

EMBRACING DIVERSITY: AUGMENTED REALITY APPLICATION FOR INCLUSIVE UNIVERSITY CAMPUS NAVIGATION

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Abstract

This academic paper explores the potential of Augmented Reality (AR) technology in enhancing university campus navigation experiences, focusing on catering to the needs of students with autism spectrum disorder (ASD). We address the limitations of traditional campus navigation methods and introduce AR as a promising solution. We consider that the mission of a future-oriented university is to enable and facilitate access to higher education and advanced research opportunities focusing on becoming more inclusive. Throughout the literature review, we delve into the interactive nature of AR, its multisensory capabilities, and the importance of spatial registration. We also highlight the complexity of AR system architecture, emphasizing the role of hardware and software components, rendering engines, and tracking algorithms. The paper then explores the utility of AR in campus navigation, highlighting its potential to improve spatial awareness and enrich educational experiences. The methodology section outlines the research objectives, including understanding the adoption of AR in universities for orientation, exploring AR technologies and platforms, and defining critical characteristics of an AR application. Within the results and discussion section, we present findings related to the use of AR applications for campus navigation in future-oriented universities. While specific university-based implementations are limited, pioneers like MIT, Stanford, and Harvard will be watched for their potential adoption of AR technology as a core stream of their long-term academic leadership strategy. To argue their positive impact, we focused on exploring technologies and platforms for developing AR applications, encompassing modeling and computer vision, geospatial technologies, sensor technologies, machine learning, cloud computing, network technologies, and frameworks. Within the section dedicated to developing AR applications for students with ASD, we emphasize stakeholder engagement, technological selection, application development, user feedback, and continuous improvement. The paper concludes by proposing a sequence diagram illustrating the interaction between parties involved in developing and using an AR campus navigation application.

Keywords

Academic leadership strategy; application; Augmented Reality (AR); autism spectrum disorder (ASD); campus navigation; future-oriented university; students.

Introduction

Due to global evolution, universities must adjust to emerging technologies and incorporate them into their educational and research methodologies (Bejinaru & Prelipcean, 2017). Navigating expansive university campuses can be a challenging experience, particularly for newcomers, international students, or those with accessibility needs. Traditional methods of campus navigation—like static maps, signages, and GPS-based mobile applications—often fall short of offering a comprehensive, interactive, and inclusive navigation solution (Liao et al., 2015).

Augmented Reality (AR)-based campus navigation systems have the potential to fill this gap by providing interactive, context-sensitive, and real-time orientation assistance. By superimposing directions, annotations, and other relevant information directly over the physical world, AR applications can create a more intuitive and engaging navigation experience. Furthermore, these systems can be customized to cater to diverse user needs, offering features like voice guidance for visually impaired users or sign language avatars for those who are hearing-impaired.

Augmented Reality is an interactive paradigm where digital elements are superimposed onto the real world, thereby boosting the user's perception and interaction with their environment (Milgram & Kishino, 1994). AR differs from Virtual Reality (VR) in that it does not create an entirely simulated environment but integrates digital information with the existing environment in real time (Billinghurst & Kato, 2002). Using a variety of technologies, including computer vision algorithms, machine learning, and sensor data, AR applications have been developed for diverse domains like healthcare, industrial maintenance, education, business administration, and others (Bejinaru, 2019). From a technical perspective, AR systems often consist of multiple components: a camera for capturing the real-world environment, a display mechanism (which can range from smartphone screens to AR glasses), tracking systems for spatial and object recognition, and a computational backend for data processing (Carmigniani et al., 2011; Wagner & Schmalstieg, 2007). These systems may use various tracking technologies such as marker-based, markerless, and simultaneous localization and mapping (SLAM) to place virtual objects precisely in the real world.

Literature review

The essence of Augmented Reality lies in its real-time interaction capabilities, allowing a seamless blend of computer-generated information with the physical world. This dynamism in the interaction is not just a technological marvel but also a fundamental shift in how we perceive and interact with digital data (Azuma et al., 2001). It challenges the passivity of traditional interfaces by engaging users directly with contextual information. Unlike many other digital technologies that isolate the user from the physical environment, AR thrives on context-awareness. The system actively uses sensorial data—captured through accelerometers, gyroscopes, and GPS—to adapt and provide relevant information, making each AR experience highly personalized

(Kretzenbacher et al., 2020). Besides the significant benefits, future-oriented universities must carefully plan and invest in the technology, considering both its short-term benefits and long-term viability to ensure its sustainability (Neamtu et al., 2020).

While most people attribute AR to visual overlays, it's worth noting that it is not restricted to the visual modality. AR can offer a multisensory experience that can also include audio and haptic feedback (Steinicke et al., 2010). This multi-modal approach opens up numerous opportunities for more immersive and engaging interactions. The concept of spatial registration is another cornerstone of AR systems. This involves the accurate alignment of virtual and physical elements, which ensures that the digital overlays are correctly positioned relative to real-world objects (Klein & Murray, 2009).

On the technical side, the system architecture of AR can be quite complex. Hardware and software components work together to create this immersive experience. The hardware often comprises various sensors for tracking movement and orientation, display devices ranging from smartphones to specialized AR glasses, and cameras for capturing real-world data (Carmigniani et al., 2011; Lee & Tuceryan, 2004). From a software perspective, the rendering engine is crucial in creating the virtual elements. Frameworks and platforms such as ARCore, ARKit, Unity3D, and Unreal Engine are widely used to develop AR applications. Additionally, sophisticated tracking algorithms, such as Simultaneous Localization and Mapping (SLAM), are employed for real-time location and orientation tracking (Klein & Murray, 2009).

Using augmented reality for campus navigation

The utility of augmented reality in navigating new spaces, particularly in the context of university campuses, represents an innovative intersection of spatial cognition, human-computer interaction, and educational technology. One of the most significant advantages of employing AR in university campus navigation is the augmentation of spatial awareness. AR can facilitate the internalization of spatial relationships by overlaying digital information, such as directional arrows or point-of-interest markers, directly onto the real world. This real-time augmentation alleviates the cognitive load involved in spatial reasoning (Sweller, 2011), thus aiding the user in quickly becoming familiar with unfamiliar spaces. Beyond navigation, the AR system can serve educational goals by contextualizing information relevant to specific campus locations. For instance, when a user approaches a science building, the application could display historical facts, ongoing research projects, and other educational material (Dunleavy et al., 2009). This enhanced engagement enriches the user's experience and contributes to a deeper learning outcome, incorporating elements of situated learning theory (Lave & Wenger, 1991).

Campus navigation applications for students with autism spectrum disorders (ASD)

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder characterized by deficits in social communication and interaction alongside restricted, repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). The term "spectrum" is used to denote the wide range of symptoms and individual differences in severity and functioning that can occur in individuals

with ASD (Baio et al., 2018). While significant challenges characterize ASD, it is noteworthy that individuals with ASD may also exhibit remarkable strengths such as enhanced perceptual skills and attention to detail (Mottron, Dawson, & Soulières, 2009).

Augmented Reality has a significant potential for creating more inclusive educational environments, especially for students with autism spectrum disorder. Campus navigation is a critical stage of university life that can be overwhelming for many students, and even more so for those with ASD, who may face challenges with social interaction, spatial navigation, and coping with new routines (Kasari et al., 2019). Integrating AR technology into campus orientation activities for ASD students could create a tailored experience that better suits their individual needs (Escobedo et al., 2012).

One of the critical elements in AR applications for ASD students is the adaptability of the user interface. These applications must be highly customizable, allowing for adjustments such as simplifying visual elements or modifying audio prompts. This conforms with Universal Design for Learning (UDL) principles and can accommodate the sensory sensitivities often associated with ASD (Rose et al., 2006). Students with ASD can also benefit significantly from AR applications' immediate feedback. Real-time tracking and feedback mechanisms are integrated within the applications to adjust the orientation process dynamically according to the students' immediate needs (Zhou et al., 2018). When triggered, AR delivers clues ranging from simple, unimodal cues, such as visual markers indicating directions, to more complex multi-modal cues incorporating sound and haptic feedback. Based on the tenets of Applied Behavioral Analysis (ABA), AR can deliver conditioned stimuli at regular intervals to elicit desired behavioral responses, such as maintaining a certain walking pace or staying within demarcated safe zones on the campus. While campus navigation is the primary goal, these AR applications can also promote the development of other cognitive skills, such as spatial awareness and problem-solving. Cognitive load theory suggests these additional skills can be incrementally integrated without overwhelming the user (Sweller, 2011).

Methodology

To be able to future develop an augmented reality application for navigation in new spaces by students with autism but also by those with normal development, we proposed the following objectives:

- O1. To understand the level of adoption of augmented reality by future-oriented universities for navigation in new spaces and how the problem of students with autism is approached.
- O2. To study the main technologies and platforms available for developing an augmented reality application.
- O3. To establish the key characteristics that the application must have.

Considering that each university has certain peculiarities regarding the location of buildings, access roads, and other campus objectives, the following research questions were formulated to fulfill the mentioned objectives:

- RQ1. How do universities implement campus navigation solutions based on augmented reality?

- RQ2. What technologies and platforms are available to develop augmented reality applications for campus navigation?
- RQ3. What should be considered for developing an augmented reality application for campus navigation for students with autism spectrum disorder?

Results and discussion

- Objective 1: The use of augmented reality applications by universities for campus navigation

Going through the scientific literature, it can be stated that AR applications have proliferated for the broader student demographic. However, information on specific universities using such applications is relatively scant. However, various universities have been at the forefront of incorporating AR technology to foster a more inclusive educational environment. Universities such as MIT, Stanford, and Harvard have been pioneers in adopting AR and VR technologies in education, and it wouldn't be far-fetched to anticipate the inclusion of features accommodating the needs of students with ASD in their AR-oriented initiatives in the near future, given their history of innovation and inclusivity (Papagiannis, 2017). Moreover, there has been a broader interest in the potential applications of AR technology for individuals with autism. For instance, researchers have been exploring how AR can be used to assist individuals with ASD in learning new skills and achieving greater independence (Kuriakose & Lahiri, 2015). In their research, the authors scrutinized how AR can enhance learning experiences and foster greater autonomy for individuals with ASD. Their pioneering work paves the way for universities globally to conceptualize and implement AR applications that address the unique needs of individuals with autism.

Future-oriented universities have a tradition of applying strategic university governance and took upon themselves the development of customized AR applications specifically tailored for their campuses (Lupan & Bejinaru, 2019). These applications generally offer features such as AR guided tours, interactive campus maps, and information pop-ups about different facilities on the campus. Although it is possible that some information is not publicly available and the applications are not entirely dedicated to orientation in new spaces, we found that some examples of notable universities and institutions where AR has been used or piloted for campus navigation or related applications are:

- *University of Arizona* – Developed an AR application that offers a 3D map visualization of the campus, information pop-ups about different facilities, and real-time event information.
- *Harvard University* – While not a fully-fledged AR campus tour, Harvard has utilized AR in various exhibitions and set-ups across the campus to offer enriched experiences.
- *MIT* (Massachusetts Institute of Technology) – Used AR in multiple projects, including campus tours that included AR-enhanced experiences of the facilities.
- *Stanford University* – Though it predominantly uses AR for research and academic purposes, AR has been used for campus navigations and tours, predominantly during exhibitions and special events.

- *University of Cambridge* – Has leveraged AR technology in public engagements and outreach programs, including interactive AR-enhanced maps of certain facilities.
- *Yale University* – Yale has employed AR in various exhibitions and public engagements, though detailed AR campus tours are yet to be instituted.
- *University of British Columbia* – Engaged in developing AR initiatives, including piloting AR-enhanced campus tours to facilitate better campus navigation and information dissemination.
- *University of Tokyo* – Involved in AR research projects and has employed AR in public engagements and tours, offering a glimpse into the campus's facilities through AR lenses.
- *ETH Zurich* – The university has employed AR in various projects, including offering AR-enhanced experiences during campus tours, particularly focused on architecture and facility demonstrations.
- Though not exclusively for campus navigation, there are applications developed to assist individuals with ASD in navigation and understanding space:
- *Autism2Ability*: This platform offers applications with visual support and AR technology to help students with ASD in various capacities, including understanding new environments that can be harnessed for navigating throughout the campus.
- *Wayfinding Project*: A specific endeavor undertaken by the University of Minnesota to assist individuals with ASD in navigating spaces using AR technology.

The landscape of AR applications tailored explicitly for campus navigation, including the needs of students with ASD, is still developing. Many existing solutions are general-purpose AR platforms that require substantial customization to meet the specific requirements of college campuses and the diverse needs of their students. This suggests that this field of research has significant potential for innovation and exploration. Given the trajectory of advancements in AR technology, it is plausible to anticipate a surge in universities incorporating AR applications in their campuses that are tailored to the needs of students with ASD, presenting an optimistic future.

- Objective 2: Technologies and platforms for developing augmented reality applications for campus navigation

Developing an augmented reality (AR) application for campus navigation involves using various technologies and platforms, including AR development frameworks, cloud computing platforms for backend support, and tools for creating 3D models and assets (Bejinaru & Balan, 2020). The following section breaks down the prominent technologies and platforms that can be leveraged to build a comprehensive AR application.

Technologies: Augmented reality platforms are usually used alongside a suite of advanced technologies that redefine the interaction between the digital and physical worlds. At the forefront are modeling and computer vision technologies like 3D reconstruction, which uses methods such as LiDAR (Light Detection and Ranging) and photogrammetry, and SLAM (Simultaneous Localization and Mapping), which facilitates the precise overlay of digital objects over the physical spaces. Geospatial technologies with GIS (Geographic Information Systems) integration providing

enhanced navigation experiences on campuses are complemented by GPS and Beacon technology for precise localization, especially indoors. The dynamism of AR is represented by a multitude of sensor technologies, including accelerometers, gyroscopes, and magnetometers, which are essential in detecting device movements and orientation, thus facilitating a more immersive AR experience. Machine and deep learning technologies amplify AR's capabilities in identifying and interpreting real-world objects and contexts. The scalability and performance of AR applications are based on cloud computing's ability to handle voluminous datasets and intricate computations. Network technologies, especially 5G and edge computing, ensure real-time AR interaction, guaranteeing faster data transmission and low latency. Collectively, these technologies stand as the basis for ensuring AR's seamless, immersive, and responsive experiences.

Platforms and software development kit (SDKs): Table 1 summarizes the most popular frameworks and SDK's for developing augmented reality applications. These platforms are at the forefront of AR development, offering a broad array of tools and functionalities to develop state-of-the-art AR applications for campus navigation. Leveraging these platforms can significantly enhance the campus orientation experience, offering students an engaging, tailored, and immersive introduction to the campus environment.

Table 1. AR Development Platforms and SDKs

(Source: Authors' own research results)

Platform	Description
Google ARCore	Enables developers to create AR applications for Android devices.
Apple ARKit	Enables developers to create AR applications for iOS devices
Vuforia Engine	A platform that provides an SDK for creating AR applications that use image recognition and tracking. It supports Android, iOS, Windows, Unity, and Unreal Engine.
Hololink	A web-based platform that enables the creation of AR through a visual no-code solution.
Unity	Cross-platform game engine for developing 2D and 3D games, simulations, and interactive experiences. It supports various platforms.
Unreal Engine	Game engine for developing high-quality games, simulations, and interactive experiences. It supports various platforms.
Wikitude	A platform that provides an SDK for creating AR applications that use image recognition and tracking. It supports various platforms like Android, iOS, Windows, Unity, and Unreal Engine.
8th Wall	A web-based platform that enables the creation of AR through a visual no-code solution. AR created in 8th Wall is served directly in the mobile browser without using an app.

- Objective 3: Developing AR applications for campus navigation for students with ASD

Developing an augmented reality application for campus navigation customized for students with autism spectrum disorder requires a multidisciplinary approach that intertwines computer science, psychology, education, and design knowledge. It is

crucial to adopt evidence-based practices to create an AR application that is effective and beneficial for students with ASD. The research identified nine steps necessary to develop such an application. Here, we outline some pivotal considerations and methodologies:

Identifying the goals and objectives: The initial phase begins with a nuanced understanding of the goals and objectives that the AR application aspires to achieve. At this point, it becomes essential to envision an app that can act as an inclusive tool, facilitating easy navigation and decipherable information about various campus facilities for students with ASD. A strong focus on these studies' sensory preferences and cognitive styles can influence the development of user-centric features.

Stakeholder engagement: As we move forward, stakeholder engagement emerges as a critical endeavor, where collaboration with students, including those with autism, faculty, and administrative personnel translates into valuable insights. Here, emphasis should be placed on creating a support system that encourages feedback and suggestions from autistic students, ensuring their unique perspectives are integrated into the app. This strategy promotes inclusivity and user-centered design (Bower et al., 2014).

Technological selection: The technological substrate forms the next layer, where choices made in selecting platforms and tools resonate with the aspirations of inclusivity. Leveraging platforms such as Unity for the overarching development and integrating AR functionalities through ARKit or ARCore stand as viable strategies. A focus here should be on technologies that enable the creation of features like simplified navigation and intuitive interfaces, which would cater specifically to students with ASD, facilitating their comfortable interaction with the app (Craig, 2013).

Content development: In the center of this developmental blueprint lies content creation and crafting of media elements and graphical overlays tailored to foster an enriching experience for all users, including those with ASD. The development team must infuse the content with an understanding of the cognitive and sensory preferences of autistic students, orchestrating an environment within the app that is both supportive and understanding of their needs (Wojciechowski & Cellary, 2013).

Application development: The technical blueprints emerge as tangible entities during the application development phase. Here, the developers use the power of programming languages and AR technologies to architect an app with rich features, responsive designs, and user-friendly interfaces. Essential in this stage is integrating ASD-friendly features, which could encompass simplified layouts, calming color schemes, and providing clear instructions to guide the students efficaciously. Furthermore, integrating the AR application with the existing campus infrastructure is a critical determinant in the system's successful implementation and operational fluidity.

Testing: A rigorous testing phase initiates to identify potential glitches as the structure receives its substantial form. „In this phase, the app undergoes several tests, potentially including usability testing with a diverse group of students, encompassing those with ASD. Tailored testing protocols for autistic students could be utilized to

ensure that the app caters to their unique needs effectively and sensitively (Dunleavy, Dede, & Mitchell, 2009).

User feedback and iterations: After the initial deployment in a controlled environment, it is prudent to foster a feedback-rich ecosystem where users, including those with ASD, can articulate their experiences and pinpoint areas necessitating refinement. The feedback should be meticulously analyzed for actionable insights, promoting a cyclical refinement process through various iterations.

Deployment: Following the iterative refinements based on holistic feedback, the deployment phase marks the inaugural launch of the application to the broader public. It would be pivotal to establish a support system, perhaps a helpline or a digital manual, to aid all students, including those with ASD, to adapt to the new technological improvement seamlessly. Engaging the university community in a comprehensive understanding of the app's functionalities would be a strategic move, ensuring smooth integration into the daily routines of all students (Bower et al., 2014).

Continuous improvement: After the deployment, the application enters a phase of dynamic evolution characterized by continuous improvements. Here, a sustained engagement with the user base, paying attention to the feedback received from the ASD community, can guide the trajectory of further developments. The constant concern on technological advancements and user preferences would need periodic updates, guaranteeing that the app remains a reliable, inclusive, and innovative tool in the educational landscape. Considering the data gathered to answer the research questions, we proposed a sequence diagram illustrating the functioning and interaction between the parties involved in developing and using an augmented reality campus navigation application (Figure 1).

Conclusions

The primary scope of this paper is to explore the potential of Augmented Reality (AR) technology in improving campus orientation experiences, with a particular emphasis on catering to the needs of students with autism spectrum disorder (ASD). We approached various aspects related to AR technology, its applications in campus navigation, and its relevance for students with ASD, and we reiterate the key findings: - Augmented Reality has significant potential in enhancing campus navigation experiences; -We documented the complexity of AR system architecture, including hardware components like cameras and displays, as well as software components like rendering engines and tracking algorithms; -AR is not limited to visual overlays and can offer a multisensory experience, including audio and haptic feedback particularly relevant for students with ASD; -Proper spatial registration ensures that digital overlays are correctly positioned relative to real-world objects.

We highlight the potential of AR technology in addressing the unique challenges faced by students with ASD during campus navigation. We emphasize the need for highly customizable interfaces, immediate feedback mechanisms, and features that accommodate sensory sensitivities. As part of our research, we outline a comprehensive methodology for developing AR applications for campus navigation. It includes steps such as stakeholder engagement, technological selection, content development, testing, user feedback, deployment, and continuous improvement. We

conclude that the field of AR applications for campus navigation, particularly for students with ASD, is still evolving. Many existing solutions are general-purpose and require customization for specific campuses. We stress the importance of user-centered design, adaptability, and continuous improvement in the development of AR applications. We suggest that universities and institutions increasingly recognize the value of AR technology in education and campus navigation.

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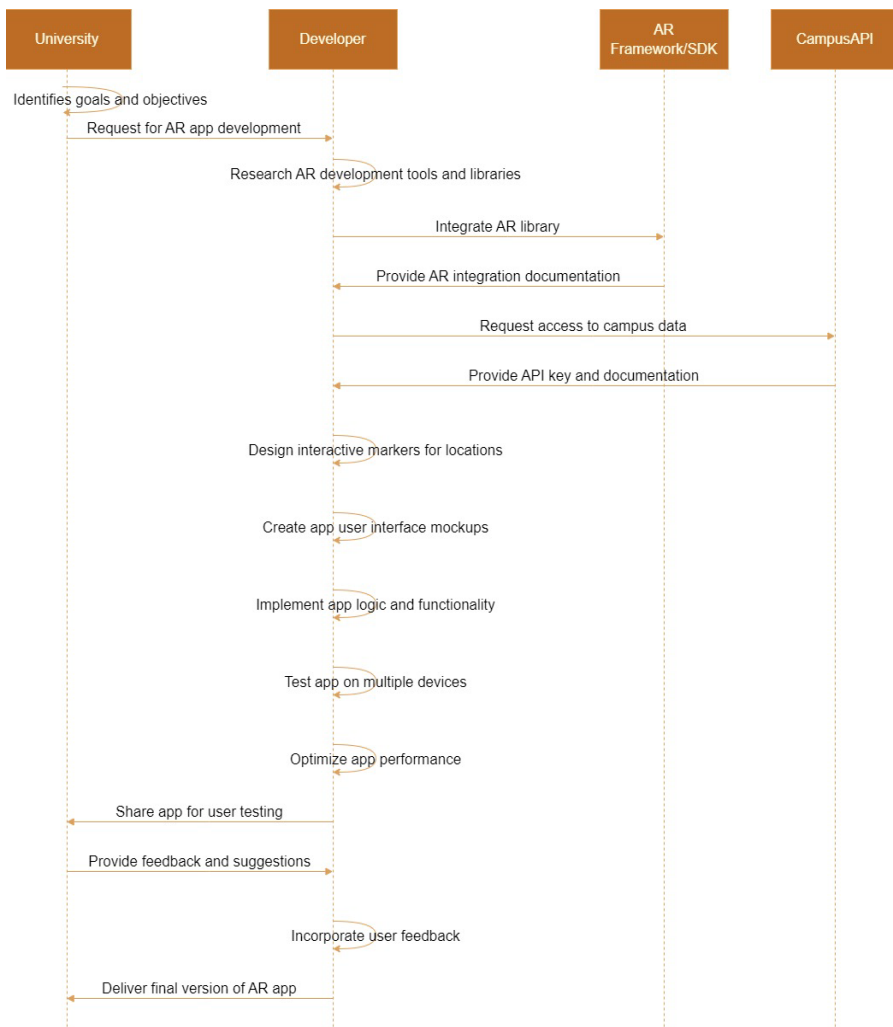


Figure 1. Augmented reality sequence diagram
(Source: Authors' own research results)

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