# A Survey on Augmented Reality and its Application in the Field of Interior Design

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# A Survey on Augmented Reality and its Applications in the field of Interior Design

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## Abstract

**In today's growing and emerging world of new technologies where new innovations are regularly done to make our lives easier, Augmented Reality is one of the fastest growing fields, with applications in almost all industries, it will be considered as one of the key technologies of the future. It is safe to assume that interior design will be one of the biggest industries to get revolutionised by AR. This survey paper discuses about augmented reality and the way it can be implemented to make an interior design application. An AR approach to interior design can also improve the outcome of the design as collaboration between the designer and their client becomes much easier. Various computer vision concepts are used to provide an interactive and immersive experience to the user. They can be implemented by using their plug-ins in game-engine softwares like Unity 3D or Unreal which are used for the development of the AR application.**

**Keywords: Augmented Reality, Interior Design, Development, Unity 3D, Marker.**

## Introduction

Since the advancements in Computer Vison technologies and the improvements in smartphone cameras, AR has evolved into a massive $18.8 Billion industry. A lot of applications of AR are possible right now but the most hyped and the most successful industry so far is the use of AR in interior design and decoration.

Interior design has its roots in Ancient Egypt where they used to decorate their mud huts with animal skins. We have come a long way since then, interior design is an industry in itself[1]. The current approach is using various Softwares like Blender, Autodesk etc. to create a 2D representation of the room. This approach is very tedious and requires a lot of resources and time as the interior designer has to change the layouts constantly according to the customer's needs. This brings us to the second issue, there is communication gap between the designer and the customer, this means the customer can't suggest changes in real time. Not everybody has good imagination power and so imagining the 2D image of the room in the real world can also be very confusing for many customers.

This is where we bring in Augmented Reality. Instead of making 2D representations of the room, the designer has to upload the 3D models and the customer can spawn the virtual objects on the room in real time. They can interact with them and set them according to their like. This is done mostly by using the camera, it tracks the virtual object in the room when the user moves around. It also gives a real visualisation of the object in the room which removes the hurdle of limited imagination.

The Augmented Reality market of interior decoration takes a significant percentage of the industry. This part of the industry is changing the norms and approach to interior decoration, making the traditional approach obsolete day by day. Better visualisation of the product, real looking 3D objects, easy interaction with virtual furniture are some of the advantages that are helping the designer and the customer to make better decisions with less wastage of resources and time when they use the traditional method of Interior design. Other advantages include real time mapping of unknown environment, real life size of virtual furniture thus helping the customer to decide whether the furniture fits in an area of their home/office etc.

Various methods are used to make AR Interior Design applications. They range from basic marker-based application with zero to no interaction, all the way to highly interactive and Markerless systems that can scan the surroundings and detect vertical or horizontal planes. This paper will survey these methods and will give an insight into how augmented reality is better than traditional approach. Each of these methods has some advantages and some disadvantages so it all depends on the developer which system they want to implement according to their functionality. It will also discuss the various concepts that are required to make an AR based Interior Design System. These concepts are the foundation of any AR system and it is a must to learn all of them to create a good system [2].

### 1. What is Augmented Reality?

The eyes of humans have the capability of seeing objects in the third dimension (3D) but, imagining how your future home is going to look by just seeing a picture is difficult for many people. The use of Augmented Reality thus came into the scene. Augmented Reality revolves around overlaying virtual objects in the real environment. This also provides its user the ability to interact with the virtual object and set it according to their like. Ideally, the

virtual object has to follow all rules of physics and react accordingly.
Augmented reality is a part of a broader general term called Mixed Reality. Mixed Reality (MR) contains various sub-fields like Augmented Reality, Virtual Reality and Telepresence. This technology has applications in various fields including medicine, engineering, design and military.
Paul Milgram's "Reality-Virtuality Continuum" divides reality and virtuality into four parts (Figure 1.1). The continuum describes about the interaction of real and virtual environments. It can be observed that AR and AV are in between both the environments. According to Milgram, the closer you get to Real Environment the more it gets important to follow the laws of physics. In the case of Augmented Reality, it is the closest to Real Environment so we can conclude that, it is important to follow all the rules of physics (like occlusion, gravity etc.) to make an AR System.
Mixed Reality can be generally classified as Immersive and Non-Immersive. Immersive MR systems require various apparatus like Head Mounted Display's (HMD), Controller Sticks that are used to give a feeling of true immersion by providing audio and visual feedback. These objects require a lot of space and time to setup so it has less portability. Non-Immersive MR systems like smartphones are much more portable compared to HMD's but what it gains in portability, it lacks in immersion. You can get a good MR experience in it but it won't be satisfactory for the human eyes [3].

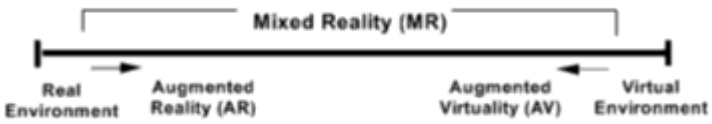


**Figure 1.1 Paul Milgram's "Reality-Virtuality Continuum"**

Ivan Sutherland was the first to develop a head mounted display in the 1960's that could spawn a virtual cube which moved with the movement of the user's head, but the first ever proper AR system was developed byLouis Rosenberg in early 1990s inside the U.S Air Force Armstrong Laboratories. It replaced the human arms with robotic ones (Virtual Fixtures). This required a lot of computing power but computers back then weren't as fast. Hence, it wasn't publicised. But as the computers got faster and smaller, these systems trickled down to the general population and hence it was released to the common population. The biggest evolution to happen after the release of "The Smartphone".

### 1.1 Different types of Augmented Reality

Experiencing Augmented Reality can be done through various means. The types of AR are:

**1. Projection Based AR**:As the name suggests, virtual objects are projected on a real-world surface like a wall from where you can interact with it. This can be done by using hardware like Projectors and RGB-D camera's in a controlled environment (a room).
If setup properly it can create a highly realistic AR Space. One of the examples is a place called Electric Playhouse in Albuquerque, New Mexico (USA). They have created a projection-based space where players can interact with it and have fun [4].

**2. Recognition Based AR**:This type of AR is used with barcodes/QR codes, images, texts etc. where the user pans the camera towards that place and the camera recognises that place/object. Biggest example of using Recognition Based AR is using Google Lens to recognise text and it uses AR to translate it to another language. You can also use it to scan an image and get an interactive model of that place.

**3. Location Based AR**:This type of AR uses the user's real time location to display data accordingly. One example is using Google Maps in Augmented Reality where it gives real time directions in AR. Another example can be Pokémon Go where the Pokémon' spawn according to your location.

**4. Superimposition Based AR**:The most popular type of AR currently is superimposition-based AR where it uses the full potential of AR by merging the real and the virtual worlds. Here the objects can interact in a much better way as they are following all rules of physics and also feel photoreal. Interior design is best suited for this type of AR. It is usually divided into two main categories:

1. Using an HMD
2. Using a mobile

### 1.2 Augmented Reality Techniques

After looking at the different types of AR, it's time to understand the different techniques used to spawn the AR content on the user's device. There mainly two main techniques used:

**1. Marker-Based Technique**

A Marker is a collection of unique points called feature points. The system uses concepts of image recognition, pattern recognition and computer vision to detect it. More feature points in a marker means easier detection. Once the camera detects marker by using the camera's frame stream, the object will be spawned. The user can interact with it once it is spawned.
The AR system uses the camera stream to render the virtual object. Rudimentary systems will only track the marker. This means that the virtual object will float around in space once the marker is detected. On the other hand, a good system will track the virtual object and keep it stationary even though the camera is moving.
This system uses the coordinate system and tracks the object accordingly. While rendering the model to track it, it uses various coordinates like the vertex coordinate, texture coordinate and normal coordinate of the object and also uses the total number of polygons in the object. Various algorithms are used to do tracking, the discussion

of which will be done in the later topics. The biggest disadvantage is that the system will not work without a marker [5].
We can say that Recognition based AR uses Marker-Based technique when you use a barcode/QR to spawn an object. The current generation of marker-based AR has improved a lot.

**2. Markerless Technique**

This system removes the disadvantage faced by marker-based technique. It can work without a marker. This is possible because instead of tracking a specific image/texture it uses computer vision to identify feature points everywhere. Unique points include different patterns, various colours. So, all unique points detected by the system can be used to spawn and interact a virtual object. This gives the user more flexibility to move around in the room and interact.
The biggest disadvantage is that a plain solid color will have almost zero unique points so it will be very difficult to spawn and track an object. This is because the current generation of computer vision algorithms are not that advanced.
It is more complex to use but provides a better solution to interact with. It is the future of AR. It is in a rudimentary phase compared to marker-based AR which is highly advanced now.

**1.3 Displaying Augmented Reality**

Augmented reality can be displayed to the user through many ways. It is up to the developer howthey want to provide experience. Immersion in the system depends on various types of the displayused. Therefore, the various types of method to display AR according to Broschart and Zeile (Broschart and Zeile, 2014) are:

**1. Projective AR (PAR)**: All the visual information and the virtual objects are spawned in the real world by using projectors and depth cameras etc. In this case the user doesn't need any visual aids as they can see and interact with the object in the real world, like a wall. If implemented correctly it will provide high level of immersion and realism. Projection based AR works on this method.

**2. Video See-Through (VST):**Here we use projection glasses to display the image. The user needs to wear them in order to get a good immersive experience. They are more portable and easier to use. They are very complex to design and manufacture as it is difficult to combine all the components in a miniature form.
VST is the future of AR and will be a replacement for the smartphone once hardware technology catches up to the level. Google glass is a good example.

**3. Optical See-Through (OST)**:A semi-transparent mirror display is used to display content to the user. No extra components required; users can see them without any visual aids. Not widely used. It provides decent level of immersion. This technology can be used to try-on clothes or accessories.

**4. Monitor AR (MAR):**This method requires a monitor display like a smartphoneor a tablet to display the AR.

The
device should be capable of rendering the objects with a good quality camera. Very low level of immersion as user has to look in a display.

Current generation of Augmented Reality uses this method to spawn virtual objects. They are very portable and can be used to move around in the scene to display more information. As the mobile devices get more and more faster the AR system also gets better. This method is an intermediate to the VST method. Monitor will be used less after complete VST implementation is done.

**1.4 Augmented Reality in Interior Design**

Augmented Reality has the potential to have big impact on the interior design industry. Thisindustry thrives on the choices given by designers and the choices made by the user. There are a lot of variables like choosing a color that matches with the room, size of the room, how a certain piece of furniture would blend with the room. Hence making a decision gets very difficult.The biggest problem is visualising how a piece of furniture is going to look at a certain place. Eventhough the designers give a visual representation by showing rendered images of that room but it isn't immersive. This is where AR gets a higher ground. It provides high level of immersion to the user by using 3D models and depth sensing compared to traditional 2D image. The user also has the ability to interact and move around the object to place it according to their like [6].
Furniture retail is a huge market in the world with a value of $545 Billion in 2018. Currently, most of the sales are coming via physical stores. But buying furniture from brick and mortar store is too inefficient and time consuming. According to The Wall Street Journal's report, the online furniture industry is one of the fastest growing industries in the world with around 15% of sales done online in the United States. AR will give a huge boost to the online industry as it will provide good visualisation and ability to try different types of furniture in the room with the advantage of staying at home hence consuming less time. As AR is implemented more, it will slowly start to replace the brick and mortar store. Hence, we can conclude that building AR systems for this industry is worth the time and effort. Once implemented, its will be considered as a revolution in the interior design industry.

**2. Augmented Reality Concepts for Interior Design**

Visualising virtual furniture in AR and making it photorealistic is a difficult task. As Paul Milgram said that since AR is closer to reality, it needs to follow the rules of physics. So, we need to know many core concepts to make a good AR system. Following are the most important concepts:

**1. Anchors:**One of the most fundamental concepts of augmented reality. They are used to hold the virtual object in place when it is spawned in the real world. Anchors use the 3D world coordinate system to map the location of the object while the user is moving.

When the object is spawned it is given a value based on its position and orientation. This value is called pose. So, when anchors are created, the pose of the object shows position and orientation relative to the world space.

**2. Feature Points:**Anchors use the concepts of feature points to stay anchored to the place where they are spawned. Feature points are the distinctive features in each frame of the system. These features include different planes, textures, colors. The most important characteristic of a good feature point is the reliability. Reliability means that the computer vision algorithm is able to fine the same feature point and detect it even when variables like lighting, camera, noise, angle change.
Quality of feature points vastly depends on the camera sensor is used in the system. This means that 2D sensors on the smartphones are less reliable in finding good feature points compared to 3D depth sensors like RGB-D and LiDAR. Some of the most important algorithms are:

1. Features from Accelerated Segment Test (FAST)
2. Scale Invariant Feature Transform (SIFT)
3. Speed Up Robust Feature (SURF)
4. Binary Robust Invariable Scalable Keypoints (BRISK)

**3. Tracking:**Tracking is the heart of the AR system. It is used to trace the user's camera relative to the environment around it. It starts with the AR camera of the system. It checks every frame of the video feed and finds out the feature points from different places in the environment like markers, edges, textures. These feature points are then passed to the camera's rendering module where the object is rendered and shown to the user. The camera uses information from markers or the edges to calculate the position, shape and size of the virtual object. There are two ways the AR camera can be stationed to track the user:

1. Inside-Out Tracking: in this technique of tracking, the camera is stationed inside the headset/mobile device of the user. Hence, the camera moves with the user.
2. Outside-In Tracking: in this technique of tracking, the camera is stationed at a fixed point in the room which tracks the free movement of the user.

**4. Simultaneous Localization and Mapping (SLAM):**
Tracking algorithms help find keypoints in the camera frames, this makes the foundation of the AR system but, to make a good AR system we need to know about the 3D position of the user's device in the environment. This is done by calculating the spatial relationship between the device and the keypoints identified by the tracking algorithm. This process is called SLAM.
When the system is initially started it doesn't know anything about the environment. It starts processing it from various sensors, including the camera of the device and also other sensors like accelerometer and gyroscope to get a more detailed value of the orientation, position and speed of the device. The SLAM algorithm uses this data to make a map of the environment which will help

locate the device in real time. Markers can also be place at known locations which can be used to triangulate the location of the device. Most of the AR frameworks like AR Core, AR Kit, Microsoft Mixed Reality use SLAM to understand the environment.

**5. Co-Design Approach:**One of the biggest advantages of using augmented reality in interior decoration is that the interior decorator can collaborate with customer. Co-design approach means that creative interior decorators and the non-trained designers i.e. customers work together to develop the interior of a place. This can help out both to be more eloquent and creative as both have the ability to offer something in the design process. The AR system can be used as a common tool to collaborate and express themselves to create the perfect design. This can improve the relation between the designer and the customer.

**6. Occlusion:**Occlusion is the concept where one object blocks the view of another object. In an AR system the virtual object needs to follow the rules of occlusion to make it feel real. It is not a widely used concept since it is difficult to find an estimation of different boundaries by using the traditional methods of 3D map construction we discussed earlier.
Another issue is the movement of the camera between two frames, which can cause jittering of the virtual object if the camera isn't aware of the difference between the two frames. To provide good level of occlusion the AR system's hardware must know the relative distance of the virtual object and all other objects in the scene. This can be done by using a depth sensor in the system. If implemented correctly it can provide a seamless integration of virtual and real objects in the scene.

**7. Light Estimation:**Light estimation is the concept of using visual cues from the known environment to render the virtual object in the similar manner to make it more realistic and hence make the experience more immersive. The human eyes have the ability to subconsciously perceive subtle cues about objects in a certain environment. So, whenever the object is missing a reflection or a shadow, we can sense that the object doesn't fit the environment thus reducing the immersion of the system [7].
It is done by using visual cues like shadows, ambient lighting, shading, reflections and specular highlights. Ambient lighting means the overall light that is present in the environment, lighting all objects. Shading is the intensity of light hitting a part of the object. So different parts can have different kinds of shading. Specular

highlights are the parts of an object that reflect the light source directly. They change according to the position of the user [8].

## 3. Traditional Approach to Interior Design

An interior designer has the duty of making interior spaces beautiful, functional, safe by determining the space required for various objects and choosing visually important features like lighting, textures and colors of the place.
The designers first determine the client's requirements and expectations. Then they collaborate with architects, engineers and the builders to figure out the functionality of the interior space. This is done by initially making sketches and drawings based on the blueprints and then designing the interior digitally by using a Computer-Aided Design (CAD) software. This digital version is then rendered into a 2D image which is given to the client for visual references. The client then proposes some changes that they feel are needed and the whole process is repeated again till the client is satisfied with the result.
This approach works well but it has a few disadvantages. It's hard to visualise 3D furniture in 2D rendered images of a place. The photo also isn't according to the scale of the room so it's hard to imagine the real size of all the objects in the room. The whole process is time consuming since the designer has to keep on changing the design till the customer is satisfied. This happens due to lack of real-time collaboration between both the parties.

## 4. AR Approach to Interior Design

### 4.1 AR App Design

Interior design is a well-established field and with upcoming new technologies if it doesn't integrate new approaches then it will be difficult to operate in the future. Technological innovations in augmented reality is the obvious next step for interior design to move towards. This means that we will need to make an application that has an AR system. Augmented reality applications provide interaction with virtual objects in real-time. This is done by using various sensors which provides raw data for the calculation of higher-level commands.
Generally, the app is designed to use the camera of the device to collect frames of the real scene to display virtual objects on it. The camera is backbone of the app through which the system runs algorithms for various functionalities. It is necessary for the camera to be of good quality for the computer vision algorithms to do their work.
An integrated AR software should use pipelining of raw data to improve the efficiency of tracking. It should also be able to spawn multiple objects while simultaneously tracking them.
The algorithms should be quick to analyse the environment and find suitable feature points to spawn the virtual object on. They work faster in an environment which contains multiple textures, colors, edges as it easier to classify unique qualities of an environment.
The app should be quick to load models and textures so that there are no rendering problems when device moves in any direction. They should also stay anchored during

movement of the device. It is important for the model to have shadows and reflection for higher immersion and be of good quality with low poly count so that it doesn't take up a lot of memory.
The system should also be able to manage the system memory when multiple objects are spawned. If not done correctly, objects will not be rendered properly and will reduce immersion.
Lastly, the app should have a minimal user interface design so that it is easier to understand its functions and be less cluttered for higher immersion [10].

### 4.2 Functionality of the app

After the application is designed it becomes important to add some features that help users to interact with the virtual objects. The functions are the most important part of the app and any future modifications will be made taking these functions in consideration. Following can be considered as some good functions to make a good AR system for interior design:

- **Inventory System**: A system designed to store the created objects in a single list and can spawn that object whenever needed by the user. It can store any number of objects and can spawn them instantly.
- **Gesture Functionality**: Gestures are the most important part of the application as they will be way through which user will be able to interact with the virtual objects. Hence, the app should be able to recognise gestures accurately and they should be coded in such a way that user can easily figure them out. Some of the important gestures are:
  - Dragging Objects: The spawned objects can be dragged anywhere across the room to place it at the desired location.
  - Rotating Objects: Objects can also be rotated when pressed to put the object in that perfect location.
    Scaling Objects: The size of the spawned object can also be changed according to user interests by just pinching the screen.
- **Detecting Orientation of Plane**: It is important to recognise the orientation of the plane i.e. vertical or horizontal, so that the system can spawn objects accordingly. For Example, Google's AR Core and Apple AR Kit have built-in algorithms to detect orientation of planes.
- **Changing Color/Texture**: Another good functionality of the system is to add the ability to change the color and texture of the objects. This gives the user ability to change the style of the object without the hassle of manually changing the color or texture of the object in the CAD software.

- **Upload Custom 3D Models**: The app can be considered useful for the designers only if they can upload their own models to show it to their clients. Hence, it is a very important feature of the app and it is not recommended to skip it if the app is going to be used for professional uses.
- **Photorealistic Rendering**: It is important for the model to look photoreal for higher immersion. The goal of augmented reality is to merge the gap between real and virtual worlds and if immersion is not maintained it can lead to bad experiences.
- **Cloud Fetching**: 3D models take a lot of storage and it is not efficient to keep all of them in local storage. It is recommended to adopt a strategy in which all the 3D models are stored in the cloud and they are fetched whenever the user spawns them. This will reduce the size of the app drastically thus increasing its efficiency.

## 5. Working of the app

The system is divided in modules that interact with each other. Each of these modules have different functions which are critical for the working of the system. The modules can be classified by:

### 1. Tracking module

As explained before it is the heart of the AR system. The tracking module calculates the pose for the virtual overlay. The module starts when the AR camera is initialised. It then starts receiving feedback from the camera. The module goes through the it frame by frame and starts detecting for any markers/feature points present in the camera stream. Once detected, it decodes the marker, calculates it's coordinates and sends this data to the rendering module.

### 2. Rendering Module

The rendering module renders the virtual model onto the marker/feature point once their coordinates are defined. This model is then displayed to the user on the device. It is important for the module to keep the rendered object in system memory so that it doesn't glitch when the device is moving in the real environment.

### 3. Interaction Module

Interaction module provides the user with the ability to interact with the virtual object. Interaction is needed in the system so that the user can change the pose of the virtual object according to their likes. This module provides gesture functionality to the system. It consists of multiple scripts of code each written for a different kind of gesture. They are written generally in C#.
The module initialises with the AR camera. It starts working when the user gives an input. The object will react according to the input given by the user. Input can be given through various ways. Fingers can be used if a multi-touch display device like a smartphone is being used. A joystick or a controller can be used if system is running on a non-touch screen display or a head-mounted display. Hand gestures can also be used by adding a Kinect sensor or any other sensor similar to it. Once the gesture is made, the pose of the object is estimated. The AR camera sets according to the estimation and hence the pose is changed. The interaction module should provide the user with easy to understand gestures which can provide a level of immersion that they can feel they are moving a real object.

## 4. System Module

System module can be considered as the parent module for all the other modules. It monitors all modules and can be considered as the channel for inter-module communications. It can be considered as the veins of the system that connects all the other parts.
It initialises with the camera and calculates the coordinates of the screen. The AR camera is then calibrated according to these coordinates and displayed to user on to the screen. Once the system is completely initialized it sends and receives feedback from all the modules. This feedback is monitored in real-time. The function of the core modules is displayed to the user only after its feedback is accepted by the system module.

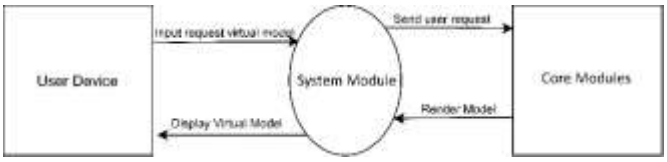


**Fig.5.1 DFD Level 0**

In this data flow diagram (Fig 5.1) the user requests for the 3D model to the system module of the application. The system module acts as an interface between the user and core modules consisting of all the core functionality of the system. The system module requests for the 3D model to the core module. The module computes the coordinates and renders the 3D model. This model is sent back to the system module which displays it to the user on the device.

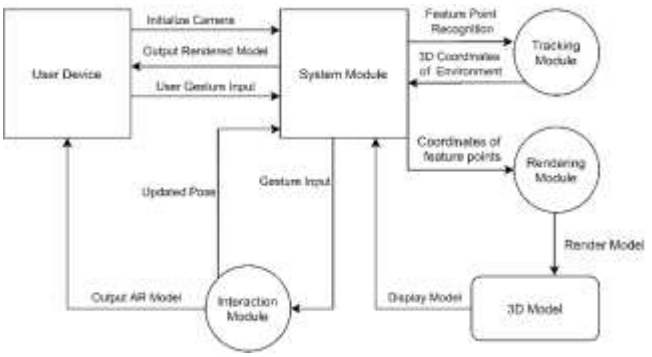


**Fig. 5.2 DFD Level 1**

In this DFD (Fig 5.2), the camera is initialized by the user. Once started, the system module sends command to

start searching for feature points to the tracking module. The tracking module sends the 3D coordinates of the environment back to the system module. This data is used by the rendering module to render the 3D model. This model is finally displayed to the user. When the user does a gesture, it goes to the interaction module where it is processed. The updated pose of the model is sent to the system module for future calculations and the output of the AR model is sent to the user's device.

**6. Software Needed for Development of AR App:**

Development of an AR application is divided into categories of softwares. All of these categories combine together to make an AR application.

**1. 3D Design Software:**

3D design can be considered as the first step to making an AR app. A virtual model is a must for bridging the gap between real and virtual world. Development of these models can be done through many apps but here are a few apps that most of the interior designers and 3D designers prefer:

1. Blender
2. Autodesk Maya
3. Autodesk AutoCAD
4. Sketchup

**2. AR Functionality:**

AR functions like feature detection, marker detection, rendering etc. are available in various forms of frameworks and plug-ins that integrate very easily with the software that is being used to develop the AR experiences. Here are some of the few common platforms in the market available currently for development of an AR system:

i. Vuforia SDK: Vuforia is a cross-platform Software Development Kit (SDK) for Augmented Reality (AR) and Mixed Reality (MR) experiences, with robust tracking and performance on a variety of hardware including mobile devices and MR headsets like the Magic Leap and Microsoft's HoloLens.

It uses built-in computer vision algorithms to find and track planes and 3D objects in relation to the real-world environment viewed through the AR camera of the device. It supports both 2D and 3D marker targets and has the functionality of "Markerless" targets and multi-target configurations.

Additional features of the SDK include 6 degrees of freedom device localization in space, runtime image target selection and the ability to create and reconfigure target sets programmatically at runtime. Vuforia provides Application Programming Interfaces (API) in C++, Java, Objective-C++, and the .NET languages through an extension to the Unity game engine. In this way, the SDK supports both native development for iOS, Android, and Universal Windows Platform (UWP) while it also enables the development of AR applications in

Unity that are easily portable to both platforms making it the most versatile AR SDK in the market.

ii. AR Toolkit: AR Toolkit is an open-source computer tracking library for the development AR experiences. It uses computer vision algorithms to determine the relation between the real and the virtual world. It can also define the pose of the user device relative to the real-world marker. It is the one of the first libraries of AR development. The current version of ARToolKit supports Microsoft Windows, Mac OS X, Linux, iOS, and Android platforms.

iii. Wikitude: Wikitude is a mobile AR company whose core product is the Wikitude SDK. It is a development framework utilizing image recognition and tracking, and geolocation technologies. The SDK includes various feature like image recognition & tracking, video overlay, 3D model rendering and location-based AR.
It also has SLAM technology which enables object recognition and tracking, as well as instant markerless tracking. The cross-platform SDK is available for Android, iOS and Windows operating systems. It is also being optimized as well for several smart eyewear devices.

iv. AR Core: ARCore is a software development kit (SDK)
developed by Google for android devices that allows for augmented reality applications to be built. Virtual content is displayed on the real world seen through the device's camera via the display by using three key technologies:

1. The phone can understand and track its position relative to the world with the help of Six degrees of freedom. Which means the device can move freely in the 3-dimensional space.
2. Environmental understanding allows the phone to detect the size and location of flat horizontal surfaces like the ground or a table.
3. Light estimation helps the phone to estimate the environment's current lighting conditions.

It supports both marker-based and Markerless AR. It requires high computational power which is why it isn't supported in older devices. A lot of manufacturers are starting to integrate it in their phones now since microprocessors have gotten so fast nowadays.

v. AR Kit: ARKit is Apple's augmented reality (AR) counterpart for iOS devices. It uses a technology called Visual Inertial Odometry to track the world around your iPad or iPhone. This enables your iOS device to sense how it moves in a room. It also uses that data to analyse a room's layout as well as detect horizontal planes like tables and floors. Any iPhone or iPad capable of running iOS 11 or later is able to install ARKit apps. Newer devices will handle the apps better as they are faster in computing and rendering.

### 3. AR Engine:

An AR Engine combines all of the above functions of the system into one package. It is basically a game engine that has an added functionality of Augmented Reality development. The engine combines 3D models, scripts and the SDK's into a single environment. This enables the developer to work on all of the major functions at one place.
These engines are compatible with multiple OS platforms which reduces the hassle of jumping between various softwares and saves time in porting the code and 3D models according to the rules of that particular OS. It supports almost all the commonly available SDK plug-ins; 3D model types and they also have multi-language support.

Unity Engine and Unreal Engine are two of the biggest AR development game engines with all of the features given above and more as well. They are gold-standard for AR development right now and are used by most developers. These game engines are evolutionary in the development of AR systems and applications. They are the reasons AR apps have become relatively easy to develop nowadays.

## 7. A look at Existing AR Applications for Interior Design

1. **Ikea AR:**Ikea is one of the world's largest furniture manufacturerand supplier. They also have invested in AR technology by launching their AR app called Ikea AR in 2014. The users can download the Ikea app for testing furniture from their catalogue in AR. The only furniture models available are from the Ikea stores, which gives very limited number of choices to the user. It is available in both Android and iOS devices.

2. **Magicplan:**Magicplan is an augmented reality app used as a tool for architectural and interior design for creation of floor plans, dimensioning interiors and developing 2D plans using mobile sensors.

The user can capture the corners of a room, by using the camera of a tablet or smartphone. The app then automatically creates a floor plan. The two-dimensional floor plans can be converted into 3D models. Additional information (e.g. photos or annotations) can be added to the created floor plan. The app also allows for automatic cost calculation of materials based on the recorded floor plan data.

3. **Houzz:**Houzz is one of the biggest communities for interior designing and decorating, landscape design and home improvement. It provides users with multiple photos of interiors of various places for inspiration. The developers have used this information and made a cost calculation app that finds out the cost of the house the user wants.
Houzz also made their own augmented reality app in 2017 containing more than a million models for home decors and furniture in their true to scale form. Initially it was made using ARCore making it an Android exclusive app but now it is also available for iOS. Houzz has a great advantage for its community of designers who provide the virtual models for the users to select and buy.

Other notable AR applications are:
1. Intiaro
2. Decolabs
3. IStaging
4. Fingo
5. View AR

All of the apps mentioned have different advantages and flaws. Many of them don't provide the basic functionality required for making an AR application. Even if some applications like Houzz come close to a user-friendly app it still has very less interaction available.
There isn't an application that can be considered as widely used and user friendly. If some apps have good functionality, they are hard to learn for the non-designer and if the application is easy to learn then it doesn't have a lot of functionality making it useless for professional and widespread use. Although all of these applications have cutting edge features, it will still take some time for them to perfectly tune these applications according to the customer's needs.

## 8. Advantages of AR in interior design

### 1. Show of content in a more authentic way

The approach of augmented reality to merge real and virtual worlds is the reason it makes the content look way more authentic than a 2D rendered CAD image. This makes the virtual object make it feel like they are real world objects. For example, the interior designer can use the app to upload their own models and can arrange them much more easily as the app uses an interaction module for smoother gesture control compared to a CAD software. Development of the interior through this way gives more comprehensive insights into what the completed interior can look like.

### 2. Higher immersion and depth perception

Traditional methods of interior design heavily depend on the 2D rendered image that have a fixed pose. This provides limited amount of depth perception and very less immersion thus leaving most of the work on your imagination. Contrary to this an AR system provides high level of immersion and depth perception as the user can move around in the environment. This means it is easier to visualise the interior. The user can also interact with the virtual object which contributes to more user satisfaction.

### 3. Optimized Workflow

Augmented reality has the power of optimizing the workflow of the interior designer by simplifying the designing process which gives them the ability to get more creative in their work thus creating a more conscious design process. This provides the user with more improved possibilities of presentation which can lead to higher client satisfaction. A better workflow also means lesser hassle of working on complex softwares.

**9. Challenges for AR in interior design**

**1. AR systems are not ready for market**

Augmented reality is still a growing field with a vast number of applications but not a lot of people know about it outside the core tech industry. It is still considered as a gaming technology by the common public. The interior design industry hasn't completely shifted to AR because there is a lack of a high-end AR CAD software that gives all the functionalities of a normal CAD software.

**2. User Interface:**

UI/UX researchers and developers are still trying to figure out the possible user interface for an AR application. AR systems are a whole new challenge for them as they need to figure out how to display the functionality of the system in a way that doesn't disturb the immersion of the user while keeping in mind that it should be easy for the user to learn the system. According to surveys, it is shown that designers still chose normal CAD softwares because they are familiar with the user interface.

**3. Hardware Limitations:**

Even though the hardware for making a matured AR system has improved drastically in the recent decade but it still isn't good enough for mass implementation. The current generation hardware although fast, is way too complex and difficult to integrate into a single high-end working system. For example, HMD's like Microsoft's HoloLens and Magic Leap are revolutionary AR Head Mounted Displays but they still aren't compact enough for public uses. They are also quite complex to operate which results in a more difficult learning curve which destroys the purpose of transferring from normal CAD to AR based CAD software.

## Conclusion

Augmented reality has come a long way since its first use by Ivan Sutherland back in the 1960's head mounted display called Sword of Damocles, but the industry still has a long way to go to commercialize AR. The industry is growing rapidly with almost a 1400% increase in the jobs required for an AR/MR developer. Many companies have already invested huge amounts of money in this technology and all of them are racing towards the "First to Market" goal. Even though many of them have already Released their AR products; they aren't good enough for user satisfaction.

The interior design industry is slowly but steadily adopting AR in their workflow. With companies and designers realising that it is much easier to convince the customer by using AR as they don't need to go to the physical store and can virtually interact with the furniture. This vastly improves the decision making of the customer thus making it advantageous for the company and designer. With the ability to revolutionize any industry with its capabilities, AR can be concluded as one of the most important technologies of the future. It is safe to assume it is the next step to mobile computing after "The Smartphone". Thus, improving public knowledge about AR is very important to solve the challenges we are facing right now.

## References:

[1] Neumann, U. and Park, J., 1998. Tracking for augmented reality on wearable computers. Virtual Reality, 3(3), pp.167-175.
[2] Li, Barmaki, J., 2019. Trends in Virtual and Augmented Reality Research: A Review of Latest preprints.org , pp.1-6.
[3] M. Volonte, A. Robb, A. T. Duchowski, and S. V. Babu. Empirical evaluation of virtual human conversational and affective animations on visual attention in inter-personal simulations. In 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), pp. 25–32, March 2018.
[4] Patil, C., 2018. Interior Design Using Augmented Reality. International Journal for Research in Applied Science and Engineering Technology, 6(3), pp.1632-1635.
[5] Viet ToanPhan, SeungYeonChoo, "Interior Design in Augmented Reality Environment", International Journal of Computer Applications, Volume 5-No 5, pp. 16-21, 2010
[6] KILIÇ, T., 2019. INVESTIGATION OF MOBILE AUGMENTED REALITY APPLICATIONS USED IN THE INTERIOR DESIGN. TURKISH ONLINE JOURNAL OF DESIGN ART AND COMMUNICATION, 9(2), pp.303-317.
[7] Reitmayr, G. (2004). On Software Design for Augmented Reality (Doctoral dissertation, Vienna University of Technology).
[8] Zheng, H.W.; Chen, S.T.; Fan, G.G. Study on the Evaluation of Students' Learning Motivation Indicators from Using Facebook Communities—Taking the Culture Thinking and Creation of Digital Photography as an Example. Int. J. Digit. Media Des. 2019, 11, 1–16.
[9] Lugmayr, A.; Reymann, S.; Kemper, S.; Dorsch, T.; Roman, P. Bits of Personality Everywhere: Implicit User-Generated Content in the Age of Ambient Media. In Proceedings of the Parallel and Distributed Processing with Applications, 2008, ISPA'08, Sydney, Australia, 10–12 December 2008; pp. 516–521.
[10] S. Bonardi, J. Blatter, J. Fink, R. Moeckel, P. Jermann, P. Dillenbourg, A. Ijspeert, "Design and evaluation of a graphical ipad application for arranging adaptive furniture", RO-MAN 2012 IEEE, pp. 290-297,

## Bibliography


1. https://www.vox.com/recode/2020/2/11/21121275/augmented-virtual-reality-hiring-software-engineers-hired
2. https://www.andreasjakl.com/basics-of-ar-anchors-keypoints-feature-detection/
3. https://xinreality.com/wiki/Positional_tracking
4. https://www.andreasjakl.com/basics-of-ar-slam-simultaneous-localization-and-mapping/
5. https://xinreality.com/wiki/Occlusion
6. https://developers.google.com/ar/develop/unity/light-estimation
7. https://www.truity.com/career-profile/interior-designer