Indoor Navigation System Using Augmented Reality Technology at the Technical University of Cluj-Napoca

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ABSTRACT
This paper presents an augmented reality application designed to enhance indoor navigation at the Technical University of Cluj-Napoca. The case study focuses on an indoor navigation system to assist students and visitors in navigating from one room to another within the 4th floor of the "M" building. Given the numerous classrooms in the faculty building on Muncii Boulevard, navigating without prior knowledge of the layout was time-consuming. A 3D model of the 4th floor was created using Autodesk Revit and exported into Unity to integrate seamlessly into an augmented reality (AR) application. The AR application was developed using Unity along with the "AT+Sync | Synchronize with Unity," "AT+Sync v2 | Synchronize from Revit," and "AT+Explore | Interactive Archviz" plugins. This application allows students and visitors to navigate more efficiently within the Technical University of Cluj- Napoca and can be easily adapted for use in other buildings. By leveraging the versatility of these tools, the application not only improves way finding but also has the potential to enhance overall user experience, reduce stress associated with finding rooms, and increase the accessibility of university facilities for newcomers and guests.

Author Keywords
Augmented reality; unity; indoor navigation; computer- aided design;

ACM Classification Keywords
CCS - Human-centered computing - Human computer interaction (HCI) - Interactive systems and tools

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INTRODUCTION
Augmented Reality (AR) is an emerging technology that superimposes digital information into a user's environment based in real time. Rather than creating a totally new artificial environment like Virtual Reality (VR) does, AR adds to the existing real-world environment through sight, sound, and more. AR apps are created using a special 3D program that allows the developer to "attach" various animations or contextual digital information to an image or object. When the AR app recognizes a known marker (such as a particular picture in a magazine), it enables the corresponding code to run and then places the images in the real environment we see through the screen. This combination enhances the user's experience in which real and virtual elements are present and can interact with each other in real time.

Creating an AR application requires expertise in advanced 3D modeling and programming. Application developers use these AR tools to make the technology synchronize with the real-world environment, then interact with digital content— such as animations, images, and videos—to the real world. These markers they attach with AR models vary according to the applications. Some applications may use QR codes but others may use specific physical objects that the AR application recognizes.

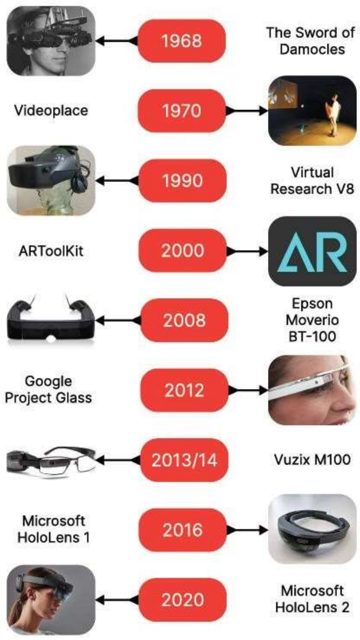


Figure 1. AR Devices and Technologies Evolution

As new AR applications are developed, AR poses the potential to change the way people interact with the world around them. In the future, more sophisticated AR applications may offer even more immersive and intuitive experiences. As hardware and software get more sophisticated, AR applications are becoming more powerful and easier to use. So, we can create the most beautiful live environment around us.

From Figure 1. the most important technological milestones were the ARToolKit, developed early in the 2000s, and the Google Project Glass developed as early as 2008. Both these 2 milestones made the development of augmented reality (AR) devices, technologies and applications, easier.

STATE OF ART AUGMENTED REALITY NAVIGATION APPLICATIONS

Nowadays, the augmented reality technology is used in a large variety of domains. Some of the domains in which this technology is used are the following: Automotive Navigation, Hospital Navigation, Tourism and even Airport Navigation.

MBUX represents a cutting-edge automotive navigation system developed by Mercedes-Benz. It stands as one of the most successful implementations of augmented reality in navigation. Integrated directly into the car's onboard computer, MBUX overlays detailed navigation instructions and real-time traffic data onto a video feed from all onboard cameras. This innovative feature allows users to view pertinent details such as house numbers, street names, and traffic light status, resulting in more efficient and expedient navigation experiences [3].

Hospitals are typically organized into numerous departments or sections, spanning multiple floors or confined to a single level. Navigating these complex layouts can pose a significant challenge for visitors and patients alike. Utilizing applications designed for this purpose can greatly streamline the process, allowing users to efficiently locate specific departments and, where applicable, navigate directly to a physician's office. This not only enhances convenience but also improves overall efficiency, ensuring quicker access to necessary healthcare services within hospital settings [1].

Google Live View is a smartphone application designed to provide users with a simpler and faster way to navigate within a specific area, offering the ability to identify various landmarks nearby such as restaurants, museums, and more. This application leverages information from Google Maps to accurately position the user and display landmarks with precision. Additionally, Google Live View enables users to share their location with others, enhancing both navigation and social interaction capabilities. This innovative tool not only enhances convenience but also facilitates seamless exploration and sharing of real-world locations [4].

Today's international airports are vast, sprawling structures covering extensive areas, sometimes spanning several square kilometers. Navigating to a specific boarding gate or other amenities such as shops or restrooms can be time- consuming. However, this process can be significantly streamlined using an indoor navigation application powered by augmented reality technology. Such applications enhance efficiency by providing real-time guidance and overlaying digital information onto the user's surroundings, thereby reducing travel time and improving overall airport experience [2].

AUGMENTED REALITY NAVIGATION SYSTEM

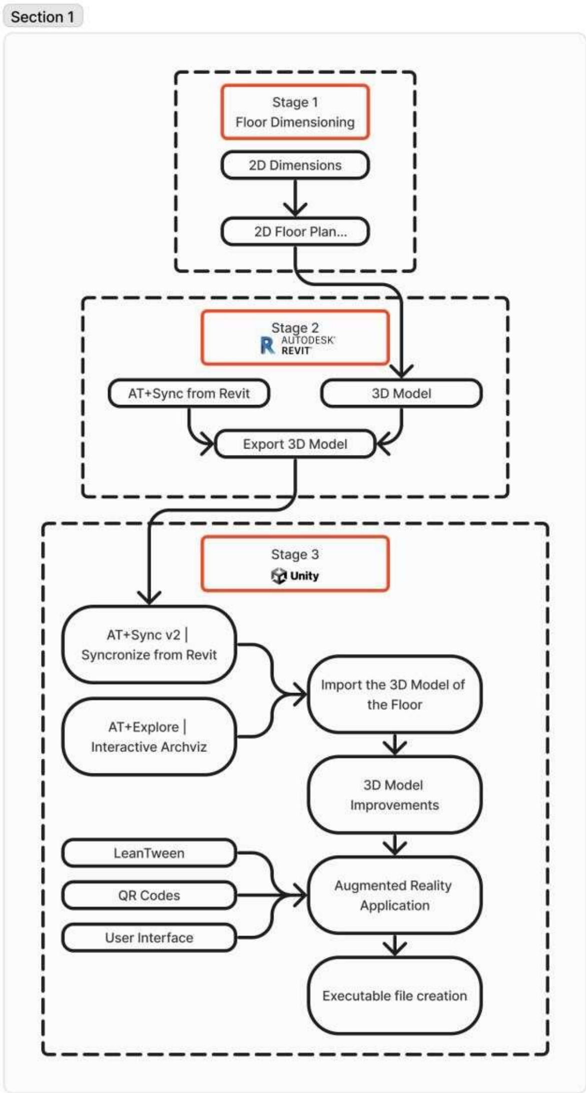


Figure 2. Development Stages

Determining and creating the Floor Plan

The first step in creating this augmented reality application involved building the 3D model, or more simply put, creating the digital map. To facilitate this process, we opted for the most effective approach, despite its time-consuming nature, which involved physically measuring the space designated for these applications. An alternative method would have been 3D scanning using terrestrial scanners, but we determined this to be significantly less efficient in terms of time compared to the former method. With 3D scanning, the time required to extract dimensions for each wall and door so they could be seamlessly integrated into Revit was considerably longer than physically measuring the workspace.

Considering that this application is intended to guide users from one point to a specific room, the exact interior dimensions of each room are not critical. The most crucial dimensions are the length and width of the main corridor and the precise locations of each door.

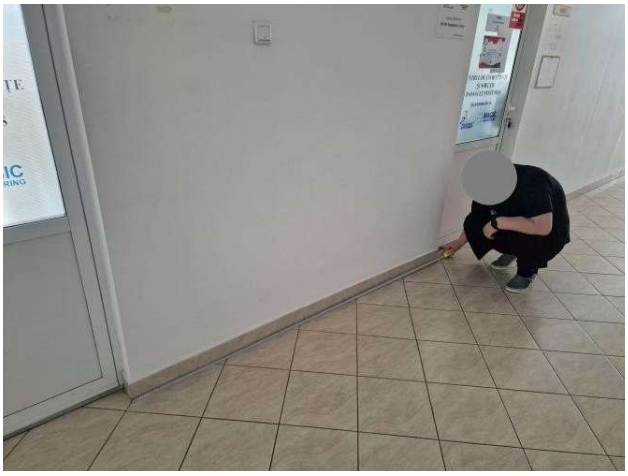


Figure 3. Determining the Floor Plan

Creating the 3D Model in Autodesk Revit

The next step in creating the digital map involved inputting the measurement data into Autodesk Revit 2021 to generate the 3D model of the space.

Autodesk Revit is specialized software developed by Autodesk for Building Information Modeling (BIM). It encompasses tools tailored for architecture, structural engineering, MEP (Mechanical, Electrical, Plumbing), and project execution phases, aiming to deliver high-quality building and infrastructure designs.

The version utilized for this project is Autodesk Revit 2021, chosen for its advanced features, including a specialized module that enables direct export of the 3D model into Unity and real-time synchronization.

Considering the space designated for this application is the 4th floor of the "M" building, the highest floor, the wall height is not crucial. However, to create a realistic model of the space, a wall height of 4 meters was deemed appropriate.

Room	Width [m]	Height [m]
M401	1.760	2.450
M402	0.885	2.450
M403	0.865	2.450
Virtual Reality Laboratory	0.885	2.450
M404	0.870	2.450
M405 – door 1	0.870	2.450
M405 – door 2	0.870	2.450
M406	0.885	2.450
M409	0.865	2.450
M410	0.870	2.450
M411	0.875	2.450

Table 1. The dimension of each door

To determine the center of each door, the simplest approach was creating a sketch using AutoCAD 2023, another Autodesk program. AutoCAD is a Computer-Aided Design (CAD) software utilized for 2D drafting and design, providing effective tools for precise detailing and layout planning.

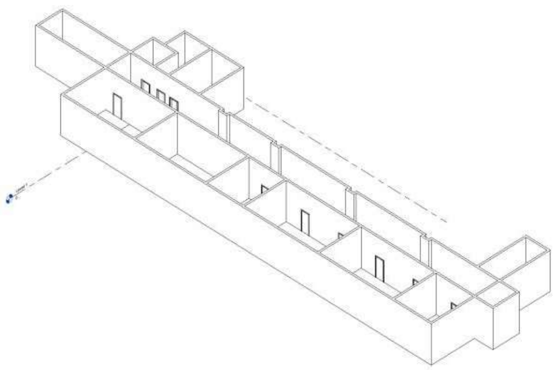


Figure 4. 3D Model of the entire floor

In Figure 5. we can observe the final 3D model of the 4th floor from the “M” building.

Exporting the 3D Model into Unity

The final step in preparing a Revit 3D model for export to Unity and Blender involves ensuring compatibility and synchronization between these platforms. Revit offers a straightforward method for exporting models in the .fbx format, which is universally supported by both Unity and Blender.

To facilitate seamless synchronization between Revit and Unity, it's essential to install a specialized plugin in both software environments. In Revit, the recommended plugin for this purpose is "AT+Sync | Synchronize with Unity," which is conveniently available on the Autodesk App Store. This plugin, developed by Ambiens VR, enables the export and synchronization of Revit projects directly into Unity scenes.

By utilizing the "AT+Sync | Synchronize with Unity" plugin, users can maintain consistency and efficiency throughout the workflow. This integration ensures that any updates made to the Revit model are accurately reflected in the Unity environment, streamlining the process of visualizing and interacting with architectural designs within Unity's interactive 3D environment.

In summary, leveraging the .fbx export format and the "AT+Sync | Synchronize with Unity" plugin facilitates a smooth transition from Revit to both Unity and Blender, enhancing the workflow for architectural visualization and interactive design purposes.

Figure 5. "AT+Sync | Synchronize with Unity" Plugin [5]

Unity Application

Developed by Unity Technologies in 2005, Unity is a game engine software primarily used for creating various types of applications across different platforms, including PCs, consoles, and mobile devices [6].

Unity features a platform called the Unity Asset Store, which allows developers to publish their assets and packages, either for a fee or for free, depending on their preference.

To simplify the development of the augmented reality navigation application, I decided to use some pre-made assets and packages from the Unity Asset Store.

"AT+Sync v2 | Synchronize from Revit" is an asset created by Ambiens VR that enables the synchronization and export of Revit projects into Unity scenes. For it to work, the Unity project must include this asset, and the Revit project must include the complementary asset, "AT+Sync | Synchronize with Unity."

"AT+Explore | Interactive Archviz" is another asset by Ambiens VR. This asset allows developers to easily convert existing projects into AR or VR applications for different platforms. Depending on the chosen platform and project type, this asset provides developers with various special functions, such as adding different types of interactions or modifying the scene to prepare for creating the executable.

Thanks to the "AT+Sync | Synchronize with Unity" plugin for Revit and "AT+Sync v2 | Synchronize from Revit" for Unity, the 3D Model of the entire floor could be very easily "transferred" from one program to another. Due to the fact that these two plugins will allow the real-time synchronization between Revit and Unity, we are able to modify the 3D model in Unity and it will change itself in real-time in Unity.

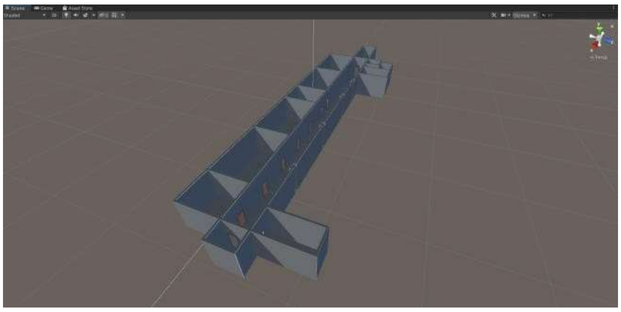
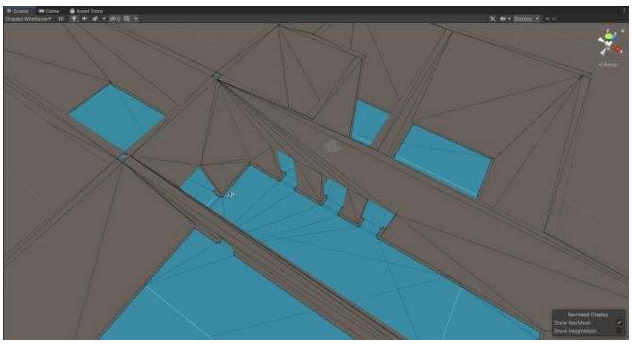


Figure 6. 3D Model of the floor in Unity

To ensure the optimal functionality of the application, the user should not see the 3D model imported from Revit while using the app. To achieve this, we can modify the material of the walls and the floor to make it transparent. Initially, we considered using an existing material from the database of any Unity project. However, during testing, we noticed that the walls and floor became transparent from any viewing angle. What we needed was a material that was transparent but could still block the view of objects positioned behind it.

The next step was to determine the navigation method. The chosen option was to create guiding "arrows" that connect the user's current position to the selected destination. The program will automatically calculate the shortest and fastest route to the chosen destination and place a series of arrows on the user's screen to guide them there. The calculated route will update in real-time, allowing the user to deviate from the initial path while still being directed to the selected destination.

After creating the navigation method, the next step was to define the area within which the user can move. This area, called the "play zone," is necessary to prevent scenarios where the user might "walk" through walls. Additionally, when this play zone is created, certain rooms can be excluded from it, ensuring the user does not have access to them. In this stage, a central point will be



placed in each room, representing the destinations the user can choose.
To ensure the application functions optimally, it was necessary to create special code that would allow the user to navigate the fourth floor as accurately as possible. Due to the reduced number of rooms found on the 4th floor of the “M” building and in order to reduce the number of bugs found in the “Testing” application, we decided that a single QR code placed near the entrance to this floor, was sufficient. The first step in creating this code was generating the QR code. To integrate the QR code image into the application, we had to create a library containing the images that could be scanned. In our case, the library created had a single element, "element 0," which contains the QR code image.

To ensure accurate navigation, it was necessary to create a function that runs continuously. The function, named "NavigationManagerIndoor," ensures the correct calculation of the shortest route from the user's position to the chosen destination in real-time. Within this function, the program checks if the user has selected a destination from the application menu and then displays the shortest route to the chosen destination, represented by a series of guiding arrows.

The User Interface

To create a visually appealing application, we decided to implement a User Interface (UI) component. The UI was developed in Unity using elements from the "Canvas" section, such as buttons, panels, text, and images. The first and possibly most important step in developing the UI was selecting the color palette to be used in the application. The application needs to be visually pleasing, so we decided to use only the selected colors.

Figure 7. The created "Play zone"

```
void Start()
{
    path = new NavMeshPath();
    elapsed = 0.0f;

    this.TargetLocations = new List<Transform>();
    foreach (Transform c in this.targetLocationParent)
    {
        //Debug.Log(c);
        if (c != this.targetLocationParent)
        {
            this.TargetLocations.Add(c);
        }
    }

    /*if (startingPoint != null)
    {
        Debug.Log("Starting Point created");
    }
    */

    ArchToolkitManager.Instance.OnVisitorCreated += this.OnVisitorCreated;
}

private void OnVisitorCreated()
{
    //Debug.Log("VisitorCreated");
    this.startingPoint = ArchToolkitManager.Instance.visitor.Head.transform;

    foreach (var t in this.TargetLocations)
    {
        var b = GameObject.Instantiate(buttonsPrefab, buttonsParent);
        b.GetComponentInChildren<TextMeshProUGUI>().text = t.gameObject.name;
        b.GetComponent<Button>().onClick.AddListener(() => { this.NavigateTo(t); });

        //Debug.Log(t);
    }
}
```

Figure 8. "NavigationManagerIndoor" function

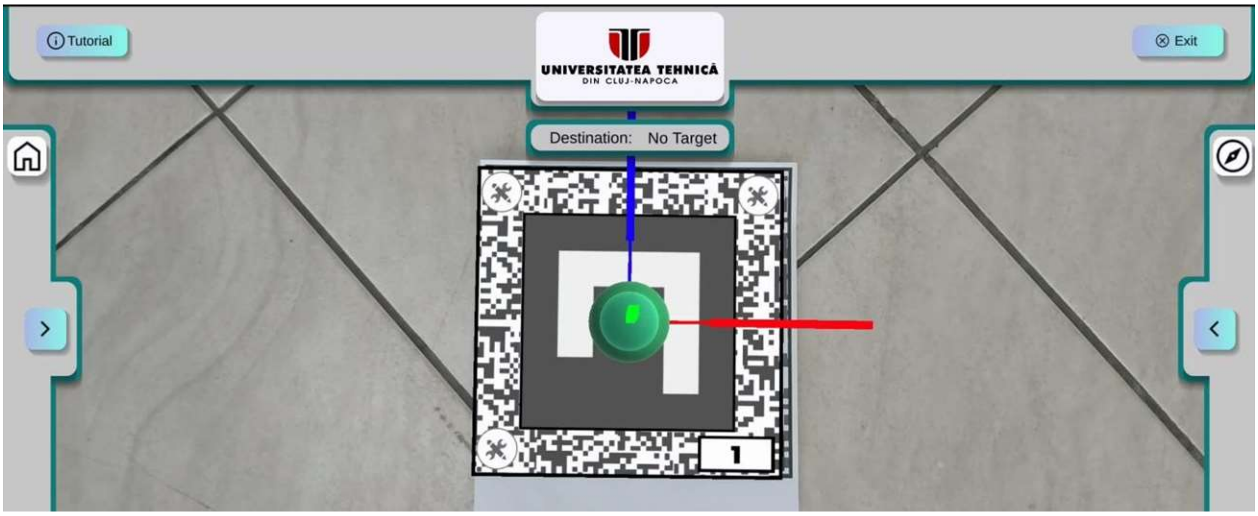


Figure 9. The QR Code

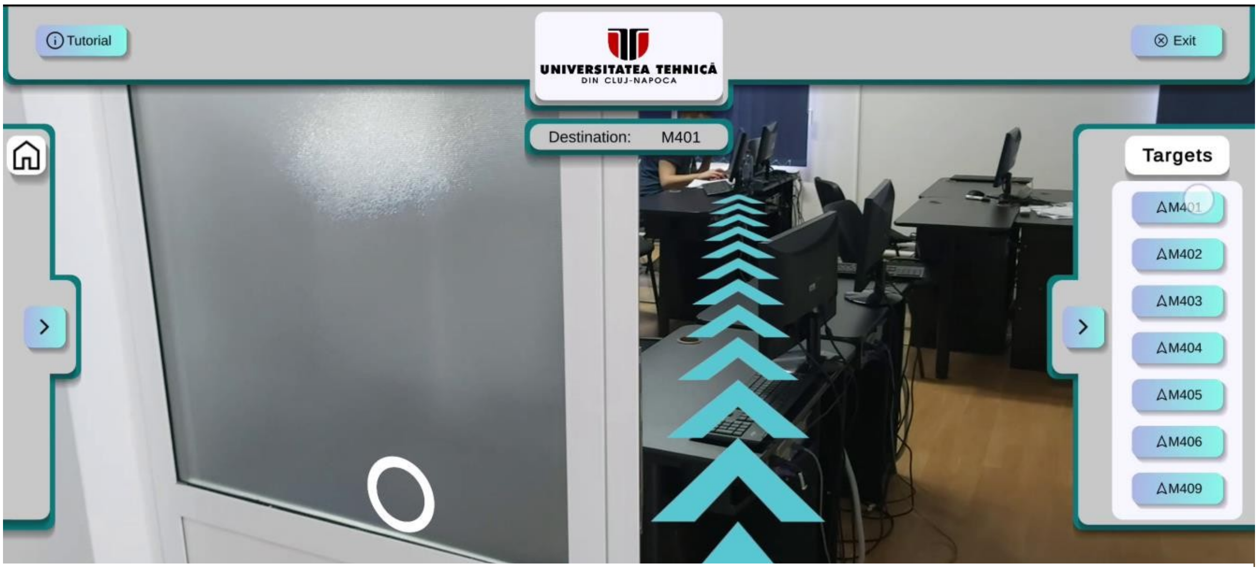


Figure 10. The User Interface

The selected colors are the following

- “Teal” – HEX code: 0E7C7B;
- “Verdigris” – HEX code: 17BEBB;
- “Chili red” – HEX code: E3170A;
- “Ghost white” – HEX code: F7F7FF;
- “Silver” – HEX code: C8C8C8;

In Figure 10, we can see the final result of the User Interface. On the left side, there is the “LeftPanel” zone, which contains three buttons: “2D Scheme,” “3D View,” and “Info”:

- The “2D Scheme” button displays a 2D layout of the 4th floor of the “M” building, including the names and positions of each room;
- The “3D View” button provides a 3D rendering of the exterior of the “M” building, with the 4th floor shown in a transparent view. This rendering was created using Blender and the “3D View: BlenderGIS” add-on, which connects to satellite data from Google Earth;
- The “Info” button presents a detailed list of each classroom, including the floor it is on and, in some cases, the names of the professors associated with it;

On the right side, there is the “RightPanel” zone, where the user can select their desired destination.
The upper section of the User Interface is called the “UpPanel.” This zone contains two buttons: “Tutorial” and “Exit”:

- The “Tutorial” button displays a step-by-step video guide on how to use the application;
- The “Exit” button closes the application;

Additionally, in the center of the “UpPanel,” the user can see the selected destination if one has been chosen; otherwise, the text “No Target” will be displayed.

The executable file

Because we used the two assets created by Ambiens VR, "AT+Sync v2 | Synchronize from Revit" and "AT+Explore | Interactive Archviz," the process of creating the application's executable was very easy.

The application was primarily developed for devices running the "Android" operating system. This was mainly due to the need for continuous testing to ensure a minimal number of bugs and an excellent user experience, as our primary device operates on "Android." Additionally, when creating the application's executable file, we had to select the type of application, which in our case, is an "AR" (Augmented Reality) application.

Even though the application was developed for Android devices, creating an executable file that allows the application to run on iOS devices requires only a few modifications. Thanks to the "AT+Explore | Interactive Archviz" asset, these modifications are just a click away.

This application is almost ready to be published on the "Google Play Store," which will allow students from the Faculty of Industrial Engineering, Robotics, and Production Management at the Technical University of Cluj-Napoca, as well as visitors, to use this application and reduce the transit time between two rooms.

Developing the application with a focus on Android ensured thorough testing and optimization, enhancing its reliability. The ability to easily adapt it for iOS broadens its accessibility, making it versatile and user-friendly across different platforms. The upcoming publication on the Google Play Store signifies a significant step towards providing a practical tool for both students and visitors, improving their navigation experience within the university.

CONCLUSION

In conclusion, this project has been an incredible opportunity for us to create an application using augmented reality technology. We're thrilled to say that the app is almost ready to be published on the Google Play Store, where it will join the vast collection of Android applications. Once it's out there, it will provide students with a modern, efficient way to navigate the Faculty of Industrial Engineering, Robotics, and Production Management at the Technical University of Cluj-Napoca (UTCN).

At the start of this project, we had so many ideas about what the app could look like, what it could do, and what challenges we might face. Our brainstorming sessions were filled with creativity and excitement, with each idea aiming to make the app as useful and user-friendly as possible. Thanks to our extensive experience in developing a variety of applications, from simple mobile apps to complex augmented reality and virtual reality projects, we were well-prepared for the development phase. This background helped us anticipate potential challenges and find effective solutions quickly.

To make sure the app works perfectly, we rigorously tested all its elements and features on different devices, each running various versions of the Android operating system. This thorough testing process was essential for identifying and fixing any issues, ensuring the app performs smoothly across all platforms and devices. Our goal was to create a dependable tool that users can rely on, no matter what device they have.

While we've achieved the main goals of the project, we know there's still plenty of room for improvement. We see many opportunities to enhance the app's functionality, 3D modeling, interactive "game zone," and user interface. Each of these areas can help us elevate the overall performance and user experience of the app. Our next step before publishing is to form a test group to gather feedback and make the necessary adjustments. This feedback will be invaluable in fine-tuning the app and ensuring it meets the highest standards of usability and performance.

Overall, this project has been an invaluable learning experience for our team. It has pushed us to apply our academic knowledge in practical and creative ways, resulting in an innovative tool that will greatly benefit students and visitors by improving their navigation experience within the university. As we move forward, continuous testing, feedback, and iterative improvements will be key to delivering a polished and effective final product. We're excited about the app's potential impact and are committed to enhancing its features to provide an exceptional user experience.

ACKNOWLEDGMENTS

We would like to extend our heartfelt gratitude to all the students and faculty members who have assisted in testing this application and provided us with invaluable feedback. Your contributions have been instrumental in refining and improving the application, ensuring it meets the highest standards of functionality and user experience.

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