AR Development For Room Design

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***Abstract*—Arranging your furniture correctly can be the difference between having a cramped, gloomy, impractical space and a cozy, elegant and functional room. Although everyone wants their place to be functional and stylish, room design demands time and expertise. While there are extensive systems for room and layout design, most of them require users to drag and drop the 3D furniture models into their 3D room, modify the furniture size/color/texture or change the camera viewpoint around to see their newly designed room from different perspectives by means of the mobile phones or tablets screen. These complications diminish the user satisfaction as well as restrict synchronous collaboration among multiple users. In this work, we propose a system for designing a furniture layout based on the augmented reality technology. Given the room floor plan and multiple QR markers, users are able to physically move their furniture (each QR marker corresponds to a 3D furniture model) around the limited space (inside the specific area defined by the room plan) to design their own functional and stylish room layout. Finally, We demonstrate that our system can not only alleviate the difficulties of existing room design systems, but also amplify the users satisfaction of room design application. Moreover, we posit that it will encourage co-design from simultaneous multiple users.**

***Index Terms*—Augmented Reality, Room design, Mobile application**

I. Introduction

For a house to be successful, the objects in it must communicate with one another, respond to and balance one another. - Andre Putman, a French interior and product designer.

Good design is not only about making a room beautiful, but also making the best possible use of the limited space so that people can call it *home*. Although everyone certainly wants to be surrounded by comfort and beauty that makes their daily experience better, making that dream come true is a challenging task.

Nowadays, many people are forced to live in the city, close by their workplace, to reduce their commute time. However, the living space in cities is outrageously expensive. In 2016, the average one-bedroom apartment size in the US was 83 square meters [1]], while the average price per square meter currently sits at $19,085 in Manhattan and $12,756 in San Francisco [2], costing more than a million dollars to own a one-bedroom apartment in both cities. This same trend happens in every large city all over the world. An 80 square meter one-bedroom apartment in Beijing costs around $964 per square meter, and the price is incredibly expensive at $4,120 per square meter in Bangkok [3].

Since the space is limited, designing the furniture layout is crucial. A well designed layout not only offers beauty, but also comfort and utility as shown in Fig. 1. While the top row shows the original rooms which are functional but lifeless, the bottom row shows the same functional room with a totally different feeling; luxurious, cozy and warm. Unfortunately, good room design requires time and expertise. Although there are extensive attempts to to develop a system to help people to design their own room, e.g., Room Creator [4], Amikasa [5], Houzz: view in my room [6], Home Design 3D [7], Rooms [8] etc. However, most of the applications are complicated (e.g., camera viewpoint control, light condition control or designing their own furniture color and texture) and also require users to be familiar with technology e.g., users should be comfortable to drag and drop objects on the mobile phone's screen.

(a) Living room makeover (b) Bedroom makeover

Fig. 1: The example images of the living room (left) and bedroom (right) before and after the room design makeover.

To mitigate the difficulties of the existing layout design systems, our work integrates augmented reality technology [9]with 3D modeling technology to develop an easy to understand and easy to use room design system. We believe that anything that we can see and touch is the easiest to understand and to use. Based on the augmented reality technology, the system provides up to five white QR markers, as shown in Fig2b, to represent the furniture which can be manipulated physically and an additional black QR marker on the room plan, as shown in Fig.2a, to represent the available but limited room space. The users are able to design the layout of the furniture by physically moving the QR Markers or furniture to their preferred location. Then, the system will calculate these QR markers' locations, match them with their corresponding furniture and then display the final room layout on the mobile

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(a) Black QR marker for room plan (b) White QR markers for furnitures (c) Example of the final layout design

Fig. 2: Our system includes 1) the black QR marker corresponds to the room plan (top left) which defined the available room space, 2) the white QR markers corresponds to uniques furnitures (top middle). other, the example image of the final layout design using the proposed system is shown in the remaining image.

phone's screen as shown in Fig. 2c.

To our knowledge this is the first attempt to integrate the augmented reality technology with both room and furniture to mitigate the difficulties of layout design. With the physical user interface tools, the users can easily manipulate their furniture layout as well as camera viewpoints at the same time. Moreover, our system is more flexible for collaborations and enhances the experience of co-design among multiple users. We posit that our system will alleviate the users' difficulties with existing layout design systems, help them to decide what is the best choice for their design and style as well as where to place them.

The rest of the paper is organized as follows. First, we review some background and related work (Sec II). We describe our furniture datasets (Sec III). Then, we describe the scenario of the proposed AR development for room design (Sec IV) and present the design of our system (Sec V). Next, the evaluations of our framework compares with one of the top commercial room design application [6] are presented (Sec VI). Finally, we conclude our work and discuss future works (Sec VII).

II. Background and Related work

This section will review some background and previous work relevant to augmented reality, quick response code, development tools and existing room layout and design systems.

A. Augmented Reality Technology (AR)

Augmented reality technology is a technology which aims to enhance the real world with virtual elements created by computer programs [9], [10]. These elements can be anything from 3D models to dialog boxes. The AR system consists of the 4 following components:

- *Marker* To indicate the position of the computer graphic elements in the real world
- *Optical Sensing Device* The component, such as a smartphones camera or a webcam, that detects the real world environment and the markers' position, then sends the collected data to the core program.
- *AR Engine* A computing component that receives data from the optical sensing device, then computes the position and angle of markers and generates a result accordingly.
- *Display* This component receives data from the core AR program and then displays the result on a screen.

The following 3 steps show how Augmented Reality works:

- *Image analysis* The first step is to detect the marker from the camera collected data. Markers, also called image targets, are the images that the AR application will use as the points of reference to display the 3D objects in the real world.
- *Pose Estimation* This step is about calculating the position of the marker relative to the position of the camera.
- *3D Rendering* The final step is to render 3D models and to display them according to the data received from the previous steps.

B. Quick Response Code (QR code)

QR code is a two-dimensional barcode first designed to be used in the automotive industry in Japan. QR code is very accurate and can pack a considerable amount of data. For this reason many other industries have adopted QR code for various aspects e.g., [11] proposes the notion of contextual QR codes that merge a public QR code and private information, in order to provide data related to a particular context. Moreover, due to its clear and distinctive look, QR code has be demonstrated as a potential marker of AR application by reducing the chances of the application matching it with a wrong marker in the database [12]. Inspired by [12], we handpicked the QR code as our marker in this work.

C. Development tools

Several softwares that has been used during the development will be discussed in as following:

- *Unity* is a game engine that can develop games and software for almost every platform available in the market.
- *Monodevelop-Unity* is the integrated development environment (IDE), also known as code editor, which comes with the Unity game engine. It includes all the basic functions of a text editor with features for code debugging.
- *QR Code Generator* This project uses QR codes as markers for the application; for this reason a QR code generator is very important. We use a website called

Fig. 3: The example images of furniture models from 4 categories: table, sofa, chair and cabinet.

www.qr-code-generator.com. This website lets users create QR code using anything from text to pictures.

- *Vuforia Augmented Reality software development kit (SDK)* is a tool which makes it easier for us to develop an AR application. The marker database for the application can be created using the Vuforia website.

D. Room layout and design systems

There are numerous systems that help users to create their floor plans or virtually design their rooms. Several of the highest rated systems with more than 4 out of 5 stars from Apple store or Google Play are :

Room Creator lets the users design a room interior by entering room dimensions, designing floor pattern, choosing wall color and adding decor [4].

Amikasa allows users to create room layouts using furniture and home decor from real brands [5]. The system also provides a walk-through mode that allows users to take a virtual tour of their newly designed rooms, together with the option to share the virtual room via social media.

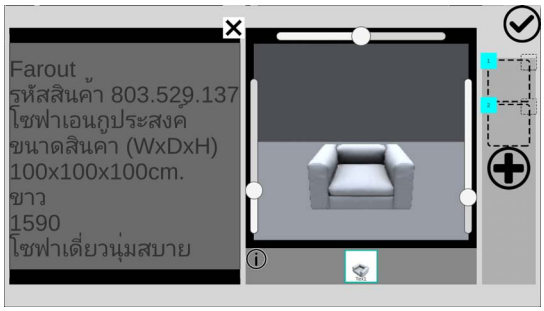


Fig. 4: 3D furniture information

Houzz Interior Design Ideas allows users to capture a shot of their room and, using the *View in My Room* 3D feature, to see how the furniture from *houzz.com* would look in their own space [6].

Home Design 3D lets users draw floor plans, furnish and visualize all their interior design projects [7] e.g., home improvement or home decor makeover.

Rooms offers various ways to play with virtual room layout ideas. Starting from entering the dimensions of their room, users can try to swap the furniture, change wall colors and flooring, and alter the scale of items to see how everything will look together [8].

Unlike the existing systems [4]–[8], our system utilizes AR technology for the layout design system where users can manipulate the furniture layout in their room by moving around the physical markers on the physical room plan. Although [4]–[8] are successful systems which help users to enhance their room design experience, these systems share some difficulties: 1) users must be comfortable with dragging and dropping objects using touch screen technology, 2) users must be familiar with viewpoint control or lighting control, 3) collaboration among multi-users is burdensome due to the inaccessibility of the single screen. In this work, we propose a system to not only mitigate the difficulties of the existing systems, but also to enhance collaboration among loved ones while designing their dream home.

III. Dataset

In this work, we collect the 3D furniture dataset from a variety of assets available from the Unity asset store [13] including the Big Furniture Pack, Chairs and Sofas Pack, Chalet Style Furniture, Chest of Drawers and Wooden table and chair.

The Big Furniture Pack [14] is a free furniture asset which includes a variety of low-polygon furniture models e.g., beds, sets of sofas, chairs and coffee tables, office tables and chairs, TV cabinets, lamps, mirrors, cabinets and etc.

Chairs and Sofas Pack [15] is a free collection of chair and sofa models with multiple colors and textures.

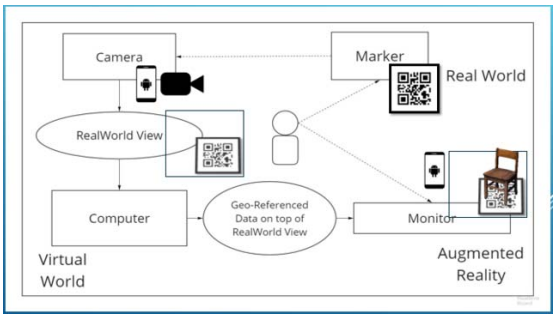


Fig. 5: System overview

Chalet Style Furniture [16] includes 16 low-polygon models for interiors in the chalet style.

Chest of Drawers [17] is a 11,076 triangles model of the chest of drawers with multiple texture maps (e.g., diffuse map, normal map, specular map and ambient occlusion map).

Wooden table and chair [18] is a free collection of table and chair models with wood texture.

The new dataset contains 32 selected furniture models across multiple assets. The dataset consists of 4 categories including table, chair, sofa and cabinet as shown in Fig. 3. Each category contains 8 items with their corresponding metadata. The furniture metadata includes item name, item code, description of the furniture, price, size, color and texture as shown in Fig. 4.

IV. Application scenario

The AR development for room design follows the application scenario as shown in Fig. 5.

There are two different QR marker colors in our system: white and black. While the white QR marker represents the 3D furniture models, the black one represents the room model. In order to design their room layout, users will follow 3 steps:

Furniture selection: Users are required to pair up the 3D furniture model of their choice with the white QR marker as shown in Fig. 2b. Users can select up to 5 furniture models simultaneously. There are 4 categories with 8 different models of furniture available in our system (Fig. 6a). Additional colors or textures might be available.

Room specification: Users can then define the width, height and opacity of their 3D room model, Fig. 6b. The system will then map the room model with the black QR marker, which can be attached to the physical room plan, Fig. 2a, or as a separate piece. The 3D room model will be displayed as the white cubicle shown in the right-hand side of Fig. 6b.

The users are able to design the layout of the furniture by physically moving the QR markers or furniture to their preferred location inside the room model or on the room plan.

3D rendering: When the layout design is finalized, the system will scan these QR marker locations, pair them with their corresponding furniture and finally display the final room layout on the mobile phone's screen as shown in Fig. 6c.

V. AR development for room design

A. Augmented reality technology

Augmented reality technology is being used in many industries, including education, games, fashion design and more. There are many tools and software applications in the market which can assist in developing an augmented reality application. We decided to use Vuforia SDK which is an extension for the Unity game engine, built specifically for developing augmented reality related applications. The Vuforia website allows developers to upload .jpg and .png files to make a marker database that can be used with Unity. It is important to learn what kind of picture is the most suitable to be used as a marker, to maximize chances of detecting and minimize chances of error.

1) Marker design: Marker or image targets represent images that the Vuforia SDK can detect and track. Unlike traditional fiducial markers, data matrix codes and QR codes, image targets do not need special black and white regions or codes to be recognized. The SDK detects and tracks the features that are naturally found in the image itself by comparing these natural features against a known target resource database. Once the image target is detected, the SDK will track the image as long as it is at least partially in the camera's field of view [19]. There are 4 types of marker:

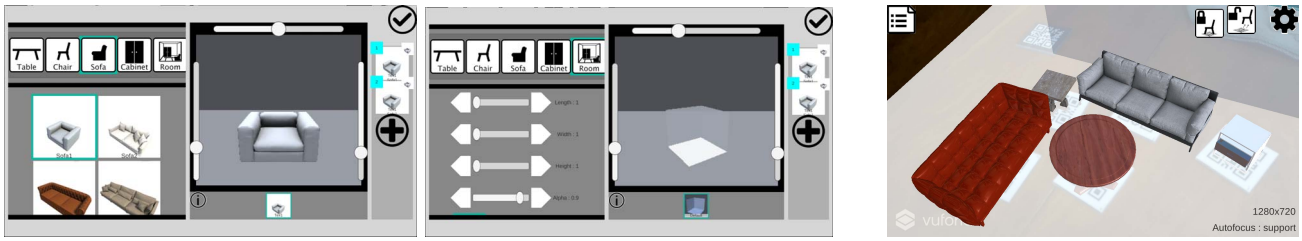
- *Single image* is an image which complies with the following rules: 1) must be rich in detail, 2) must have good contrast, with bright and dark regions, and 3) no repetitive patterns can be present.
- *Cuboid* is a cube or box shaped multi-target which consists of multiple image targets in a defined geometric arrangement, commonly used to recognize and augment printed media and product packaging.
- *Cylinder* is a cylinder-shaped marker which can be used to engage product packaging that is cylindrical or conical in shape, e.g., soda cans, coffee cups, mugs, etc.
- *3D object* or an arbitrary 3D object can be used as a marker for an application.

In this work, we handpicked the QR code as our marker due to following reasons: 1) since there can be multiple markers at the same time, our marker must be a single image marker, 2) the QR code satisfies all the single image requirements, and 3) our supplementary experiments show that the QR code markers achieve the lowest detection and tracking error rate compare to others.

B. User Interface

To maximize the user experience while using our system, we carefully design our user interface as follows:

1) Camera screen: Fig. 7 shows the first window of the application which displays the video feed from the devices camera. When the white QR marker is shown in this window, the corresponding unique number or marker ID of the marker will be shown. Using the marker ID, users can match up the unique furniture model with each individual marker. To pair up the marker with the 3D furniture model, the users are required



(a) Furniture selection (b) Room specification (c) Example of the final room design

Fig. 6: The user interface (UI) in each step of the AR based room design system scenario: (a) The furniture selection, (b) The room specification and (c) 3D rendering.

Fig. 7: Camera screen.

to click a cog icon, at the top right conner of the screen, to enter the settings menu.

2) Settings screen: The settings menu can be divided into 2 sections: 1) the left section is the catalogue of the furniture and 2) the right section shows a preview of the furniture that is being selected.

At the top of the furniture catalog window, there are 4 different icons corresponding to 4 different furniture categories and one icon for room settings. When users click on any of the furniture categories, small images of all furniture in that category will be displayed on the left-hand side, while a preview of the selected furniture will be on the right-hand side. In the preview windows, users are able rotate the furniture, zoom in or zoom out and raise or lower the viewpoint to visualize the model. The additional details about the current model (or metadata), e.g., price, dimensions or material etc., will be shown on the left section if the info button, at top middle position, is clicked.

The selected furniture will be paired up with a QR marker when the users click on the empty square shown in the rightmost column of the screen. *Note: the empty squares, from top to bottom, correspond to the QR markers ID: 1 to 5.*

Finally, furnitures will be placed on the corresponding QR markers and presented on the display for users to evaluate their final design. Additional final designs are shown in Fig. 8.

VI. Evaluations

To evaluate our framework, we designed the room designing task and asked 20 users: 15 males and 5 females with an average age of 22 years old, to complete the task using both our application and another room design application called Houzz Interior Design Ideas [6]. With the *View in My Room 3D* feature, Houzz Interior Design Ideas application [6] helps users visualize how furniture from *houzz.com* will fit in their room. Since [6] has quite a similar concept to our framework, we believe that it is a strong baseline for our application.

A. Room design task

To evaluate the performance of both application, all users were tasked to design a room with a table and a chair using Houzz Interior Design Ideas application [6] and our application. Before complete the task, a short description about both applications are briefly explained to users.

We have recorded the time each user needed in order to finish the task. The results from Fig. 9 show that 55% of users were able to complete the task within a minutes using our application and the rest of them were able to complete the task within 5 minutes. Unlike using our application, 50% of users required 3-5 minutes to finish the same task using [6]. Moreover, 20% of users struggled, taking more than 5 minutes or unable to complete the task, with the baseline application.

After the users finished the task, we asked each user a serie of the following questions:

- *Which application is easier to use?* The result shows that 85% of users favor our application over the Houzz Interior Design Ideas application [6].
- *Which application's user interface is easier to understand and navigate?* The result shows 50% of users prefer our user interface. Meaning that the user interface of our application is comparable with a top commercial application in the market.
- *How much do QR markers help in designing the room?* In this question, users are asked to rate the advantage of the QR markers from score 1-5, where 1 means 'Do not help' and 5 means 'Very useful'. The average score of 3.7 emphasizes that the QR markers are the functional tool for the room design task.
- *How highly would testers rate AR development for room design?* Similar to the previous question, users are asked to rate our application from score 1-5, where 1 means 'Hate it' and 5 means 'Love it'. The average rating at

Fig. 8: Additional visualization of final layout designed by the proposed system.

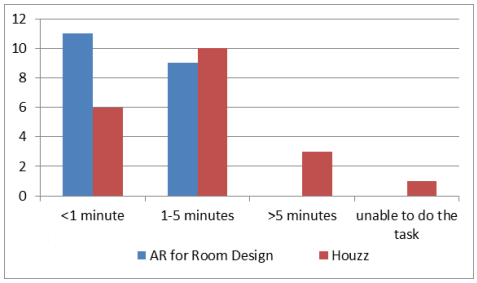


Fig. 9: Time requirement for users to complete the room design task using our application and the baseline [6].

3.7 demonstrates that users have the positive feedback with our application.

VII. Conclusion and Future work

In this work, we present an AR development for room design that aims to help users visualize furniture layout in a virtual room before purchasing the furniture. Based on the AR technology, the proposed system detects and recognizes the marker or QR code position and pose from the live camera feed. Users are required to map QR markers to their selected furniture model and then specify their room dimensions. Unlike existing systems, when the corresponding furniture models and room model are rendered on the furniture markers and room plan, the users can physically rearrange the markers inside the room plan without any obstacle from using the touch screen. The final design will be captured with a screenshot in the last step. We demonstrated that by utilizing the AR technology, the proposed system will mitigate the complication of the existing systems and encourage the collaboration of simultaneous multiple users.

There are several future directions to extend our work: 1) allow users to customize the furniture models or add new categories. Then, an image of the new model can be passed through the image search engine to find the most similar existing model from a furniture store which will facilitate the users experience to access their desired product in the real world, 2) optimize the system performance to support even more markers simultaneously which would allow users to put more furnitures into their room and finally 3) allow users to capture an image of their actual room and use it as a virtual room in the application. With this function, the users will be able to assess the compatibility of the new furniture in the context of their actual room.

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