Performance Evaluation of Augmented Reality based 3D Modelling Furniture Application

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***Abstract*— The advances in information and computer technology allows humans to interact with both real and virtual world objects. Augmented Reality (AR) is one such technology that integrates digital information with the users' environment in real time. It superimposes virtual objects such as information, computer generated images etc. on the users' view of the real world. In this paper, we propose to develop and evaluate an android app with augmented reality based system "AR Furniture App"; which makes use of Kudan SDK to put the AR content onto natural features detected from the surroundings. Using this application the user can visualize how the furniture would look in the real world, offering preview of furniture in one's real environment. By the usage of this application, the furniture sellers can win competitive edge in the market. The system also prevents revenue loss to the business, spoilt brand image of the service provider, customer attrition and deterioration of stakeholders' interests as the customers can try visualizations of furniture placements in the available space before purchasing them.**

Keywords— Augmented Reality, Android AR app, Furniture, Computer Vision, Marker-less augmented reality

I. INTRODUCTION

Purchasing products for interior design is a challenging task. It is essentially connected with the problem that the product cannot be put into its place before it is purchased. Customers may wonder how the furniture would look in its tentative place. Visualizing the furniture in the real world can be made possible through Augmented Reality applications.

Augmented Reality is a technology that overlays computer generated objects (information, images or data) on the real world objects providing composite view. The significance of Augmented Reality lies in the fact that it not only projects the digital information onto person's perception of the real world, but does it using immersive sensations that are perceived as natural objects of the environment. AR as technology has existed from several decades, but it has gained a lot of popularity over the last few years.

The principal reason for this development has been the evolution of mobile and handheld devices coupled with the advances in the technologies such as Computer Vision and Object Recognition. Applications in Augmented Reality that make use of these technologies make the user's surroundings interactive and manipulable.

In this paper, we propose an Augmented Reality based application to visualize the furniture. AR offers solution to the problem of visualizing objects in real world. AR applications can be of two types, marker-based applications and marker-less applications.

In marker-based AR applications, the images or the image descriptors to be identified from the camera data are provided ahead of time. The application is aware of what it is looking for in the camera data (frames). On the other hand, a marker-less AR application recognizes all the natural features in the user's environment. These applications don't have any information about what exactly they should look for in the camera data, hence it is difficult to design or implement such systems

Most of the AR applications that are designed for Interior design visualization purposes, to the best of our knowledge, are marker-based applications. The support for marker-less Augmented Reality has not evolved much in comparison to marker-based Augmented Reality. Some of the Software Development Kits are not available in all countries and some of them are limited to only IOs platforms.

In this paper we discuss design, implementation and evaluation of one such marker-based AR android application for visualizing furniture in the real world. We make use of the Kudan SDK for tracking the features of all the objects in a scene and augmenting the virtual object on top of a horizontal surface.

II. RELATED WORK

Augmented Reality, as we use it today, has been the result of advances in handheld and mobile devices. The beginning of Augmented Reality can be dated back to the year 1960 when a research scholar at Harvard named Ivan Sutherland developed a Head Mounted Display (HMD) to display virtual objects. Though the features were primitive, that was the first ever display that realized Augmented Reality.

AR has been in use from a very long time. It is being used in education to superimpose text, graphics into a student's real time environment, in medicine, to provide surgeon the patient's data, in fighter jets to display the flight path and in tourism, to access real-time information about a monument using the location and (or) picture of the monument.

AR has profound applications in interior design. A background study of the current systems that are in place for visualizing furniture's in real world has been carried out and a brief report of the same is presented in this section.

In the research article "AR Furniture: Integrating Augmented Reality Technology to Enhance Interior Design using Marker and Markerless tracking" published by Waraporn Viyanon [1] et al, the system proposed makes used of Kudan SDK to analyze and track the images and camera data (frames). The Kudan SDK supports both marker-based AR and marker-less AR. The drawback of the system was that user had to create a 3D model on his/her own, and no prebuilt models were provided.

Jeff K. T. Tang [2] et al in the paper entitled "AR Interior Designer: Automatic Furniture Arrangement using Spatial and Functional Relationships" have developed a windows application that can be used to arrange furniture in the available space. They have used the Microsoft's Kinect Depth camera to find the supporting surfaces and calculate the spatial and function relationships between the virtual and real objects and arrange the furniture. The system proposed in this paper was based on RANSAC algorithm for simultaneous tracking. The drawback of this algorithm is that it does not produce results in real-time and involves large number of un-necessary calculations in finding the spatial and functional relationships. Similar applications can be built using much simpler and cheaper methods.

Khushal Khairnar [3] et al proposed a system in the paper "Furniture Layout Application Based on Marker Detection and Using Augmented Reality". The application developed was a windows application developed using Unity Engine, the same application could be extended to phones with Android OS. The drawback of the application was that the application didn't support translocation and rotation of the furniture object.

Benjamin Neurneberger [4] et al in the paper entitled "SnapToReality: Aligning Augmented Reality to the Real World " developed a system that precisely aligns the AR virtual objects to the real world subject to the constraints of the real world in real-time. This proof of concept systems extracts the 3D planar surfaces and edges and aligns the objects by assigning a cost metric to each of the edges of the object. This was a research work undertaken by University of California and Microsoft Research.

Kriti Motwani [5] et al in the paper "Furniture Arrangement Using Augmented Reality" proposed a interactive system for furniture arrangements which includes translation, rotation and scaling of the 3D objects, as per the choice of the user that made use of Vuforia SDK to augment furniture on to the real world. In the proposed system lays emphasis on creation of 3d mesh, unwrapping mesh and rendering it. All this is a tedious task for a person who does not have knowledge about the mesh and 3d objects. This is a major drawback of the system.

Deepak Uplaonkar [6] et al in "Virtual Furniture Application based on Augmented Reality", have proposed a new model for trying virtual furniture. This method does not include user's evaluation of the system. Vaibhav Raut [7] et al in "Furniture Layout AR Application Using Floor Plans Based on Planar", proposed a new system. The shortcomings of the system the user had to capture pictures of furniture that was already there. Hence there was no need of application to envision the furniture.

Raviraj Patrakar [8] in "Marker Based Augmented Reality Using Android OS", developed a system which did not use any SDK to augment the furniture. There were too many calculations that could have been reduced if SDK's were used, thereby improving the efficiency of the system.

Taiki Fuji [9] et al in "Furniture Layout AR Application Using Home Plans Based on Planar", Mai Lee [10] et al in "An Augmented Reality Application Previewing 3D Décor Changes" and many others have proposed many such systems. Some of these systems never considered evaluating user experiences, some were simple prototypes limited to only one furniture object, limited to only one platform using old techniques and inefficient methods that involve too many calculations and some of them made use of expensive hardware such as head mounted displays (HMDs).

Considering all these factors, we propose a new AR Furniture android application that overcomes most of the shortcomings of the above mentioned systems.

III. Augmented Reality

Augmented Reality is a technology that augments the current world of the user with virtual information, data or objects which are perceived to be natural objects. AR is defined by Wikipedia as follows: "Augmented reality (AR) is a direct or indirect live view of a physical, real-world environment whose elements are "augmented" by computer-generated perceptual information such as sound, video, graphics or GPS data".

Paul Milgram defines AR as subset of Mixed Reality (MR) which in turn is defined as "continuum of real to virtual environments". This means that the virtual continuum changes from completely real environment through to the completely virtual environment as shown in Fig. 1. Augmented Reality and Augmented Virtuality (AV) exist between these extremes. AV is another branch of Mixed Reality that deals with merging real world objects into virtual worlds.

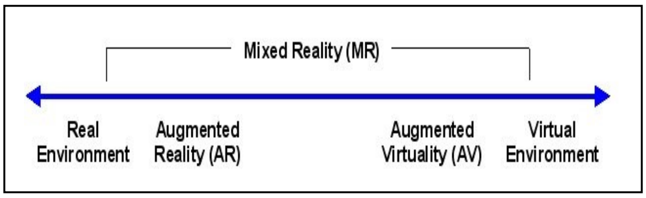


Fig. 1. Milgram's Reality-Virtuality Continuum

Augmented Reality (AR) as a technology that empowers businesses and industries is becoming very popular in different fields such as education, design, navigation and medicine. Due to swift development of mobile technologies, AR is growing rapidly and becoming persistent on this platform. It is important to discuss the key elements that constitute the AR system.

A. Generic design of an Augmented Reality System

Fig.2 explores the various components of the AR system. The system is made up of three units.

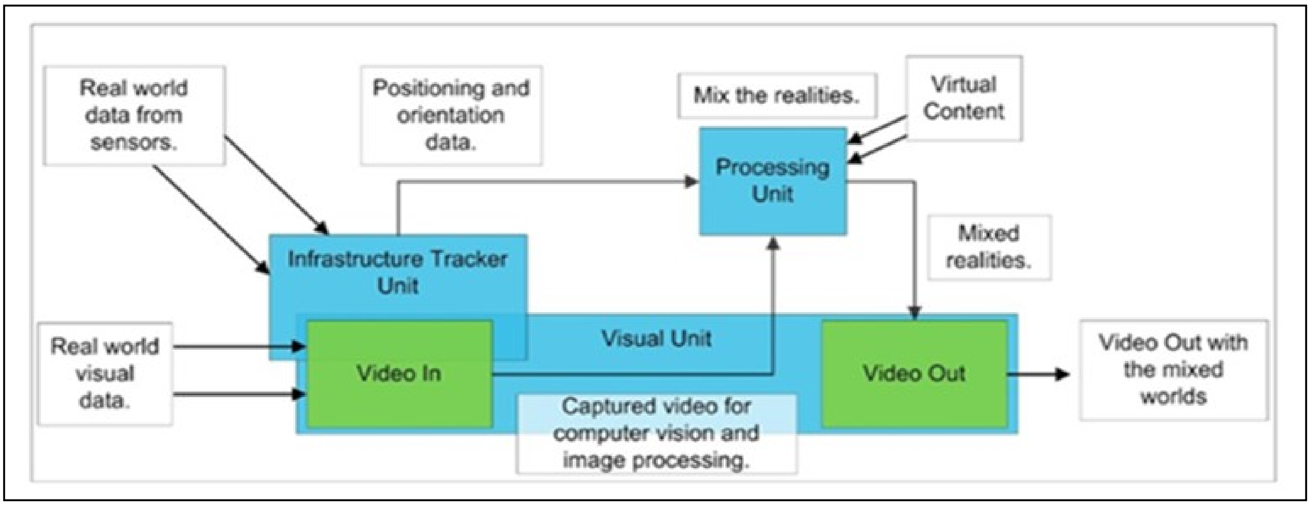


Fig. 2. Generic design of an Augmented Reality System

1) *Infrastructure Tracker Unit:*

It usually consist of a camera to capture the live feed of the surroundings and sensors such as GPS. Both of are bundled together and made available in the market as mobile devices (smartphones). The camera and sensors work together to collect the visual data from the real world.

The infrastructure tracker unit transfers the camera frames and information about position and orientation of the real world to the processing unit. Sometimes infrastructure unit can also be constituted only with a camera, Head Mounted Display or depth sensor camera such as Microsoft's Kinect Sensor.

2) *Visual Unit*

The visual unit applies the algorithms on the camera feed before it is transferred to the processing unit. Most of the algorithms that are applied are from computer vision, human computer interaction and image processing domains.

3) *Processing Unit*

This is the unit where the "augmentation" occurs. The virtual content is mixed with the real world. Many processing units are intelligent enough to suggest the user about best place for a furniture item.

B. *Types of Augmented Reality Applications*

1) *Marker Based applications:*

In marker-based applications, the images or the equivalent image contours to be recognized are provided in advance. The application is aware of the target that it has to recognize. On encountering the target, the virtual data is augmented onto the target. These applications focus more on the recognition of the object. The marker tracking allows the use of a digital image to identify image targets and keep estimating their relative orientation to the camera itself.

2) *Marker-less applications:*

Marker-less AR depends on the natural features of a surrounding rather than fiducial marker tracking. The marker-less AR system typically makes use of the GPS feature, in-built in the device in order to locate and interact with the available augmented reality resources.

C. *Software development Kits(SDKs)*

To support rapid development of AR apps, many SDKs have been released by various companies. These SDKs have been developed over the years, maintained properly and well documented. Utilizing these SDKs gives the developers a head start. Some of the popular SDKs are ARToolKit, Wikitude, Vuforia, Kudan, ARCore and ARKit.

ARToolKit is a old SDK. Its last stable release was in 2016. Wikitude is mostly used to develop AR applications that use GPS services. Vuforia and Kudan are two of the most popular SDKs that offer free development keys.

Vuforia doesn't support marker-less Augmented Reality where as Kudan supports both marker-based and marker-less AR. Kudan makes use of SLAM (Simultaneous Localization And Mapping) techniques to calculate relative position and orientation of objects in the scene. ARCore is limited to Samsung and Google's Pixel and nexus devices. ARKit is limited to iOS devices.

IV. System Design

As depicted in Fig. 3, the Architectural design of the system consists of the user, a mobile device with a camera and the AR application installed onto the device. Once downloaded, the user chooses the furniture item that he/she wants to visualize in his/her environment. This information is passed on to the scene where augmentation takes place. The system collects information about the surrounding environment by applying Simultaneous Localization and Mapping (SLAM) techniques to the camera frames.

In a marker-less application, the application doesn't have information about what it is looking for in the environment. When the user clicks on "place object button", the virtual 3D model of the furniture is augmented onto the horizontal surface where the camera is pointing to. The user can move, scale and rotate the furniture object.

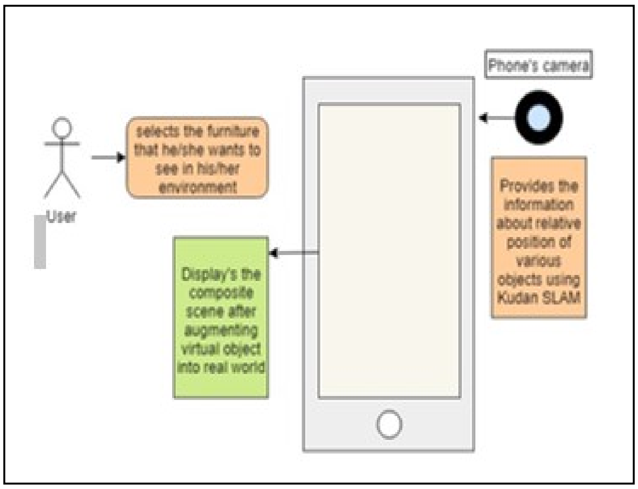


Fig. 3. Architectural design of the system

V. IMPLEMENTATION

The implemented system can be classified into four different stages. They are as shown in the Fig. 4.

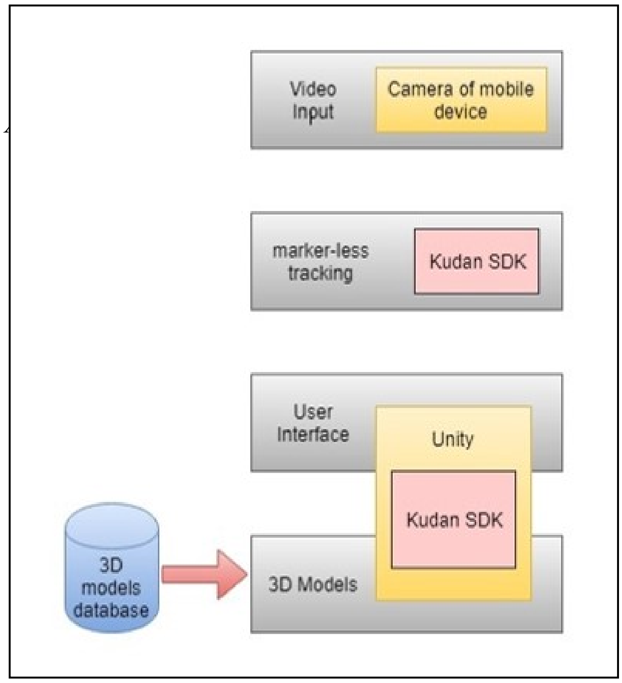


Fig. 4. Overview of Implemented System

A. *Video Input*

The video input is provided by the camera of the mobile device. It sends our 30 frames per second to the application. Some devices have camera with better resolution, therefore they send more number of pixels to the processing unit than it is expected. To overcome this scenario, video is compressed and sent to the processing unit.

B. *Markerless tracking*

In Augmented reality applications based marker-less tracking, the camera doesn't have any information about what it should look for in the camera frames. It detects all the natural features from the camera data using Simultaneous Localization And Mapping algorithms. We make use of Kudan SDK, to perform this operations.

C. *User Interface*

The user interface for the application is created using Unity3D UI tools. Unity comes with User Interface tools such as image, raw image, button, text and many more. Any element can be made interactive, by adding Event Trigger script component. This makes the element to respond to events.

D. *3D Models*

The 3D models used in this application have been imported from the Unity Asset Store. Users can create their own 3D models using CAD software such as 3ds Max, CATIA, SketchUp, Autodesk Revit and many others. The 3D models, in order to be used in Unity, should be exported in .fbx format.

The following algorithm is used to perform Simultaneous Localization And Mapping [11].

Algorithm 1 3D points updating with Occlusion Handling

for each valid feature point x (its corresponding 3D point is X) in each selected keyframe, **do**
  Compute its projection x' in the current frame.
  if $n_x^T n_{x'} < \tau_n$, **then**
    compute the appearance difference $D_c(X)$ by (2)
    if $D_c(X) > \tau_c$, **then**
      find a set of tracked feature points $\phi(X')$ in the current frame whose distance to x' is less than r1 pixels
      if $\phi(X')$ is not empty $ZX_y \geq ZX$ for all $y \in \phi(X')$ **then**
        set $V(X) = 0$
      else
        for each point $y \in \phi(X')$, **do**
          project X and X_y to the frame where X initially appeared.
          if $|X_p - Y_p| < r_2$, **then**
            Set $V(X) = 0$
          end if
        end for
      end if
    end if
  end if
end for

In the SLAM algorithm above, we first find the key frames. A key frame is one whose camera pose can be estimated and is different from the other frames. Five frames that have most common features between them are selected as key frames. A feature track is constituted using the matched points in key frames and input frame. A difference of color histogram is calculated from the histograms of these five key frames. If the difference is more than one, the feature point from this frame is projected onto the key frame.

If x is a feature point, X is its 3D position and it is calculated as:

$$X_i = min_{xi} \sum_{j \in \phi(xi)} \|xij - \pi(K(RjXi + Tj))\|^2 \quad (1)$$

$\phi(Xi)$ denotes the set of frames that Xi appears in. x' is projection of x in the current frame. $V(X)$ is used to denote the status of 3D point X. $V(X) = 0$ if it is invalid, else we set $V(X) = 1$. We compare the 3 appearance and 3D structure between x and x0 to determine whether X is valid or invalid. n_x and n_x are centers of key frame and current frame, respectively. The angle between $n_x^T n_{x'}$ is the angle between x and x'. If it is less than τ_n, set $V(X) = 1$ as it is very likely that feature point x will not be visible in the current frame. Otherwise compare the distance between x and x' as

$$D_c(X) = min_{y \in W(x)} \|Iy - Iy0 + d\| \quad (2)$$

I_y denotes color of y. y' is the projection of y by the estimated depth and camera parameters, d is a small translational vector.

All the scenes (Unity equivalent for levels) were created and SceneManagament package functions were used to switch between scenes. Kudan Camera prefab was added to hierarchy panel. You need to enter the right Editor API key, API key, and Bundle Identifier to run the application.

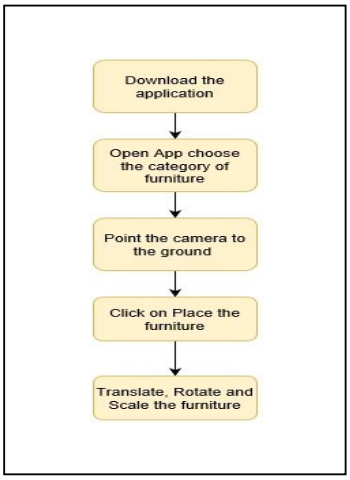


Fig. 5. Flow of activity to be followed to visualize the furniture

Change the build platform to Android and disable multithreaded rendering. The camera sends data to processing unit through pipelines. Some elements take more time to be processed compared to others. This causes blockages in the data flow and screen would be black. Some screenshots of the application in use are shown in Fig. 6.

Marker-less augmented reality cannot be verified using the unity play mode. User has to build either android or iOS application.

VI. System Evaluation

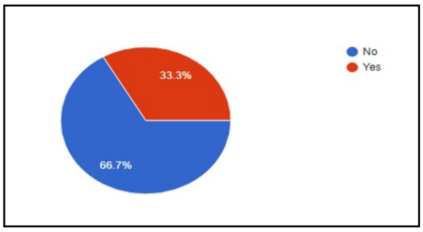
After developing the application we conducted a survey of user satisfaction with the application and to determine the usability of the application. A rating scale was used, 5 being the highest and 1 being the lowest. This survey was conducted on 25 people. Out of them 17 were engineering students from different streams. The application was shared with the people participating in survey via a google drive link.

Fig. 6. Some screenshots of the app. From left – Main menu screen, and furniture being envisioned

This survey was conducted on 25 people. Out of them 17 were engineering students from different streams. The application was shared with the people participating in survey via a google drive link. Both written and verbal instructions were given to them, about how to use the application and responses were collected using Google Forms. After the responses were collected from the users, they were exported in .csv format. The sum and average ratings for each of the ratings were calculated. Out of the 25 participants, only 33.33% of them knew what Augmented Reality was and the rest were hearing about it for the first time. The pie chart in Fig. 7 shows the same. It is seen from the survey that the application got an average rating of 4.04 in the five metrics. The metric Q1 through Q5 with their relevant names and rating is shown in the Fig. 8.

TABLE I. Definition of Metrics

Metric	Definition of metrics
Q1	How easy was it to run the application for the very first time?
Q2	How quickly can the tasks be performed using the application?
Q3	How easy was it to remember all the steps to accomplish the task?
Q4	Did you encounter many errors while accomplishing the task?
Q5	How satisfied are you with such an application?



Fig, 7. Pie chart showing the percentage of people who know augmented reality among the people who participated in the survey.

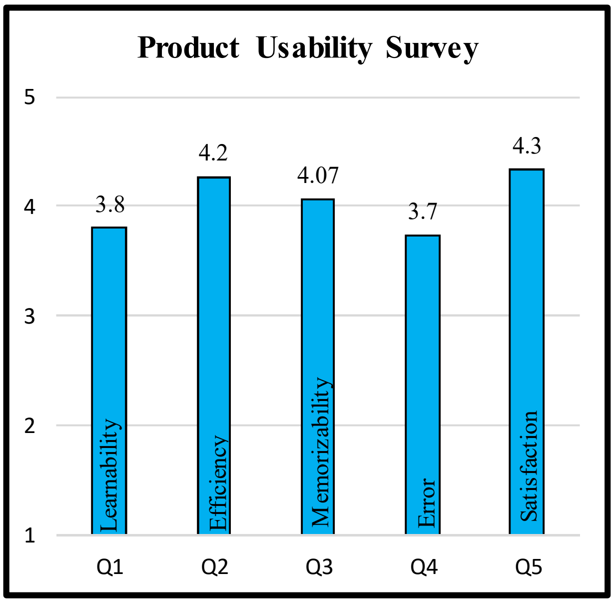


Fig. 8. Results of survey

The average rating was 4.04. Error rate is 3.7. This error rate could be due to bad lighting conditions or usage of application to envision furniture in a congested place. About 80% of the users were satisfied with the experience.

Fig. 9 contains the responses of the participants in the form of a table. The names have been omitted due to privacy concerns.

Know Augmented Reality	Q1	Q2	Q3	Q4	Q5
No	4	4	3	4	4
No	4	5	5	4	5
No	4	4	4	4	4
No	4	4	4	4	4
Yes	4	4	4	3	5
No	3	4	5	4	5
No	4	4	4	4	4
Yes	4	5	4	4	5
No	4	4	5	3	5
No	4	4	4	3	4
Yes	4	5	4	4	4
No	4	5	3	4	4
No	3	5	5	4	5
No	3	4	4	3	4
Yes	4	4	5	4	4
No	3	4	3	4	4
Yes	4	5	4	4	5
No	3	4	4	3	3
Yes	3	4	3	4	5
No	4	3	4	3	5
No	5	4	3	4	4
No	3	5	3	4	3
Yes	5	3	5	4	4
Yes	3	4	4	4	5
No	4	3	3	3	4
Average	3.8	4.2	4	3.7	4.32

Fig.9. Responses of participants in the survey

VII. Conclusion and Future Work

In this paper, the design of an android application that uses the Augmented Reality techniques has been presented that helps the user envision the furniture item before buying it. The application utilizes the Kudan SDK to provide marker-less augmented reality solution.

A direction for the future work of this project is to include user logins. User logins can help the user to see their search history. The application can be made intelligent to give suggestions to the user about the other suitable furniture that can be bought along with the furniture that is being planned to buy. This classification of furniture can be based on the type of the furniture opted for purchase and the area of the house where the furniture is to be placed.

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