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# AN OVERVIEW OF AUGMENTED REALITY AND ITS APPLICATION IN THE FIELD OF INTERIOR DESIGN

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*Abstract*

In today's growing and evolving world of new technologies, where new innovations are regularly emerging to make our lives easier, augmented reality (AR) is one of the fastest growing fields, with applications in almost every industry.

It is safe to assume that interior design will be one of the biggest industries in which AR will revolutionise. As we are living in the era of digitalization and technology, and these days every industry is more or less connected or becoming connected with new technologies, and even those industries that categorically could not be connected with technology are nowadays being integrated with new technologies. This review looks at AR and how it can be applied to interior design. The AR approach to interior design can also improve the design outcome, as the collaboration between the designer and his or her client becomes much easier. Various computer vision concepts are used to provide an interactive and immersive experience for the user. These can be realised by using plug-ins in game engines such as Unity 3D or Android Studio, which are used to develop an AR application.

**Keywords:** augmented reality, interior design, development, Unity 3D, marker.

*Аннотация*

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## ОБЗОР ДОПОЛНЕННОЙ РЕАЛЬНОСТИ И ЕЕ ПРИМЕНЕНИЯ В ОБЛАСТИ ДИЗАЙНА ИНТЕРЬЕРА

В современном мире новых технологий, где регулярно появляются новые инновации чтобы сделать нашу жизнь проще, дополненная реальность является одной из наиболее быстро развивающихся областей, имеющей применение практически во всех отраслях промышленности. Можно с уверенностью предположить, что дизайн интерьера будет одной из самых больших отраслей, в которой Augmented reality (AR) произведет революцию. В данном обзоре рассматривается дополненная реальность и как она может быть применена в дизайне интерьера. AR-подход к дизайну интерьера также может улучшить результат проектирования, так как сотрудничество между дизайнером и его клиентом становится намного проще. Различные концепции компьютерного зрения используются для обеспечения интерактивный и захватывающий опыт для пользователя. Они могут быть реализованы путем использования плагинов в игровых движках, таких как Unity 3D или Android Studio, которые используются для разработки AR-приложения.

**Ключевые слова:** дополненная реальность, дизайн интерьера, разработка, Unity 3D, маркер.

*Аңдатпа*

## ТОЛЫҚТЫРЫЛҒАН ШЫНДЫҚҚА ШОЛУ ЖӘНЕ ОНЫ ИНТЕРЬЕР ДИЗАЙНЫ САЛАСЫНДА ҚОЛДАНУ

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Біздің өмірімізді жеңілдету үшін үнемі жаңа инновациялар пайда болатын қазіргі заманғы жаңа технологиялар әлемінде кеңейтілген шындық өнеркәсіптің барлық салаларда қолданылатын ең жылдам дамып келе жатқан салалардың бірі болып табылады. Интерьер дизайны Augmented reality (AR) төңкеріс жасайтын ең үлкен салалардың бірі болады деп сеніммен айтуға болады. Бұл шолуда толықтырылған шындық және оны интерьер дизайнында қалай қолдануға болатындығы қарастырылады. Интерьер дизайнына AR-тәсілі жобалау

нәтижесін жақсарта алады, өйткені дизайнер мен оның клиенті арасындағы ынтымақтастық әлдеқайда жеңіл болады. Пайдаланушы үшін интерактивті және қызықты тәжірибені қамтамасыз ету үшін әртүрлі компьютерлік көру тұжырымдамалары қолданылады. Оларды AR қолданбасын әзірлеу үшін пайдаланылатын Unity 3D немесе Android Studio сияқты ойын қозғалтқыштарындағы плагиндерді қолдану арқылы жүзеге асыруға болады.

**Түйін сөздер:** толықтырылған шындық, интерьер дизайны, әзірлеу, Unity 3D, маркер.

**Introduction**

Starting with the advancement of computer imaging technology and smartphone cameras, AR has grown into a huge $18.8 billion industry. There are now many AR applications, but the most exciting and successful area at the moment is the use of AR in design and interior design.

Interior design has its origins in Ancient Egypt, where they decorated their pets with animal skins. Since then we have come a long way, interior design is an industry it self [1]. Nowadays various software such as Blender, Autodesk etc. are used to create a 2D view of a room. This approach is very tedious and requires a lot of resources and time, as the interior designer has to constantly change the layout according to the needs of the client. This brings us to the second problem: there is a disconnect between the designer and the client, which means that the client cannot suggest changes in real time. Not everyone has good powers of imagination, so displaying a 2D image of a room in the real world can be confusing to many customers.

This is where we introduce AR. Instead of creating a 2D view of the room, the designer has to upload 3D models, and the client can create virtual objects in the room in real time. They can interact with them and adjust them as they see fit. Basically, this is done with a camera that tracks the virtual object in the room as the user moves around. It also allows a clear visualisation of the object in the room, removing a limited imaginary barrier.

The AR interior decoration market is taking a significant share of the industry. This part of the industry is changing the norms and the way interiors are designed, making the traditional approach obsolete by the day. Better product visualisation, realistic 3D objects, and easy interaction with virtual furniture are some of the benefits that will help the designer and client make better decisions while spending less resources and time with the traditional method of interior design. Other advantages include real-time display of unknown environment, realistic sizing of virtual furniture which helps the client to decide if the furniture is suitable for home/office, etc.

AR various methods are used to create interior design applications. They range from basic applications based on zero interaction markers to highly interactive markerless systems that can scan the environment and detect vertical or horizontal planes. In this article, we look at these methods and give an insight into how AR is better than the traditional approach. Each of these methods has some advantages and disadvantages, so it all depends on which system the developer wants to implement according to their functionality. He also discusses the different concepts needed to create an AR-based interior design system. These concepts are the foundation of any AR system, and to create a good system it is necessary to learn them all [2].

**What is augmented reality?**

People's eyes can see things in the third dimension (3D), but many find it difficult to imagine what your future home will look like when you see the image. Thus, the use of augmented reality has entered the scene. Augmented reality revolves around the superimposition of virtual objects in a real environment. It also allows the user to interact with the virtual object and customise it according to their preferences. Ideally, the virtual object should follow all the rules of physics and act accordingly. Augmented reality is part of a widespread term called mixed reality. Mixed reality (MR) includes various indoor fields such as augmented reality, virtual reality and Telepresence. The technology is used in various fields, including medicine, engineering, design and the military. Milgram's "reality-virtuality continuum" of gender divides reality and virtuality into four parts (Figure 1).

The continuum describes the interaction between real and virtual environments. You can see that AR and AV are in between the two environments. According to Milgram, the closer you get to the real environment, the more important it is to follow the laws of physics. In the case of augmented reality, it is close to the real environment, so we can conclude that it is important to follow all the rules of physics (such as occlusion, gravity, etc.) to build an AR system. Mixed reality can be classified as general immersive and non-immersive. Immersive mr systems require various devices such as head-mounted display (HMD), controllers that are used to create a realistic immersive experience by providing audio and visual feedback.

These objects require a lot of space and time to set up, so they are less stable. Non-immersive MR systems, such as smartphones, are much more portable than HMDs, but because they have more endurance, they lack immersion. You can get a good MR experience for that, but it won't be satisfactory to the human eye [3].

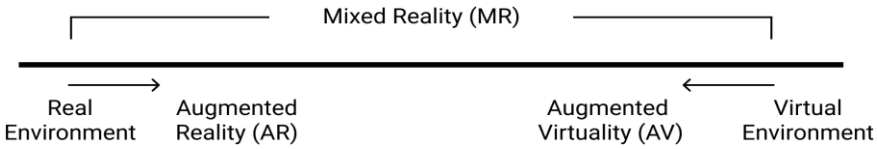


*Figure 1. Paul Milgram's "Reality-Virtuality Continuum"*

Ivan Sutherland was the first in the 1960s to invent a display capable of creating a virtual cube that moves when the user's head moves, but the first proper AR system in history was developed by Louis Rosenberg at the US Armstrong Air Force Laboratories in the early 1990s. He replaced the human hand with a robotic (virtual device). This required a lot of computing power, but computers at the time were not that fast. Consequently, it was not made public. But as computers became faster and smaller, these systems spread to the general population, so they were produced for the general population. The biggest evolution comes after the release of the 'smartphone'.

Augmented reality can be experienced in many different ways. Types of AR:

1. Projection AR: as the name implies, virtual objects are displayed on the surface of the real world, like a wall, which can be interacted with. This can be done in a controlled environment (a room) using equipment such as RGB-D projectors and cameras. When set up correctly it can create a very realistic AR space. One example is New Mexico (USA), a place called Electric Playhouse in Albuquerque. They have created a projection-based space where players can interact with it and enjoy [4].

2. Recognition based AR: this type of AR is used with barcodes/QR codes, images, texts, etc. where the user points the camera there and the camera recognises that location/object. The biggest example of using recognition-based AR is using Google Lens to recognise text and using AR to translate it into another language. You can also use it to scan images and get an interactive model of that location.

3. Location-based AR: This type of AR uses the user's location in real time to display data appropriately. One example is the use of Google maps in augmented reality, where they provide real-time instructions in AR. Another example would be Pokémon Go, where Pokemon appears based on your location.

4. Overlay-based AR: Currently, the most popular type of AR is overlay-based AR, where it takes full advantage of AR by combining real and virtual worlds. Here, objects can interact much better because they follow all the rules of physics and also feel photorealistic. Interior design is well suited to this type of AR. It usually falls into two main categories:

1. Using the HMD
2. Using a mobile phone

**Augmented Reality methods**

Having looked at the different types of AR, it is time to understand the different methods used to create AR content on the user's device. There are mainly two main methods used:

1. Marker-based techniques

A marker is a set of unique points called unique points. The system uses the concepts of image recognition, pattern recognition and computer vision to identify it. Having more characteristic dots on a marker means easy detection. Once the camera finds the marker using the camera's frame stream, the object is created. The user can interact with it once it is created. An AR system uses the camera stream to render a virtual object. Simple systems only control the marker. This means that the virtual object moves in space once the marker is detected. A good system, on the other hand, tracks the virtual object and holds it even if the camera moves. This system uses a coordinate system and therefore tracks the object. When rendering, it uses different coordinates such as top coordinate, texture coordinate and normal coordinate of the object to track the model and also uses the total number of polygons in the object. Various algorithms are used for tracking, which are discussed in the following sections. The biggest drawback is that the system doesn't work without the marker [5]. It can be said that using barcode/QR to create a recognition-based AR object uses a token-based technique. The current generation of marker based AR has improved considerably.

2. Method without marking

This system eliminates the disadvantage of marker-based techniques. It can work without a marker. This is possible because instead of tracking a specific image/structure, it uses a computer representation to identify unique dots all over the place. Unique dots include different patterns, different colours. In this way, all the unique points identified by the system can be used to create and interact with a virtual object. This gives the user the flexibility to move and interact around the room. The biggest disadvantage is that a normal solid colour has zero unique points, so it would be very difficult to create and track the object. This current generation of computer vision algorithms is not as advanced. It is more difficult to use, but offers a better solution for interaction. This is the future of AR. It is currently in the initial phase compared to AR based on very advanced markers. The user also has the ability to interact and move around the object to place it appropriately at will [6]. Augmented reality can be shown to the user in different ways. This is because the developer wants to provide an experience. The immersive experience depends on the different types of display used. Thus, different types of AR display methods according to Broschart and Zeile (Broschart and Zeile, 2014):

1. Projective AR (PAR): all visual information and virtual objects are created in the real world using projectors, depth cameras, etc. In this case, the user does not need any visual aids, as he/she can see the object and interact with it in the real world, e.g. a wall. When implemented correctly, this provides a high level of immersion and realism. Projection-based AR works with this method.

2. Transparent video (VST): here we use projection glasses to display the image. The user has to wear them to get a good immersive effect. They are portable and easy to use. They are very difficult to design and fabricate as it is difficult to combine all the components in miniature. Light estimation is the concept of using visual cues from a known environment to visualise a virtual object in the same way, to make it more realistic and make the experience more interesting.VST is the future of AR and replaces the smartphone when hardware technology reaches this level. Google glass is a good example [7].

3. Optically Transparent (OST): A transparent mirror display is used to display content to the user. No additional components are required; users can view it without visual tools. Not widely used. This will provide a decent level of immersion in water. This technology can be used for clothing or accessories.

4. AR monitor (MAR): this method requires a monitor display, such as a smartphone or tablet, to display AR. The device must be able to display objects using a quality camera. A very low level of immersion, as the user has to look at the display. The current generation of augmented reality uses this method to create virtual objects. They are very portable and can be used to move around the scene to display additional information. As mobile devices become increasingly faster, the AR system is also improving. This method is intermediate to the VST method. The monitor is little used after the VST implementation [8].

**The traditional approach to interior design**

The interior designer has to make the interior beautiful, functional, safe, determine the space required for the various objects, and choose visually important features such as lighting, textures and colours of the room. Designers first define the client's requirements and expectations. They then work with architects, engineers and builders to determine the functionality of the interior space. This is done by creating first sketches and drawings based on blueprints, and then by digitally designing the interior using computer-aided design (CAD) software. This digital version is then turned into a 2D image, which is transmitted to the client for visual reference. The client then suggests some changes that they consider necessary, and the whole process is repeated until the client is satisfied with the result. This approach works well, but it has a few drawbacks. It is difficult to represent 3D furniture in 2D visualised seating images. The photo is also not to the scale of the room, so it is difficult to imagine the exact number of all the items in the room. The whole process is time-consuming, as the designer has to keep changing the design until the client is satisfied. This is due to the lack of cooperation between the two parties in real time[9].

Interior design is an industry with a proven track record, and with the advent of new technology, unless new approaches are integrated, it will be difficult to operate in the future. Technological innovation in augmented reality is the next step forward for interior design. This means that we need to create an app with an AR system. Augmented reality applications provide real-time interaction with virtual objects. This is done by using various sensors that transmit raw data to calculate high-level commands. Typically, a programme is designed to use a camera device to collect frames of a real-life view to display virtual objects. The camera is the basis of the application in which the system runs the algorithms for the various functions. The camera has to be of high quality for the computer vision algorithms to do their job. The integrated AR software should

use pipeline processing of raw data to increase the efficiency of monitoring. It should also be possible to create multiple objects when monitoring them. Algorithms must quickly analyse the environment and find object points suitable for creating a virtual object. They work faster in environments with many textures, colours, edges as it is easy to classify the unique properties of the environment.

The software must load models and textures quickly so that there are no problems when moving the unit in any direction. They must also be fixed when the device is moved. Shadows and reflections are important for a deeply immersive model, so it does not require a lot of memory. The system must also be able to manage system memory when creating multiple objects. If this is not done correctly, the objects will not display correctly and reduce immersion. Finally, the application should have a minimal user interface design, so its functions should be easier to understand and less blocked for deeper immersion [10].

The system is divided into modules that interact with each other. Each of these modules has different functions that are very important for the operation of the system. Can be classified by module:

1. Control module

As explained earlier, this is the heart of the AR system. The control module calculates the pose for the virtual overlay. The module starts when the AR camera is initialised. It then begins to receive feedback from the camera. The module looks at the name-by-frame data and starts detecting any markers/characteristic points in the camera stream. Once detected, it decodes the marker, calculates its coordinates and transmits this data to the display module.

2. Visualization module

The visualization module displays a virtual model on the marker/characteristic point after determining the coordinates. This model is then displayed to the user on the device. It is important for the module to store the visual object in the system memory so that it does not fail when the device is moved in a real environment.

3. Interaction module

The interaction module provides the user with the ability to interact with the virtual object. Interaction is required in the system so that the user can change the pose of the virtual object according to their preferences. This module provides gesture functionality to the system. It consists of several code scripts written for different gestures. Generally, they are written in C# language. The module is run through an AR camera. When the user enters data, it starts working. The form responds according to the input given by the user. The implementation can be done in different ways. If a device with a multi-touch display, such as a smartphone, fingers can be used. If the system works without a touch screen or head-up display, a joystick or controller can be used. Hand gestures can also be used by connecting a Kinect sensor or any other sensor similar to it. Once a gesture is made, the position of the object is estimated. The AR camera adjusts itself according to the assessment, so the pose changes. The interaction module should offer the user simple gestures that can provide a level of immersion so that they feel they are moving a particular object.

4. System Module

The system module can be seen as a parent module for all other modules. It controls all modules and can be seen as an inter-module communication channel. It can be seen as the root of the system linking all other parts. It runs through the camera and calculates the screen coordinates. The AR camera is then calibrated to these coordinates and displayed to the user on the screen. Once the system is fully activated, it sends and receives feedback from all modules. This feedback is monitored in real time. The function of the main modules is only displayed to the user when the system module accepts its feedback.

This is shown in the data flow diagram (Figure 2) the user requests a 3D model in the system module of the application. The system module acts as an interface between the User and the main modules, which consists of all basic system functions.

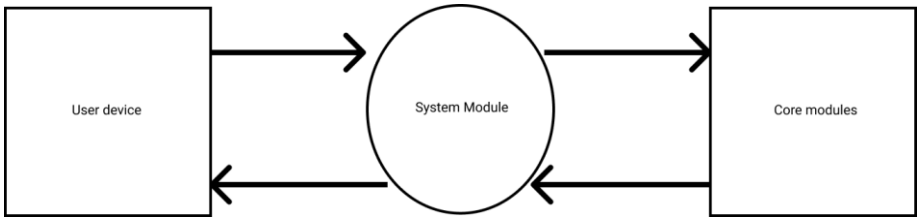


*Figure 2. DFD Level 0*

The system module requests the 3D model from the main module. The module calculates the coordinates and visualises the 3D model. This model is sent back to the system module, which shows it to the user on the device. This in the DFD the camera is activated by the user. Once activated, the system module sends a command to start searching for points specific to the control module.

The control module sends the 3D coordinates of the environment back to the system module. This data is used by the visualisation module to visualise the 3D model. This model is displayed to the user. When the user makes a gesture, it moves to the editable interaction module. The pose of the updated model is sent to the system module for future calculations, and the output of the AR model is sent to the user's device.

**The software required to develop the AR application**

AR application development is divided into software categories. All of these categories are combined to create an AR application.

1. 3D design software:

3D design can be seen as the first step towards creating an AR application. A virtual model is needed to bridge the gap between the real world and the virtual world. These models can be created using many applications, but here are a few applications preferred by most interior designers and 3D designers:

- Blender
- Autodesk Maya
- Autodesk AutoCAD
- Sketchup

2. AR functionals:

Do not use the AR interface, marker, cursor, or other AR functionals in the same way as the other devices. Do not place the device on an unstable surface or in an unstable position:

1. Vuforia SDK: Vuforia is a cross-platform software suite (SDK) for augmented reality (AR) and mixed reality (Mr) applications with robust control and performance on a variety of hardware, including mobile devices and Mr headsets such as Microsoft's Magic Leap and HoloLens. It uses built-in computer vision algorithms to find and track planes and 3D objects related to the real environment viewed by the device's AR camera. It supports 2D and 3D marker targets and has functionality for 'non-marker' targets and multi-tasking configurations. Additional features of the SDK include 6 degrees of device localization in space, run-time target image selection and the ability to programmatically create and reconfigure target sets at run-time. Vuforia provides application programming interfaces (APIs) in C++, Java, Objective-C++, and other languages through an extension to the Unity game engine. As such, the SDK supports native development for iOS, Android and the Universal Windows Platform (UWP), and allows AR applications to be built in unity that easily switch to both platforms, making it the most versatile AR-SDK on the market.

2. ARToolKit: ARToolKit is an open source computer monitoring library for developing AR applications. It uses computer vision algorithms to determine the connection between the real world and the virtual world. It can also determine the location of the user's device relative to a real world marker. It is one of the first AR development libraries. The current version of ARToolKit supports Microsoft Windows, Mac OS X, Linux, iOS and Android platforms.

3.Wikitude: Wikitude is a mobile AR company whose main product is the Wikitude SDK. It is a development platform that uses video recognition and tracking technologies as well as geolocation. The SDK includes various features such as image recognition and tracking, video overlay, 3D model mapping and location-based AR. It also features SLAM technology, which provides object recognition and tracking, as well as markerless, real-time tracking. The cross-platform SDK is available for Android, iOS and Windows operating systems. It is also optimised for multiple smart glasses devices.

4. ARCore: ARCore is a software suite (SDK) developed by Google for Android devices that enables the creation of augmented reality applications. Virtual content is displayed in the real world as seen through the device's camera using a display using three core technologies:

- The phone can understand and control its state in relation to its surroundings using six degrees of freedom. This means that the device can move freely in three-dimensional space.
- Understanding the environment enables the phone to determine the size and location of flat horizontal surfaces, such as the ground or a table.
- illuminance estimation helps the phone estimate the current lighting conditions of the environment.

5. AR Kit: ARKit is an augmented reality (AR) analogue for Apple iOS devices. It uses technology known as visual inertial odometry to track the world around your iPad or iPhone. This will allow your iOS

device to determine how it moves around the room. It also uses this data to analyse the layout of the room, as well as identifying horizontal planes such as tables and floors. Can install any iPhone or iPad Market app that can run on iOS 11 or later. Newer devices process apps better because they calculate and visualise faster.

1. Realistic display of content

The augmented reality approach to merging real and virtual worlds is that CAD makes content more realistic than a 2D visualised image. This makes the virtual object feel like objects from the real world. For example, an interior designer can use an app to upload their models and organise them much more easily, because the app uses an interaction module for smoother gesture control than CAD software. This development of the interior gives a more complete view of the appearance of the completed interior.

2. Deep immersion and acceptance of depth

Conventional interior design methods mostly involve a 2D visualised image with a steady posture. This provides limited depth perception and very little immersion, leaving most of the work to your imagination. In contrast, an AR system provides a higher level of immersion and depth perception as the user can move around the environment. This means that the interior is easier to imagine. The user can interact with the virtual object, which increases user satisfaction.

3. Optimised workflow

Augmented reality has the ability to optimise an interior designer's workflow by simplifying the design process, allowing them to be creative in their work, thereby consciously creating a design process. This provides the user with enhanced presentation capabilities that can lead to client satisfaction. A good workflow means less work when working with complex software.

1. AR systems are not ready for the market

Augmented reality is still an emerging industry with many applications, but few are aware of it outside of the mainstream technology field. It is still regarded by many as a gaming technology. The interior design industry has not fully moved on to AR because there is no high-quality AR CAD software that offers all the features of stable CAD software.

2. User interface:

Researchers and UI/UX developers are still trying to define a possible user interface for an AR application. AR systems are a completely new challenge for them, because they have to display the functionality of the system in such a way that it does not interfere with the user's immersion, and the user has to be able to explore the system easily. According to surveys, designers still choose typical CAD software because they are familiar with the user interface.

3. Hardware limitations:

Although the hardware for building an advanced AR system has improved considerably over the last decade, it is still not good enough for mass deployment. Modern hardware, although fast, is very complex and difficult to integrate into a high-performance working system. For example, HDs such as Microsoft and Magic Leap Hololens are revolutionary AR-head-mounted displays, but they are still not compact enough for public use. They are also very complex, creating a complex learning curve that defeats the purpose of moving from conventional CAD to AR-based CAD software.

**Conclusion**

Augmented reality has come a long way since Ivan Sutherland was first used on a head-mounted display called the Sword of Damocles in the 1960s, but there is still a long way to go to commercialise AR. The industry is growing rapidly and the number of jobs needed for an AR/MR developer has grown by 1400%. Many companies have already invested heavily in the technology, and they are all striving towards the goal of "getting to market first". Although most of them produce their own AR products, they are not enough to meet the needs of users. The interior design industry is slowly but steadily incorporating AR into its workflow.

Companies and designers are realising that convincing a customer with AR is much easier because they don't have to go to a physical shop and can actually contact the furniture. This greatly improves the customer's decision-making process, making it useful for the company and the designer. Revolutionising its capabilities in any field, AR can be considered one of the most important technologies of the future. One can assume that it is the next step towards mobile computing after the 'smartphone'. Thus, raising public awareness of AR is crucial to meet current challenges.

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