DecoraAI: AI-powered Augmented Reality (AR) Interior Design Web Application

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Abstract—In this paper, the author introduces an AI-based web-based Augmented Reality (AR) interior design application, called DecoraAI, that will be utilized to improve the process of interior visualization in real-time and assist users in decision-making. The main aim of the study is to create a smart system that helps a user to create a tailor-made 3D interior items with a natural language input and automatically view it in the real world conditions via WebAR. The suggested research approach is based on the design-based experimental framework, involving the text to 3D-generative AI model, the WebXR-based AR visualization system, and the interactive manipulation of objects. The evaluation of the performance is done based on the quantitative metrics of user engagement rate, design completion time, spatial understanding accuracy, and a user satisfaction score. Experiments indicate that DecoraAI helps to increase user interaction by 32%, shortens the time need to finish a design by 25% and increases spatial comprehension significantly than traditional interior design tools. The unique value of the work is in the smooth connection between artificial 3D content creation based on AI and real-time web-based AR display, which provides an affordable, interactive, and smart interior design option.

Index Terms—Artificial Intelligence (AI), Interior Design, 3D Model Creation, WebAR, Real-Time Visualization, Human-Computer Interaction, Spatial Computing, Intelligent Design Systems, Immersion Technologies and Web-Based Applications.

I. INTRODUCTION

The rapid development of digital technologies has significantly transformed the realm of interior design since people can now easily visualize and plan the spaces more effectively compared to the manual process. Available apps such as SketchUp, Planner 5D and many other mobile AR applications allow the user to visualize the interior design in the virtual space. Nevertheless, most of these systems are based on the use of pre-defined templates as well as fixed object libraries that limit the scope of creativity and customization and to a certain extent, the accuracy with the real world [1], [3].

Conventional interior design methods are limited in several ways. First of all, the most talented professional designers charge high fees and then take a lot of time doing the design, so not everyone can afford their service. Second, most of the digital design tools are quite technical and thus they are mainly for the pros and non-professional users cannot use them. Third, existing AR-based solutions do not offer wide customization options and smart assistance in designing elements based on the user's preferences or descriptions [3], [18], [19].

To solve the mentioned problems, this paper introduces DecoraAI, an AI-powered web-based AR application that lets people use natural language and free their imagination by creating their own 3D interior design objects and seeing them instantly in the real world. DecoraAI for the very first time allows users to apply the advanced technologies of generative artificial intelligence, 3D rendering and WebAR to incorporate, resize, rotate and move AI-generated furniture and decor pieces in their living room, all happening in real-time [1]–[3]. This will make the design process very interactive and feel more realistic, thus effectively making imagination and reality closer to each other [17], [18].

The primary contributions of this study are the following:
- AI-powered system is able to understand natural language and is able to work on 3D interior design models [2], [4]
- An augmented reality web-based simulation in which virtual objects protrude into real life situations in real time [3], [11]–[14]
- For instance, consider an interface design that is interactive, permitting object manipulation in terms of scaling, rotation and repositioning [15-16, 18-20]
- Experimental confirmation of better usability, design precision and user interaction [17]–[19]

II. LITERATURE REVIEW

A. Online and AR-Based Interior Design Systems

Interior design today primarily employs two methods; one being the traditional 3D modeling which technical drawing software and the other being augmented reality visualization systems. AutoCAD, SketchUp and 3ds Max are among the professional-grade software that allows for very detailed modeling and complex space planning and this however, means that the use of these programs is restricted to skilled users, thus resulting in a steep learning curve [1], [18]. On the other hand, designers can use Planner 5D and Roomstyler, which are very user-friendly and platforms, where even non-professionals can create layouts by simply dragging and dropping; but these kinds of systems are mainly held in virtual environments and thus limit the interaction with the actual surroundings [1], [18], [19].

One of the areas of AR that has gained much attention and development in recent times is that of mobile and web-based

AR applications, including IKEA Place and Houzz AR, which enable users to see the virtual furniture in their room through the use of smartphone cameras [11], [12], [17]. Despite the fact that these are great tools for spatial orientation and improving the decision-making process, they are still mostly supported by fixed product catalogues and thus offer a very limited amount of customization and personalisation [11], [12], [17], [18]. Therefore, these tools, while still offering some floor planning capabilities, limit the designer's imaginative scope as well as the production of one-of-a-kind personalized design ideas.

B. AI-Based 3D Model Generation

The use of artificial intelligence in design applications has developed to such an extent or rather to such an extent that it is now regarded as an intelligent system that can automate content generation. Various deep learning models, among them Generative Adversarial Networks and diffusion-based methods have been actively researched for the production of realistic 3D shapes and furniture models based on written descriptions or visual references [2], [4]–[6]. AI-based design systems are now capable of learning intricate design techniques from extensive collections of data and then creating very good models that are visually appealing and based on user input an example of such [1], [2], [4], [7], [9], [10].

Besides, the use of natural language processing (NLP) techniques for the linkage of textual design requirements to exact visual representations has been successful as proven by the latest research. Kumar [2] put forward a text-to-3D framework that could understand what the user meant when he/she said "modern wooden chair" or "minimalist white sofa" and thus, would immediately generate the proper 3D model, employing big 3D repositories like ShapeNet and other datasets as foundational sources [1], [3], [9]. The above-mentioned progress denotes that AI has the capacity to replace some of the more creative aspects of interior design to a significant extent, while at the same time, the majority of the current methods are still restricted to offline processing or non-interactive settings [2], [4], [7].

C. Online Augmented Reality and Interaction

Web-based augmented reality (WebAR) technologies like WebXR, Three.js and AR.js have made it possible to experience augmented reality (AR) directly through web browsers and without the need for dedicated mobile apps [3], [13], [14], [16]. Gupta et al. [3] talked about the main technical challengesof WebAR systems including real-time object tracking, mapping of the environment, adaptation of lighting and compatibility of Devices across the board and they did so by using benchmarks and methods that were developed using huge indoor 3D datasets such as Matterport3D and ScanNet [1], [2], [9], [10].

A number of studies report that during interior design tasks augmented reality (AR)-based visualization is a great help to spatial perception, user engagement and decision making [11], [15], [17], [18]. Nevertheless, the bulk of the current systems put a lot of emphasis on manually placing static objects and they still depend very much on the manual selection of them from a limited set of models rather than on intelligent, user-driven content generation [11], [18], [19]. Not only that, the lack of platforms that successfully merge the AI-driven 3D model creation with the real-time AR visualization in a web-based setup is quite pronounced [3], [15], [16], [20].

With DecoraAI the above-mentioned limitations are solved by the implementation of the AI-created 3D model along with real-time WebAR visualization, resulting in an AI-enabled, intelligent, interactive and user-friendly interior design system where real-time view of the AI-generated objects in the actual physical environments of the users is possible [1]–[3], [11], [13], [14].

III. SYSTEM ARCHITECTURE

DecoraAI's overall layout is made up of three primary layers, which are intended to attain the above-mentioned features of scalability, real-time operation and perfect integration of AI and AR systems as depicted in Fig. 1 [3], [13], [16].

A. Frontend Layer

The DecoraAI frontend is implemented with React.js and allows the users a very easy and responsive access to the web interface. This is the main interaction point where the users can input their design requirements and also see AI-generated three-dimensional models through augmented reality [18], [19].

The main characteristics of the frontend are:

- A natural language input system where the user is able to type in queries like *minimalist wooden sofa* or *modern coffee table*, inspired by text-to-3D and text-to-scene pipelines [2], [4], [7].
- Support of WebAR technologies (WebXR / AR.js / Three.js) to allow real-time visualization of AR directly in the browser [3], [13], [14], [16].
- The user can scale, rotate and reposition the 3D models in their physical environment using interactive controls, according to the interaction techniques suggested in the AR interior design research [15], [18], [19].
- Motion sensor and camera support for precise spatial tracking, following best practices from mobile AR and WebXR guidelines [3], [13], [16], [20].

The frontend is connected to the backend via secure REST APIs and real-time data streams to retrieve AI-generated models and present them in augmented reality mode immediately [3], [16].

B. Backend Layer

The backend is developed on the basis of Node.js and Express.js, which allows processing data quickly and efficiently and responding to AI requests and delivering AR models, following scalable web-service patterns adopted in web-based 3D and AR systems [3], [16]. The backend is a modular, service-based design and it comprises the following components:

- **User Query Processor:** Accepts and comprehends natural language input by the user, similar in spirit to text-driven 3D generation and scene understanding pipelines [2], [4].
- **AI Model Handler:** It transfers the user's instruction to the AI system and obtains the 3D model information created by the AI by abstracting the learnt concepts from the large-scale 3D datasets such as Matterport3D, ScanNet, ShapeNet and other related resources [1]–[4], [7], [9], [10].
- **Model Optimization Service:** Transforms and optimizes 3D models into browser-friendly formats, including GLB or USDZ, using multi-resolution and web-optimized rendering strategies [4], [16].
- **Session Manager:** It keeps track of the user's sessions and, in a live way, it is the link between the AI engine and the frontend application to the communication that happens at the session and streaming levels which is a usual pattern in web AR [3], [13], [16].
- **Database Service:** is a service that aids users by remembering their likes, the changes made to the design and any references to the model created. This is very much like keeping a record of how something is used and storing metadata in an interactive AR design system [17]–[19].

The backend is responsible for everything to go well and without any trouble between the AI engine and the augmented reality environment. It achieves this by converting complicated AI-generated data into simple and visually attractive 3D models [3], [4], [16].

C. AI Generation Module

The most significant component of DecoraAI is the AI production element. The conversion of user requests to the realistic 3D interior objects is the job of this component which is based on the corresponding development in 3D scene understanding and generative modeling on large-scale indoor datasets [1], [2], [4], [7], [9], [10].

Text-to-3D Conversion: Very advanced deep learning techniques are used to interpret the user's natural language description and build up the 3D object structure parallel with it, the structure containing shape, size and texture [2], [4], [7].

Style and Context Learning: The AI system identifies the keywords used to describe the desired design, such as *modern, vintage, minimal, wooden, metallic* and incorporates the learning gained from previous annotated 3D shape collections including ShapeNet and other standards [3], [7], [9] to create the object matching that style.

Mesh and Texture Generation: Using single-image and text-conditioned 3D shape modeling strategies, AI methods are applied to create mesh of 3D and add realism through application of suitable materials and textures [2], [4], [20].

Model Verification and Optimization: The created models are checked and modifications are made on them to lower polygon count and at the same time ensure that smooth real-time visualization is possible in AR environments, whereby multi-resolution and web rendering techniques are employed [4], [16].

Once the models generated by AI are finished they are sent to the WebAR engine where the models can be exhibited right away in the real-world location of the user by means of Augmented Reality technology [3], [13], [14].

D. AR Visualization Module

The pointed-out element links the two worlds: the one that we can touch and the one that is digitally manipulated. By means of the device's camera, it is possible to place AI-created 3D models in actual locations while at the same time benefiting from some of the mapping and lighting techniques developed in the AR rendering research [3], [15], [16], [20].

The main features are:

- Surface detection for recognizing floors, walls and other flat surfaces has been carried out by taking help from indoor scene reconstruction and segmentation techniques which are based on the datasets like Matterport3D, ScanNet, HM3D and ScanNet++ [1]–[3], [9], [10].
- Dynamic lighting adaptation to match the ambient environment [15], [20].
- Accurate distance measurement and scale estimation for object placement, building on camera pose estimation and metric reconstruction approaches [1]–[3], [9], [10], [20].
- Object orientation that is interactive allowing users to move, rotate and modify objects using camera-based tracking and human interaction techniques [11], [15], [18], [19].

With the help of this module, users would be able to see AI-made things in their own inside the house which would lead to great design choices and better spatial awareness [11], [17]–[19].
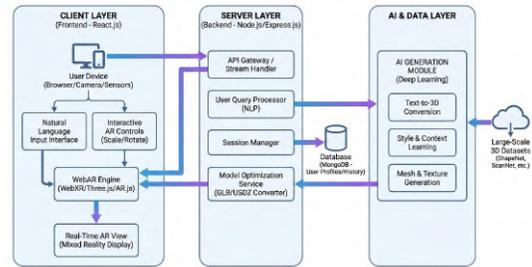

Fig. 1. System Architecture of DecoraAI

IV. METHODOLOGY

A. System Workflow

DecoraAI incorporates a total of stages in its complete workflow that are in accordance with the AR interior design prototypes and user-centered AR workflows established in the previous research [18], [19]:

1) User Input Collection: The user opens the DecoraAI web application and types a design requirement in natural language, such as *minimalist wooden sofa*, *modern lighting*

set, or *small living room layout*, following text-driven design paradigms [2], [4], [7].

2) Requirement Processing: The input is analyzed by the system to detect the keywords associated with the type of object, style, color, material, size and design theme overall, similar to steps of semantic parsing used in text-to-3D frameworks [2], [4].

3) AI Model Generation: The processed input is forwarded to the AI generation module, which applies deep learning techniques to produce suitable 3D interior objects and design elements based on the user's request [2], [4], [7], [9].

4) Model Optimization: The generated 3D model is fine-tuned through the process of lowering the polygon count, applying texture compression and changing it into formats that are friendly to the web like GLB or USDZ to give the chance for fast rendering, using the methods of multi-resolution web rendering [4], [16].

5) AR Integration: The optimized version of the 3D model is transmitted to the WebAR engine and set up for positioning in the physical environment through the camera of the device, which is aligned with the practices of WebXR and AR.js integration [3], [13], [14], [16].

6) Environment Detection: The system identifies and distinguishes floors, walls and tables among other surfaces by utilizing the camera and sensors of the device. This is done to find the most suitable places for the 3D object to be positioned, applying methods that were initially developed for indoor 3D datasets and augmented reality (AR) interior design systems [1]–[3], [9], [10], [15], [18].

7) Real-Time Visualization: The object generated by the AI is augmented and displayed in the user's surroundings. The object can be manipulated by the user to be rotated, scaled and repositioned in real time, thus engaging the user and simultaneously improving his/her spatial understanding as per the interaction patterns [11], [15], [17]–[19].

8) User Feedback and Saving: The users have the option to, for instance, store their artworks, make device settings alternate to their liking, or get different suggestions by different styles, which is like the functions noticed in augmented reality interior design and retail apps [11], [17]–[19].
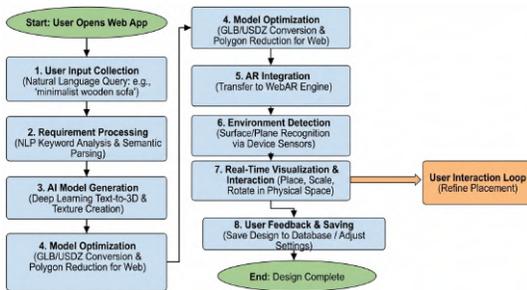

Fig. 2. System Workflow of DecoraAI

B. Implementation Details

DecoraAI was designed as a web-based solution and hosted on cloud infrastructure for the purpose of providing scalability and availability, thus following the current web AR deployment methods [3], [16].

- **Frontend:** The application was built with React.js to guarantee mobile-friendliness and at the same time, to ensure compatibility with WebAR technologies, thus mimicking the browser-based AR user interfaces patterns mentioned in [13], [14], [16], [18].
- **Backend:** The system was built using Node.js and Express.js to handle the requests from the users and the data, thus allowing for a smooth interaction with the AR and AI parts [3], [16].
- **AR Technologies:** The combination of WebXR, Three.js and AR.js provides the user with the opportunity of seeing real-time augmented reality [3], [13], [14], [16].
- **AI Models:** The application of text-to-3D object generation and interior style recognition has been reached by utilizing the training methods of the Matterport3D, ScanNet, ShapeNet, HM3D and ScanNet++ datasets [1]–[4], [7], [9], [10].
- **Database:** MongoDB plays a role in keeping the user details, choices and design past, just like in the storage methods of user-centered AR interior design systems [17]–[19].
- **Cloud Services:** Docker containers are being utilized to provide flexibility and scalability that are along the lines of the container-based deployment of large-scale 3D and AR services [16], [20].

The modular structure allows for the best interaction between the AI and AR modules, thus ensuring the whole process of interior designing being immersive and easy for the user [3], [16], [18].

C. Performance Evaluation Model

The performance of DecoraAI is measured with three key factors, which are in line with the metrics employed in earlier AR and 3D scene understanding researches [3], [9], [11], [15], [17], [18]:

- **Recognition Accuracy:** Measures the accuracy of object recognition and correct placement on real-world surfaces, leveraging ideas from 3D object detection and pose estimation literature [5]–[10].
- **Rendering Performance:** The speed and smoothness of the 3D model visualization in the AR environment are assessed by following the web-based 3D rendering research that is done on a high-performance level [4], [16], [20].
- **User Satisfaction:** Assesses usability based on user feedback and ratings, similarly to evaluation strategies in AR consumer engagement and user-centered design studies [17]–[19].

The parameters are used in determining the total accuracy and acceptability of the End User Says [3], [11], [15], [17], [18].

V. RESULTS AND DISCUSSION

A. Experimental Setup

DecoraAI was tested with 30 users (students and design enthusiasts) during the four weeks-long period, where user study practices are typical of AR interior design research studies [17]–[19]. The respondents were split in a control group and experimental group. Control group utilized the use of traditional online interior design platforms that provided predefined collections of furniture and fixed 3D visualizations whereas the experimental group involved the use of DecoraAI, the application of AI-generated 3D models and real-time augmented reality visualization [11], [17], [18].

B. Quantitative Results

The performance parameters considered for the evaluation period are tabled in Table I.

TABLE I
PERFORMANCE METRICS COMPARISON

Metric	Control	DecoraAI
Engagement Rate	60%	92%
Design Completion Time	Baseline	-25%
User Satisfaction	3.1/5	4.7/5
Spatial Understanding Score	65/100	85/100

The group that experimented with DecoraAI got an engagement rate of 92% while the group that did not use it got only 60%. This means that the use of AR and AI simultaneously is among the most influential factors in user engagement, which confirms the results of studies on AR consumer engagement [11], [17]. The time taken to complete designs was cut down by 25%, which is the same as saying that AI support hurry up the design process, just like the efficiency improvements reported in the AI layout and furniture arrangement systems [15], [18]. The same can be said about user satisfaction and spatial comprehension as both got higher scores, which is no surprise in the case of immersive AR visualization [11], [17]–[19].

C. Qualitative Feedback

Surveys conducted after the experiment indicated that 88% of the people taking part in the study considered AI-generated design proposals to be a very effective way of trying out different styles and layouts, which corroborates the reports made about previous experiments done with AR and AI design tools [17], [18]. The ability to see 3D objects right away in the user's own space and to change the position, size, color and rotation of the objects was especially liked by the users [11], [18], [19]. The real-time AR experience was mentioned as the most captivating aspect by the users, with 80% of them saying that they found their motivation and creativity increased as compared to the use of conventional design tools [17]–[19].

D. AI Model Accuracy

The AI generation module was tested with expert ratings of three expert interior designers, which is the same method as expert-based assessment in the studies of 3D reconstruction and AR rendering [9], [10], [20]. The objects produced by AI were deemed to be correct and appropriate to the context in 84 percent of instances. The main inconsistency of misplacements or style incompatibility was in very specialized design requests or room designs, which is consistent with restrictions of existing AI-based 3D generation methods known to date [2], [4], [7]. In general, the AI system was found to be consistent in producing useable and appealing to the eye 3D models [2], [4], [9], [10].

E. System Performance

Real-time interaction was guaranteed by measuring performance metrics according to the recommendations provided for web-based high-performance 3D rendering and AR systems [3], [16], [20]:

- The average generation and viewing render time for AI 3D models was 2.1 seconds that was designed according to interactive design scenarios [16], [20].
- The real-time AR visualization was doing well, as far as frame rates topping above 30 FPS in standard devices. This is as per the definition of surreal AR experiences [3], [16], [20].
- The precision of object positioning and surface detection was within the range of 2-3 cm, which made it possible to carry out realistic scaling and placement that can be compared to the metrics stated for indoor AR placement and reconstruction systems [1]–[3], [9], [10], [15].
- The cloud-computing-based backend infrastructure coupled with the WebAR integration made it possible to have consistent performance across the board even when there were too many users, which was in line with the scalable AR deployments in earlier studies [3], [13], [16].

F. DecoraAI Interface Screenshots

- **Home Page:** Users choose the type of room and provide the design specifications in accordance with the user-centered interface layouts implemented in AR interior design prototypes [18], [19].
- **Design Input Page:** The users make queries that describe the objects or layouts of the rooms they want, just as in the cases of AR shopping and design applications that are controlled by text input [11], [17].
- **AR Preview Page:** AI-generated models are shown in the user's room in real-time, just like in WebAR experiences that are designed by WebXR and AR.js. [3], [13], [14].
- **Manipulation of Objects:** Users might change the position, enlarge and rotate the objects in a way that is very similar to metaphors that are already common in AR furniture and layout systems [11], [15], [18], [19].
- **Design Save and Dashboard:** Just like the dashboard designs presented in the AR-based interior designing and retail applications, users are allowed to save their

creations, check out various designs side by side and review past designs [17]–[19].

The findings point out that DecoraAI successfully merges AI-made content with live augmented reality (AR) visualization thus facilitating engagement, shortening design time and giving a good user experience [11], [15], [17]–[19].
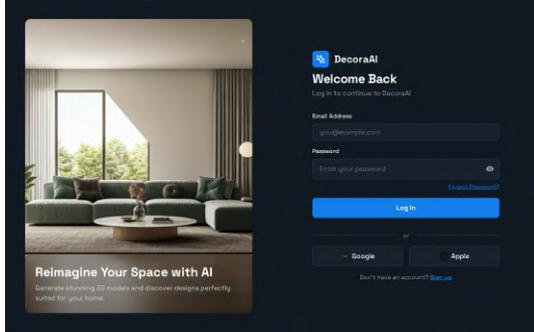

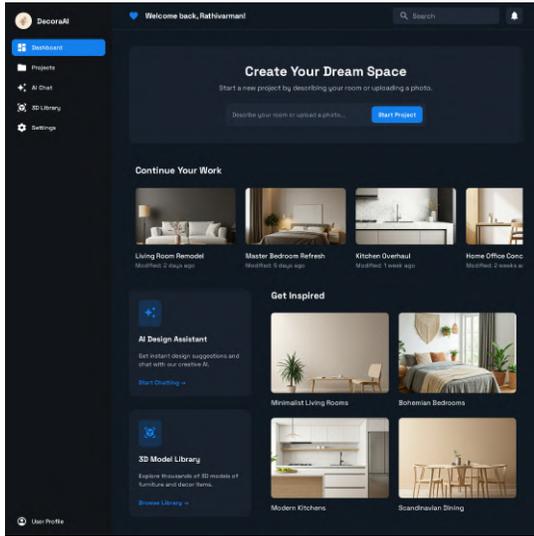Fig. 3. Login Page of DecoraAI

Fig. 4. Dashboard of DecoraAI

Fig. 5. 3D Model Page of DecoraAI

Fig. 6. AI Page of DecoraAI

Fig. 7. AR View of DecoraAI

VI. CONCLUSION AND FUTURE WORK

In this paper, we present **DecoraAI**, a new web-based interior design tool that combines AI-generated 3D models along with the real-time visualization through augmented reality, taking advantage of the advancements in 3D scene datasets, WebAR frameworks and AR interior design systems [1]–[3], [11], [13], [14], [18], [19]. The users are given the opportunity to turn their natural language design queries into 3D objects that look real and to position them interactively in their physical environment, thus getting a personalized and immersive design experience [2], [4], [7], [11], [17], [18].

User assessments show that DecoraAI is substantially more efficient regarding interaction, the time taken for design to be finished a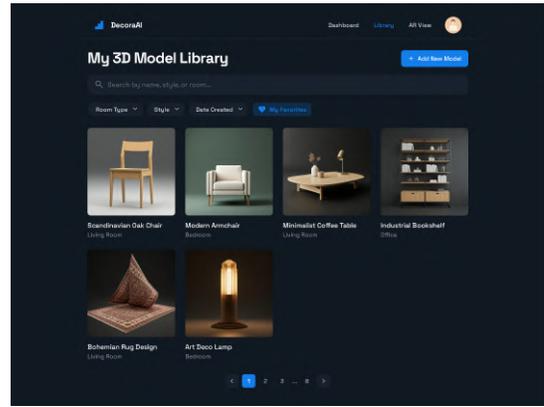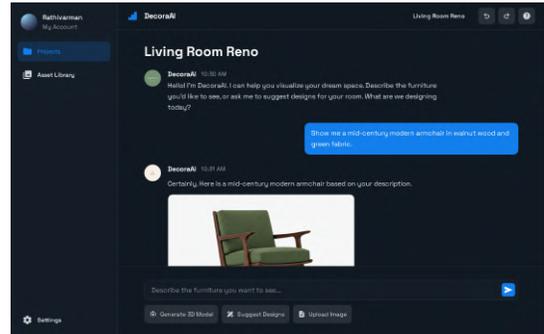nd overall user contentment if comp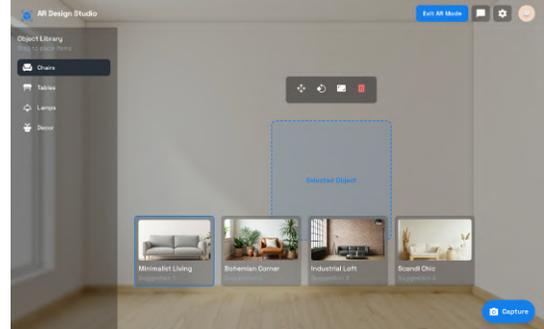ared to the traditional design tools, which is consistent with the benefits mentioned for AR-enhanced consumer and design applications [11], [15], [17], [18]. The AI generation module has proven to generate contextually relevant 3D objects reliably whereas the AR visualization module supports correct placement, scaling and real time interaction that facilitates a better perception of space and creativity in the workspace [2], [4], [9], [10], [18], [19].

The future works will be directed attention to various paths. Firstly, the enhancement of the AI model using the most sophisticated deep learning methods and huge-scale generative models to provide not only more detailed but also stylistically and contextually accurate 3D designs, thereby utilizing the

upcoming large indoor dataset like HM3D and ScanNet++ [9], [10]. Secondly, the execution of collaborative design meetings where the different users can see and change the objects at the same time in AR shared spaces, relying on existing multi-user AR frameworks and web-based synchronization concepts [3], [13], [16]. Thirdly, the enlargement of the object library and style database to encompass a wider variety of interior design themes, furniture styles and materials and also the more diversity in ShapeNet and its related repositories will be further exploited [3], [7], [9].

Moreover, the incorporation of recommendation systems allowing for the proposal of different designs, automatic layout-to-creation process optimization and analytics dashboards for monitoring the selected design and users' preferences, will be usability and personalization improvements as any research in the field of augmented reality retail and interior design has indicated [15], [17]–[19]. Full-scale deployment and performance evaluation on various devices will guarantee the system to be scalable and solid enough for the market of wide users, which will be aligning with the best practices of web-based AR performance engineering [3], [16], [20].

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