is the login page where admins enter their email and password to access the management system. Fig. 11(b) is the forgot password interface that prompts the admin to enter their email address to request a reset password form. The blue highlighted texts act as hyperlinks, allowing navigation between the login and forgot password pages.



(a) **(b)**

Fig. 12 *Category management module interface for (a) Category listing; (b) Add category form*

Fig. 12 shows the two interfaces of the category management module. In the management interface shown in Fig. 12(a), all categories are displayed in a table format. Each row includes an edit and a delete button for managing individual records. Admins can add, edit, or delete categories, and changes will affect all linked furniture items. A search bar is available to filter categories by keywords. A shared interface is used for both adding and editing categories, where admins input the category name and upload an icon shown in Fig. 12(b). The furniture and inspiration management modules share a similar interface structure, differing only in specific data fields used.

Table 6 *C# Script for Room Vision Admin System*

Functions	Source Code	Description

Login	`const userCredential = await signInWithEmailAndPassword(auth, email, password);`
	`const user = userCredential.user;`
	`const docRef = doc(db, "Admin", user.uid);`
	`const docSnap = await getDoc(docRef);`
	`if(docSnap.exists()){`
	`  window.location.href = "home.html";`
	`}else{`
	`  alert("Login failed. You are not an admin.");`
	`}`
		Authenticate the admin and verify that the logged-in email belongs to an admin.

Fetch data	`const docRef = collection(db, collectionName);`
	`const q = query(docRef, orderBy(orderField, "asc"));`
	`const querySnapshot = await getDocs(q);`
	`const tableBody = document.querySelector("#content tbody");`
	`tableBody.innerHTML = "";`
	`let i = 1;`
	
	`// Display documents in table`
	`querySnapshot.forEach((doc) => {`
	`  const data = doc.data();`
	`  const row = document.createElement("tr");`
	
	`  // Populate row with relevant data`
	`  row.innerHTML = `...`;`
	`  tableBody.appendChild(row);`
	
	`  i++;`
	`});`
		Generalized code snippet for fetching and displaying records such as furniture, categories, or inspirations in a table.

Search record	`searchInput.addEventListener("input", e => {`
	`  const value = e.target.value.toLowerCase();`
	`  let hasVisible = false;`
	
	`  module.forEach(piece => {`
	`  const match = piece.data.field.toLowerCase().includes(value);`
	
	`  const isVisible = match;`
	`  piece.element.classList.toggle("hide", !isVisible);`
	`  if(isVisible) hasVisible = true;`
	`  });`
	
	`  document.getElementById("noResults").style.display = hasVisible ? "none" : "block";`
	`});`
		Generalized code snippet for searching records such as categories, furniture, or inspirations.

Delete record	`const docRef = doc(db, collectionName, documentId);`
	
	`await deleteImage(collectionName, docRef.id);`
	`await deleteDoc(docRef);`
	
	`alert("Inspiration deleted successfully.");`
		Generalized code snippet for deleting a record and its associated image from the database.

Table 6: *(Continued)*

Functions	Source Code	Description

Add or edit record	`try {`
	`  if(documentId){ // Edit mode`
	`  await setDoc(docRef, {`
	`  ...data,`
	`  image: imageUrl,`
	`  }, { merge: true });`
	
	`  alert("Record updated successfully!");`
	`  window.location.href = "inspiration.html";`
	`  }else{ // Add mode`
	`  await setDoc(docRef, {`
	`  ...data,`
	`  image: imageUrl,`
	`  createdAt: Timestamp.now()`
	`  });`
	
	`  alert("Record added successfully!");`
	`} catch (error) {`
	`  console.error("Error adding document:", error);`
	`  alert("Failed to add data. Check the console for errors.");`
	`}`
		Generalized code snippet for adding a new record or editing an existing record in the database.

3.4 Test Phase

Testing is a critical phase after the development of each module in every sprint. The purpose of testing is to identify and resolve bugs, validate the functionality of module and ensure it meets the stated requirements. During the development, alpha testing will be performed to identify bugs and ensure the product works as intended. After the alpha testing is complete and no issue encounter, beta testing will proceed. The purpose of beta testing is to identify issues that have not been found in alpha testing, especially usability issues and real-world performance problems. The application will be tested by target users using the System Usability Scale (SUS) and feedback will be gathered. 20 respondents aged 18 to 30 were selected to test the application. The usability test was conducted in person, and participants completed a questionnaire via Google Form.

3.5 Deploy Phase

This phase marks the transition of application from development to the live environment, where they become accessible to target users. This phase only initiated when the application has complete development. The application will undergo final validation to ensure critical issues are resolved and the functionalities meet the requirements. After validation, the application is prepared and released in production-ready format, such as an APK file for Android. The application and user manual will be distributed to target users by direct download link. Upon post-deployment, feedback will be collected from users to assess the overall experience, identify any usability issues, and gather suggestions for improvement. In addition, both the application and system will be monitored to ensure stable performance in a live environment.

3.6 Review Phase

This is the last phase of every sprint. In this phase, it involves a formal evaluation of the work completed in the sprint, ensuring the project is aligned with the objectives and requirements. All the activities done in a sprint will be reviewed to check if there are any improvements and modules to be fixed in the next sprint. All the feedback gathered will also be reviewed to improve the application. The project was completed in approximately six sprints over two semesters. Sprint reviews were conducted at the end of each sprint to evaluate progress, identify issues and plan improvement for the next iteration.

4. Result and Discussion

In this section, the testing of Room Vision mobile application will be discussed in detail. The subsection displays the result of SUS performed during the beta testing.

4.1 Beta Testing

Beta testing was conducted on the target users such as homeowners, renters, interior designers, and individuals aged 18 to 30 years old. The questionnaire and mobile device with the application installed are handed to them for testing. There are a total of 20 respondents answering the questionnaire and their rating is calculated using SUS, to assess their experience with a mobile application. The score on the system usability scale on the application is 71.88, which falls to grade C. Table 7 shows the tabulated data of SUS. Based on user feedback, several improvements were made to enhance usability and fix reported issue.

Table 7 *Respondents' score*

Respondent	Item Score										Odd Score	Even Score	Total Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
R01	5	3	4	3	4	2	3	2	5	2	16	13	72.5
R02	5	5	5	1	5	1	5	1	5	1	20	16	90
R03	4	3	3	4	4	1	3	2	3	4	12	11	57.5
R04	3	2	5	3	5	3	5	5	5	5	18	7	62.5
R05	4	3	4	3	3	4	4	2	4	3	14	10	60
R06	4	1	5	2	5	1	5	1	4	2	18	18	90
R07	1	4	2	4	3	3	3	4	3	4	7	6	32.5
R08	4	2	5	2	5	1	5	2	4	2	18	16	85
R09	5	1	5	1	5	1	4	1	5	1	19	20	97.5
R10	4	3	2	1	4	2	5	2	5	3	15	14	72.5
R11	2	3	4	3	4	3	3	2	3	2	11	12	57.5
R12	3	2	4	3	4	3	4	2	3	1	13	14	67.5
R13	2	1	4	1	3	2	5	3	4	1	13	17	75
R14	3	2	3	1	5	2	3	4	4	1	13	15	70
R15	1	1	5	1	4	1	4	2	4	1	13	19	80
R16	4	3	4	4	5	1	5	1	5	1	18	15	82.5
R17	1	1	5	2	3	2	3	1	3	1	10	18	70
R18	4	2	4	2	5	1	5	2	4	1	17	17	85
R19	2	1	5	1	3	2	4	1	4	1	13	19	80
R20	1	2	4	4	3	2	3	3	2	2	8	12	50
												Average Score	71.88

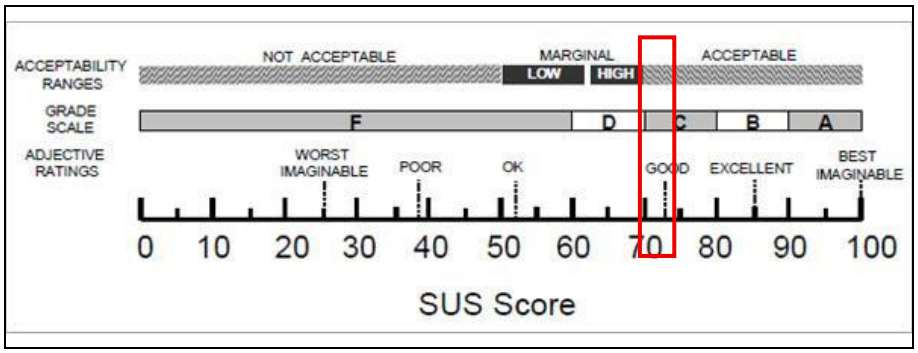


Fig. 13 *System Usability Scale*

The formula used to obtain usability results based on the SUS is:
Total score = (odd items + even items) x 2.5
Average score = Total score / Total respondent
Where:

Odd items (Q1, Q3, Q5, Q7, Q9): Score contribution = Response - 1
Even items (Q2, Q4, Q6, Q8, Q10): Score contribution = 5 - Response

Therefore,
(72.5+90+57.5+62.5+60+90+32.5+85+97.5+72.5+57.5+67.5+75+70+80+82.5+70+85+80+50) / 20
= 71.88

The calculated average score is 71.88. Based on the System Usability Scale, the app falls just below the threshold for a "Good" rating, corresponding to a grade of C. Room Vision is perceived as a usable and acceptable application by users, but further improvements in user interface and experience could enhance its usability rating.

5. Conclusion

The Room Vision project successfully delivered a mobile application for interior room planning using 3D and AR technologies. It achieved the proposed objectives, including designing a user-friendly interface that is visually appealing and allows for easy navigation within 3D interior design project, developing 3D object manipulation that allows users to position furniture, integration of AR viewing type, and evaluating the app by target users through the SUS. The app receives a SUS score of 71.88, corresponding to a Grade C. The application offers advantages such as real-scale AR visualization and 3D layout planning, a user-friendly and intuitive interface, and inclusion of inspiration guidance. However, limitations such as lack of offline support, non-interactive resizing room, and longer loading times for 3D models fetch via Unity Addressables indicate opportunities for further development. Future enhancements may include interactive room editing, spatial analysis to detect impractical designs and multi-room layout support. Overall, Room Vision lays a solid foundation for future enhancement and contributes meaningfully to mobile-based interior design tools.

Acknowledgement

The authors would like to thank the Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Kok Yuin Foong, Ezak Fadzrin Ahmad Shaubari;* ***data collection:*** *Kok Yuin Foong, Ezak Fadzrin Ahmad Shaubari;* ***analysis and interpretation of results:*** *Kok Yuin Foong, Ezak Fadzrin Ahmad Shaubari;* ***draft manuscript preparation:*** *Kok Yuin Foong, Ezak Fadzrin Ahmad Shaubari. All authors reviewed the results and approved the final version of the manuscript.*

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Appendix A: Unified Modelling Language (UML) Diagram

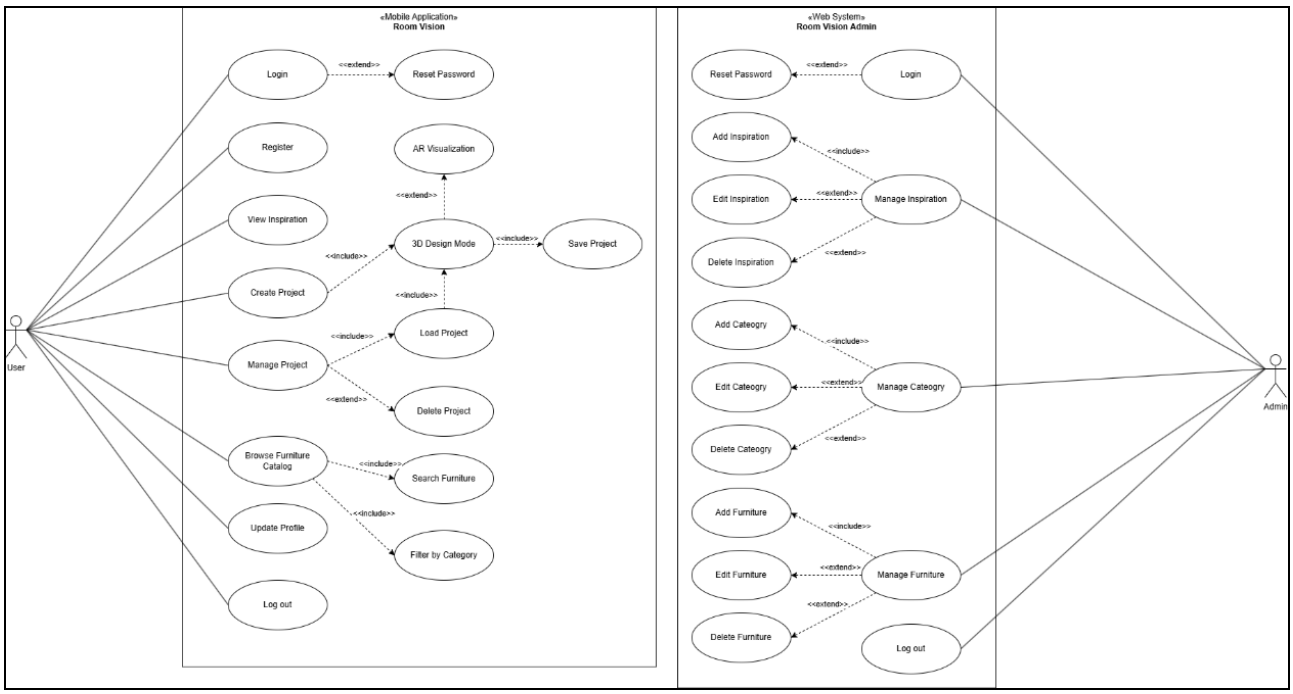


Fig. 14 *Use case diagram*

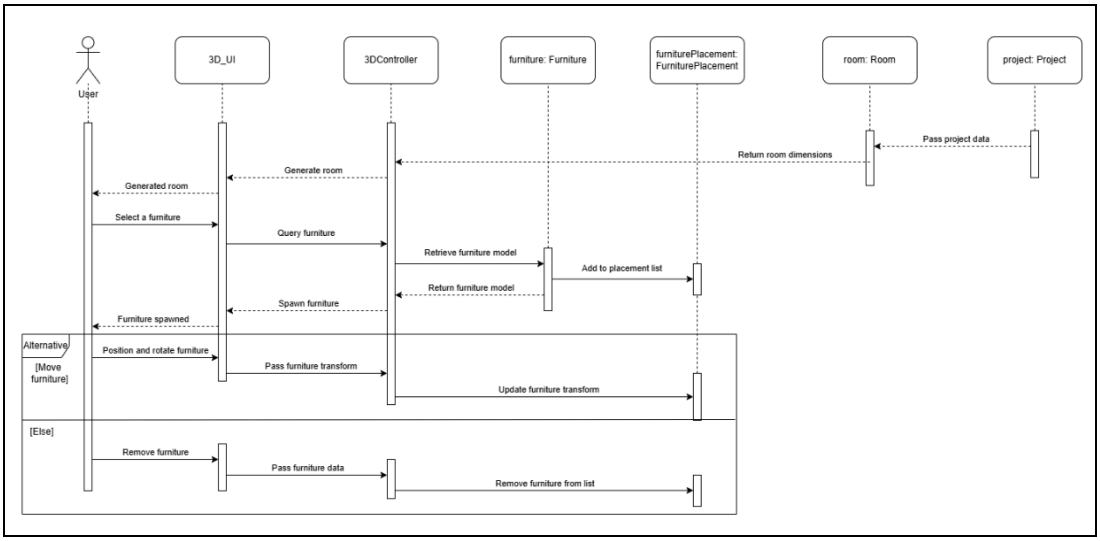


Fig. 15 *3D design mode sequence diagram*

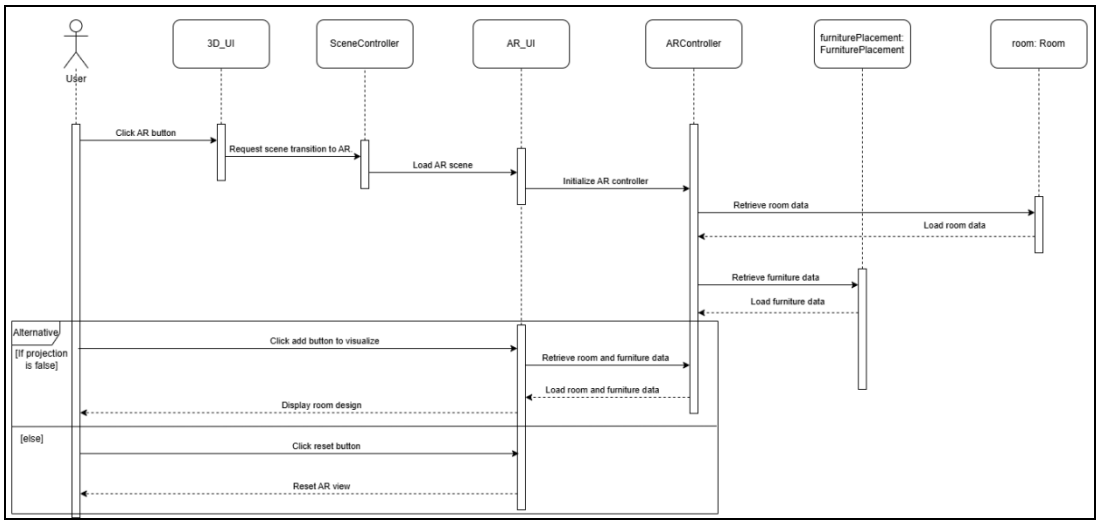


Fig. 16 *AR visualization sequence diagram*

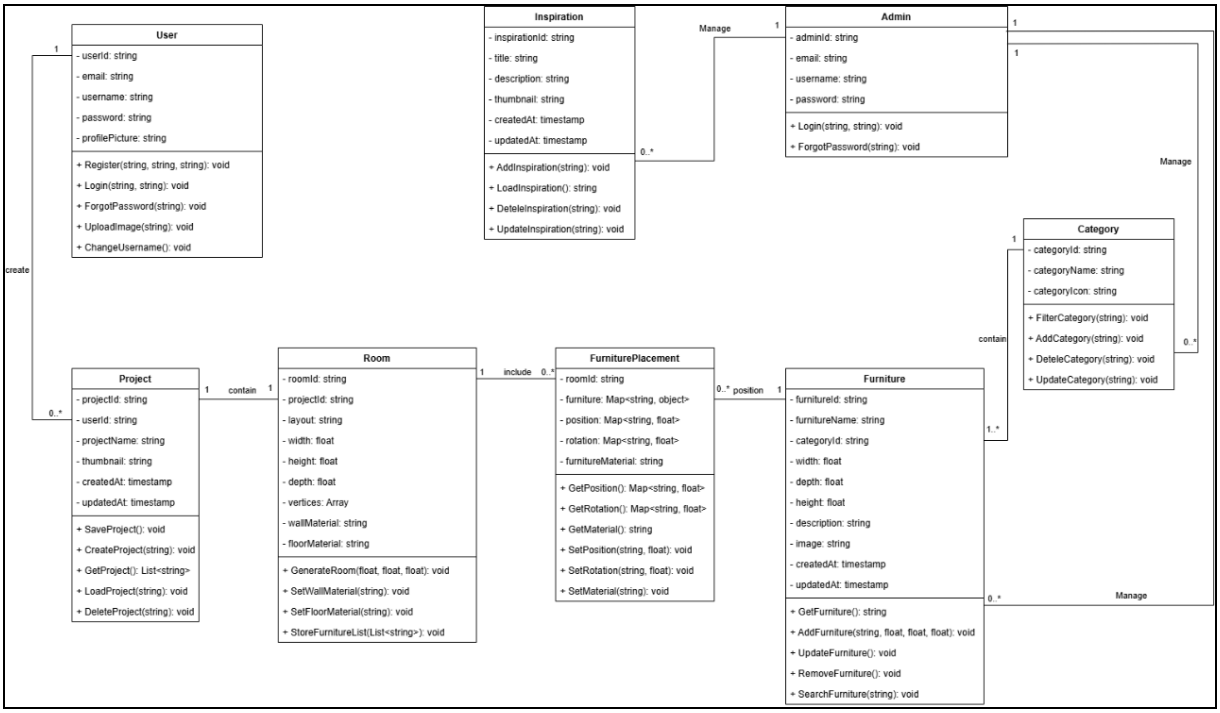
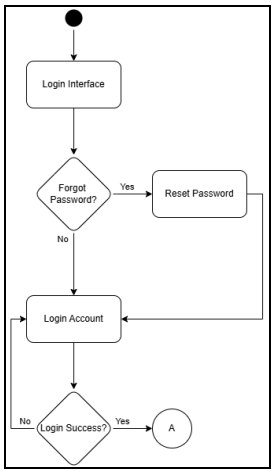
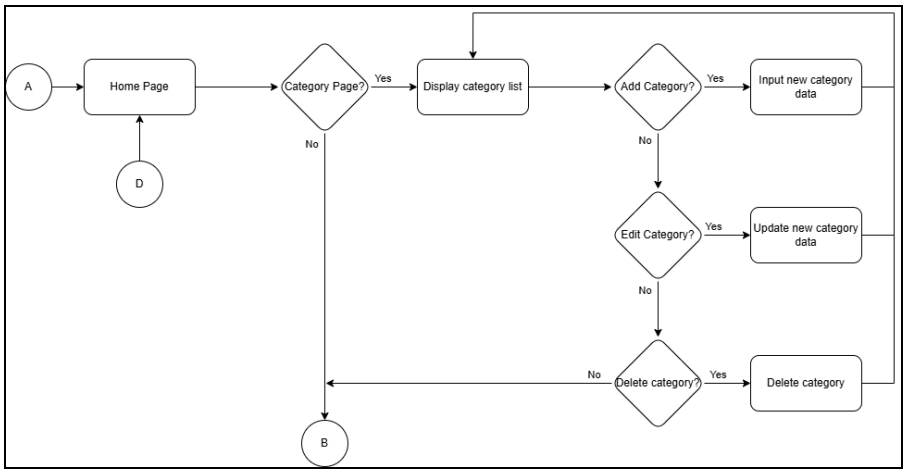


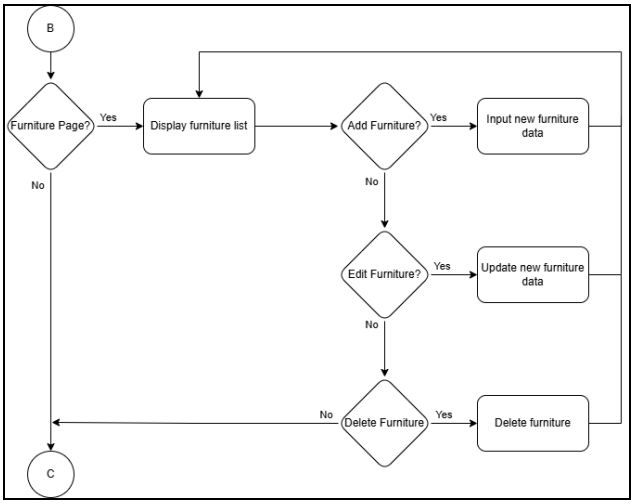
Fig. 17 *Class diagram*



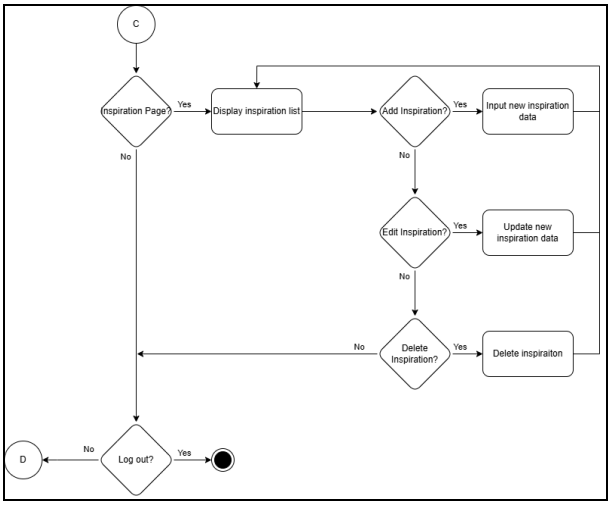
(a)



(b)

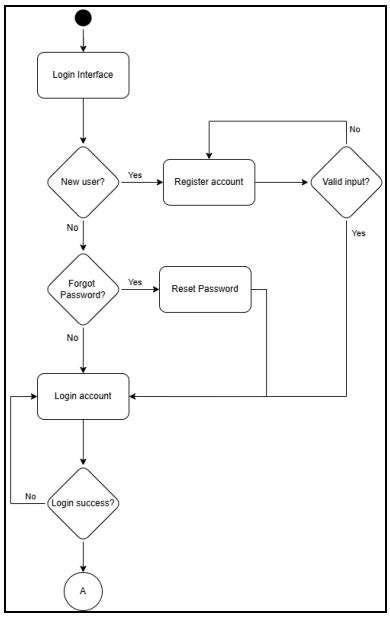


(c)

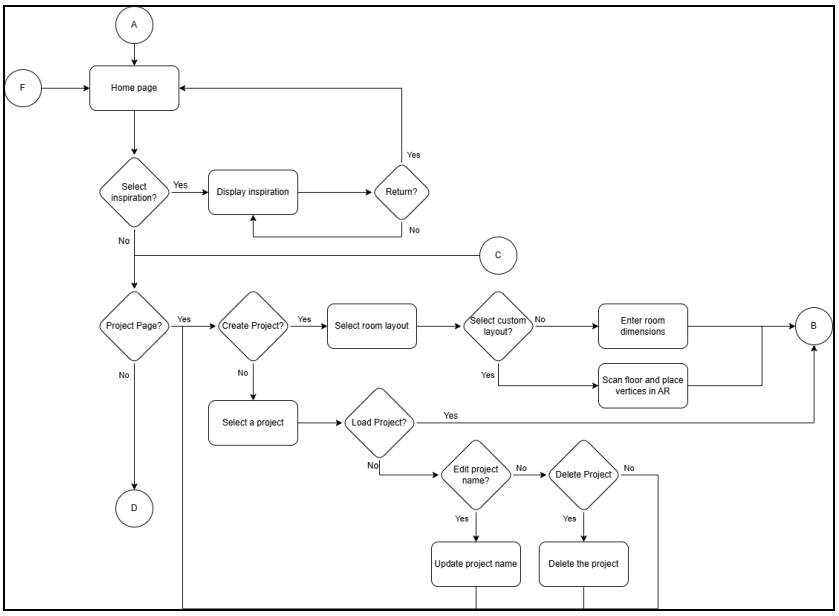


(d)

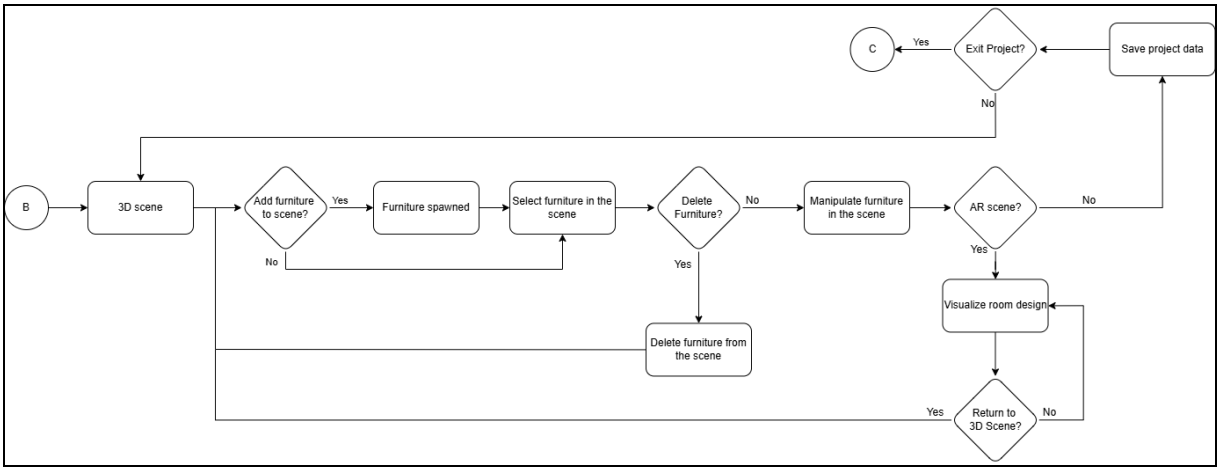
Fig. 18 *Admin activity diagram (a) First; (b) Second; (c) Third; (d) Fourth*



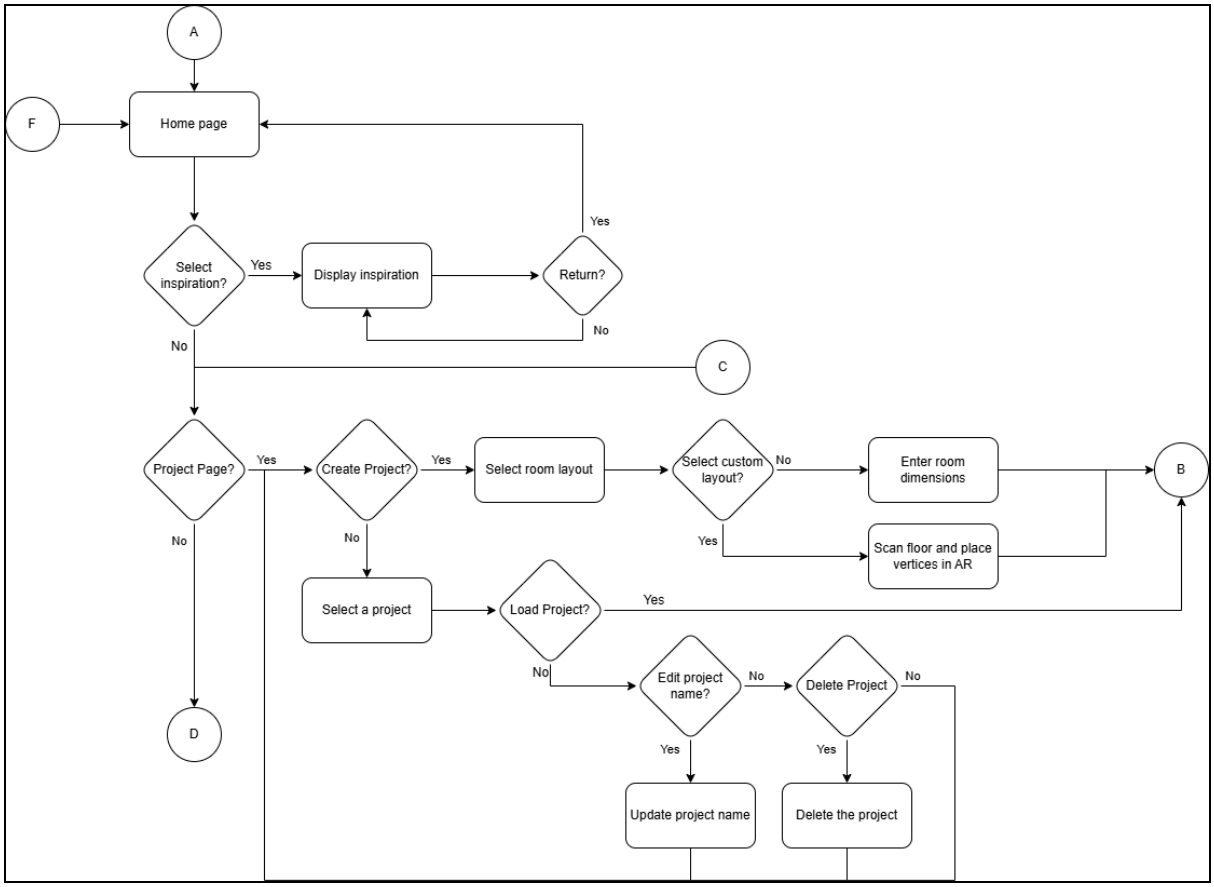
(a)



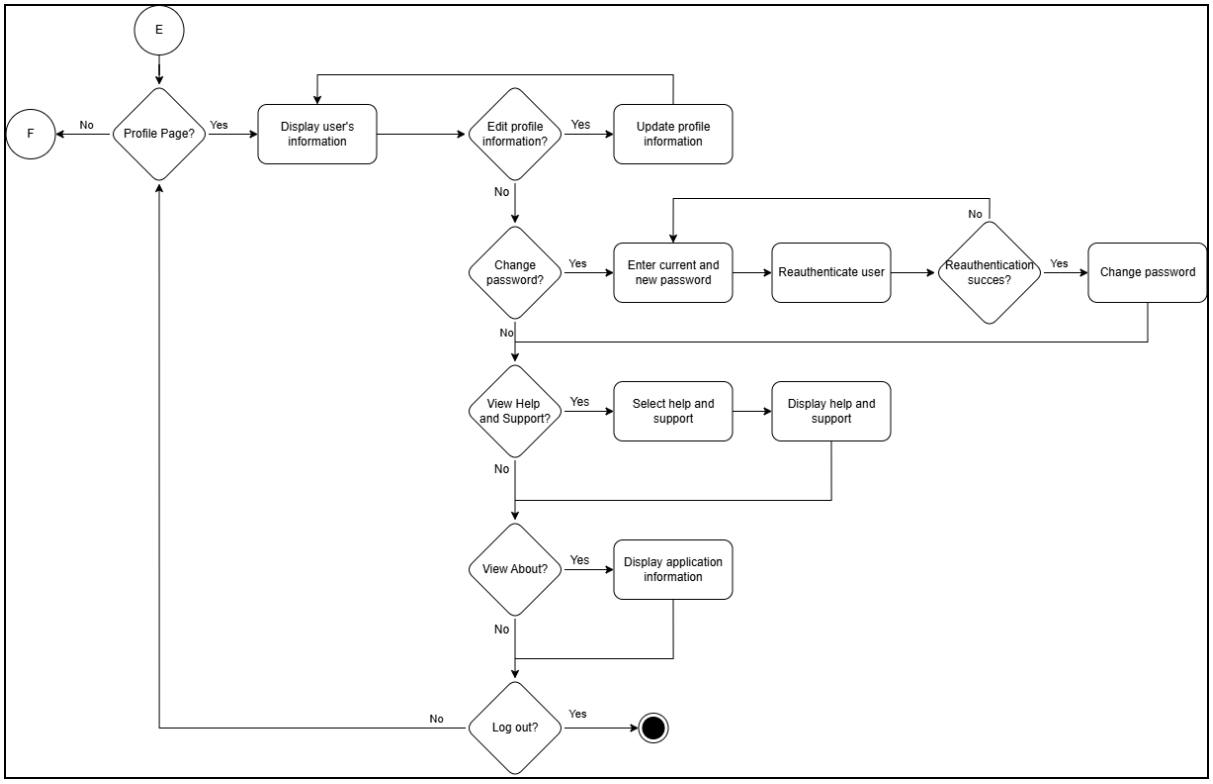
(b)



(c)



(d)



(e)

Fig. 19 *User activity diagram (a) First; (b) Second; (c) Third; (d) Fourth; (e) Fifth*

Appendix B: Data Flow Diagram (DFD)

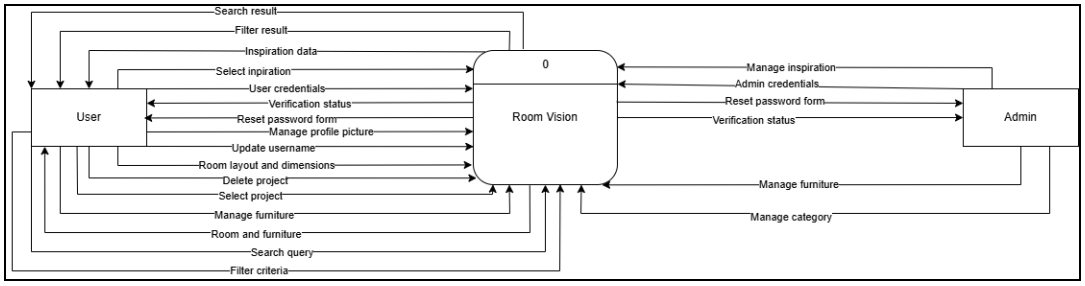


Fig. 20 *Context diagram*

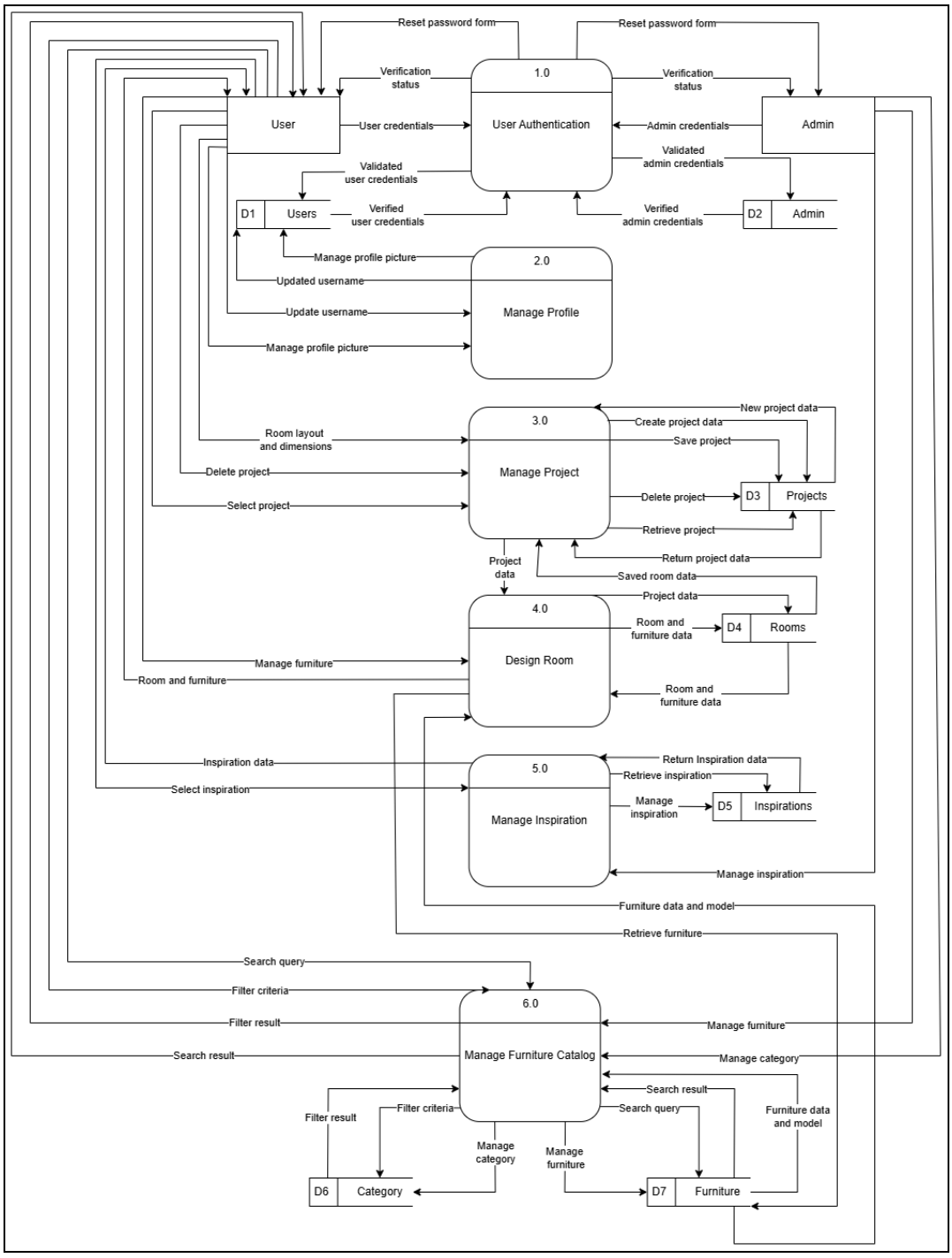


Fig. 21 *Level 0 diagram*