Journal of Advances in Management, Engineering and Science (JAMES)
Volume 01, Issue 01, March 2023

CHALLENGES AND OPPORTUNITIES INNOVATION IN MOBILE AUGMENTED REALITY SYSTEMS

Kakoli Banerjee
Associate Professor, Department of Computer Science and Engineering
JSS Academy of Technical Education,Noida, Utter Pradeesh, India
Email: kakolibanerjee80@gmail.com

Abstract: This paper provides a comprehensive overview of the current state of the art in Mobile Augmented Reality, including its technologies, systems, and applications. It details the efforts of numerous research groups, the motivations for developing new Augmented Reality systems, and the issues that have arisen when attempting to implement some of these applications. It provides a comprehensive look at the problems that can occur and the specifications that must be met by mobile augmented reality systems. This paper provides a concise summary of the existing uses for AR, as well as some speculation on its potential future uses and the directions in which current research may take its development. The widespread use of mobile and, in particular, wearable devices has led to the rise in popularity of augmented Reality (AR) apps for mobile platforms. Many MAR applications rely on computing complex computer vision algorithms with stringent latency requirements, but these devices often have limited hardware capabilities. Since these features are essential to the operation of any MAR application, we talk about recent developments in tracking and registration, as well as the necessity of the communication networks of the devices used to run MAR applications. We then move on to discuss the significance of managing data in MAR systems, as well as the performance and sustainability of these systems, and finally, we outline some of the most pressing issues currently facing the field. MAR applications shouldn't rely solely on the development of infrastructures because of the wide variety of wireless networks. Future challenges that we can foresee for augmented Reality are also discussed, along with the difficulties that have already been encountered in taking these applications from the lab to the industry.

Keywords: *Virtual Reality, Augmented Reality, Mobile Augmented Reality, mobile computing, human-computer interaction.*

1. INTRODUCTION

AR switching is network capacity and especially delay constrained, like many other real-time applications. If not managed properly, connecting to external services can quickly rack up massive costs. In this article, we discuss how to take advantage of communication channels to offload augmented reality computation to a remote machine, and we offer recommendations for the design and implementation of transport protocols to ensure that offloaded applications are able to meet the bandwidth and delay constraints of today's and tomorrow's networks.

Innovative and creative methods are used to engage customers with virtual products through the use of devices such as fixed window displays, projectors, wearable headsets, tablets, and smartphones. A greater sense of immersion in a product may be achieved by the use of media such as videos, GPS data, music, a variety of rich media, and product simulations. By enhancing product visualization and facilitating seamless communication between the user and virtual items, the augmented reality shopping experience boosts brand loyalty and, ultimately, sales. On the other hand, virtual reality (VR) technology uses a headset to isolate the user from their surroundings, allowing them to fully immerse themselves in a 3D virtual world where they can enjoy a novel and exciting retail experience. Users can physically move around in the virtual world and interact in real-time by using motion tracking to capture the movement of their limbs and heads. For virtual reality (VR) technology to be widely adopted, it is essential that users get both comfortable headsets and believable, immersing virtual effects. Virtual Reality (VR) is a type of interactive computer simulation that allows users to feel as if they are physically present in a simulated environment through the use of one or more of their senses to supplement or replace the input typically received from the real world.

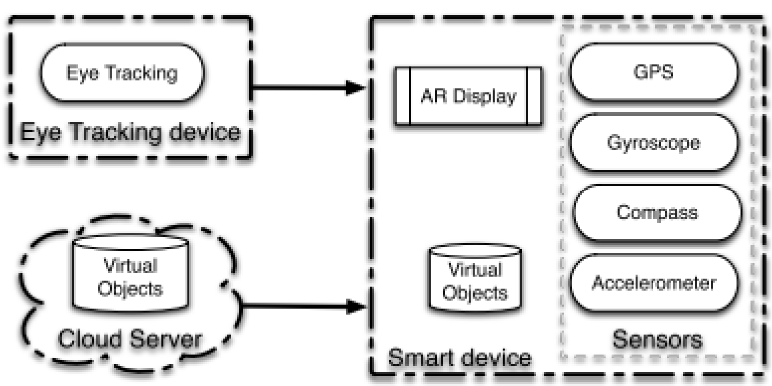

Figure 1. Architecture

1.2 Mobile Augmented Reality and Virtual Reality

• There are a number of different ways to characterize AR and VR. For the purposes of this article, we will use the following definitions of VR and AR:

• Virtual Reality (VR) is an engaging technology that transports the user to a computer-generated environment where they must follow predetermined actions and interactions. When one or more of a user's senses are replaced by artificial stimulations, that person is effectively cut off from the real world.

• To define augmented Reality, virtual Reality is often used as a counterexample. AR seeks to complement the real world by adding a virtual layer, in contrast to VR's isolating effect. At the crossroads of virtual Reality and telepresence, actual and virtual objects coexist in real-time.

1.2 Application Fields

The widespread availability of mobile devices, the introduction of wearable technologies like smart glasses, and developments in computer vision have all contributed to the overall usefulness of MAR applications. Here, we give a sample of our work in the following broad areas: Information Assistant Governance (Section II-E), Assembly and Maintenance (Section II-D), Geometry Modeling and Visual Construction (Section II-A), and Tourism and Navigation (Section II-B) (Section II-F). Subsection II-H, as a final point

An example AR system design for TBS is shown in Figure. 1. Compared to the pure JavaScript library/plugin method, the browser-kernel extension solution offers a promising and potent self-contained Web AR planning solution. However, before browsers that support augmented Reality become standardized, widespread promotion of Web-expanded reality applications will be hampered by the disparate APIs proposed by various browser kernel-extension solutions. There have, thankfully, been the first attempts towards standardization.

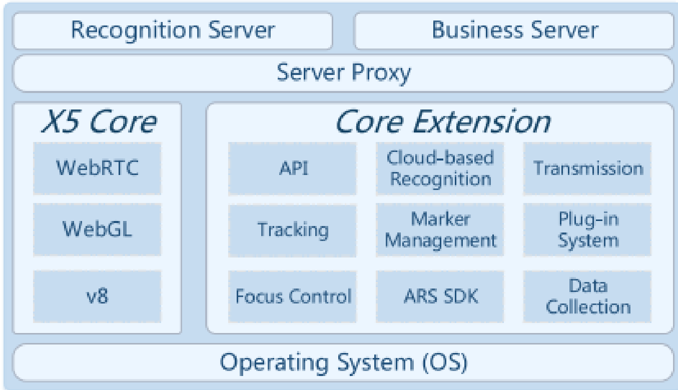

Figure 1.Virtual Reality Architecture

Virtual Reality (VR) has been a popular technique for providing an immersive, interactive simulation until recently. However, its fundamental drawback is that it requires the user to be immersed in the simulated environment, which prevents them from forming meaningful connections with the actual world and their immediate surroundings Fig 2. However, augmented Reality makes this kind of interaction possible since it relies on the fusion of real-world environments with data provided by computers. One of the critical reasons why AR is becoming more and more popular among consumers is because of this. When using an augmented reality app, you can see 3D and 2D visuals superimposed on top of your actual surroundings. This indicates that the knowledge pool may be dynamically expanded, employing the creation of novel artefacts. The AR apps then use the geolocation data or, more recently, Augmented tags, which are easily read by smartphones and computers, to insert and manage the objects and 2D images Figure 2.

Nevertheless, the precise technology needs for augmented reality mobile applications vary significantly from one use case to the next. Web servers are essential to all augmented reality mobile systems because they stored information like databases and extended reality tags that may be used to locate places of interest (POIs). In addition, smartphone availability is a must for using such applications. Additionally, a gyroscope and GPS system are required in situations of location-based mobile AR apps so that the user's location and orientation may be determined. Every mobile device must have a powerful central processing unit, plenty of random access memory, a camera, and Wi-Fi or 3G connectivity for data transfer. It's worth noting, though, that most modern smartphones can run augmented reality apps on the go.

2. LITERATURE SURVEY

To improve the material found in structural engineering textbooks and exercises by using augmented Reality (AR) and 3d interactive models to see discrete structural components, therefore illustrating how the structures respond under varied stress circumstances. Using the expanded reality interface, students may alter the load and instantly see the effect on the system. By examining the difficulties associated with content integration and interaction, this study explores the viability of AR ideas and interaction metaphors, as well as the possibilities of employing AR for teaching structural analysis. The educational efficacy and design principles of an AR application are evaluated in a pilot study done in a junior-level structural analysis class [1].

The present and potential future applications of virtual and augmented Reality (VR/AR) technology in the e-commerce sector are examined in a variety of settings, from the sale of homes to the sale of cosmetics. It's common to see product-focused opportunities [2]. Online shoppers might feel more at ease with their purchases because of visual aids like virtual clothing fitting, haptic gloves, and product visualization [3]. When online shopping, haptic gloves may be used to simulate the feel of the product's texture, weight, and pattern by sending electric pulses to the hand. If you've shopped online before, you'll notice a vast improvement in the quality of your shopping experience thanks to this new technology [4]. As an example, the LensKart app lets users choose frames online that are tailored to their facial features, while the Nykaa app uses augmented Reality to help users select cosmetics that complement their skin tone [5].

Multiple industries are now making use of augmented reality applications, including healthcare, teaching, and virtual training. It is also put to use in the tourism industry, where it is hoped that it will lead to happier and more fulfilled visitors [6]. On the one hand, several case studies have demonstrated that AR can help tourism organizations and professionals reach a broader audience by functioning as the delivery medium of engaging multimedia material and mobile applications tailored to different skill sets. Numerous programmes have been created using the existing frameworks and toolkits [7]. Some of these were only available as research or pilot projects but are now on the market to the general public. But maybe most significantly, the examples cover a wide range of situations. This section provides an example of an augmented reality app for mobile devices. While we do recognize their own differences, we also acknowledge that they are all made with the visitor in mind [8].

Augmented reality (AR) mobile learning system that uses GPS positioning of virtual things to place them in the actual world in the context of Natural Science endeavours. Results from an investigation showed that using an augmented reality mobile system boosted the pupils' ability to study. However, the suggested system does have significant limitations, such as the precision with which GPS can place objects. Education-related work on MAR has already been done. The authors highlight the need to investigate how AR might enhance the learning process as well as other pedagogical concerns in the classroom [9].

Students can benefit from MAR systems both in and out of the classroom. Although a lack of content production tools is currently a barrier to using MAR in educational contexts, the usage of books and notebooks with MAR systems can contribute to an improved learning experience. Using the concept of Studier's tube as its foundation, Construct3D is a geometric modelling programme that operates in three dimensions [10]. For the purpose of interacting with spatial 3D geometric constructs, they don a stereoscopic head-mounted device that provides an augmented reality in 3 sizes. An expanded reality system designed to enhance the educational value of museum visits. Functions like zooming in on a virtual image are made possible by the system because it detects and superimposes relevant data over live photos [11].

Give a classification scheme and give some data-driven examples from real-world applications. We recommend classifying these sectors as follows: (1) Retail; (2) Tourism; (3) Healthcare; and (4) Public Services. Better product details, responsiveness to customers' moods, and tailored offerings are just a few ways in which MAR applications for retail may enhance the consumer experience. MAR applications in the tourism sector employ geospatial data to facilitate consumers' navigation of new areas, while in the healthcare sector, they support medical professionals in the performance of procedures and the provision of treatment. Final thought: MAR solutions in public service improve people's lives in small ways all the time. Each of these examples relies on access to large data sets to work. In Figure 3, we demonstrate how big data may be applied to the depiction of wind direction and speed. Since this type of representation can't be modelled, it's clear that a massive quantity of data is needed to portray it accurately [12].

3. MOBILE AUGMENTED REALITY (MAR)

3.1. Characteristics of MAR Applications

We consider a mobile app to be MAR if it meets the following criteria regarding the flow of data:

• Input: It takes in information from the device's own sensors (camera, barometer, audio, GPS), as well as from any auxiliary devices.

• Processing: It gets to decide the details that are going to render on that screen of the mobile. This may need retrieving data either locally on the device or from a remote server.

• Output: It projects its output to the computer monitor of the mobile device together with the current view of a user (i.e., it augments this same Reality of the user).

The reflected information is instantly and permanently overlaid on the actual world, making AR glasses the most outstanding alternative for pervasive MAR. But their limited processing capacity means that most applications are elementary. Smartphones, with their increased computational power and mobility, are another viable choice; however, they need the user to point and hold the device in order to take advantage of its augmented reality features [13]. As they get larger and less portable, tablets, personal computers, and laptops may become a hassle. In Table I, we can see a quick summary of the features of each of those tools.

3.2 Requirements of MAR Applications

The most portable gadgets are often the weakest when it comes to augmented Reality. Parts of a programme may be run in a cloud stand-in, depending on its requirements (such as storage space, graphics processing power, and network access). Vision-based apps are complicated to implement on smartphones and nearly impossible to implement on wearables due to the need for powerful graphics processing units (GPUs). Only a home computer or a dedicated server is suitable for some tasks. This led to the concept of computation offloading, in which intensive calculations are transferred to a separate, more potent device [14]. At one end of the spectrum, a smartphone may serve as an accompanying device to a set of smart glasses, and at the other end, it can be a virtual computer with practically unlimited processing power, memory, and storage. FoG and D2D technologies fill the gap between these two extremes [15].

3.3 Past, Present and Future of Access Networks

In the early 1990s, the first dial-up modems became available to the general public. Broadband Internet access, however, sparked widespread adoption (ADSL and Cable). These technologies improve throughput and reduce latency but have asymmetric capacities; i.e., they have more bandwidth on the downlink than the uplink. Broadband Internet users in the US had steadily increased since 2005, when they surpassed dial-up users, reaching an estimated 67.8 million in 2014. Despite the widespread use of optical fibre as a replacement for ADSL/Cable, asymmetrical offerings are still relatively prominent in some regions. The French ISP Orange, for instance, still offers asymmetrical (500Mp/s down, 200Mb/s up) optical fibre connectivity to its clients as of the writing of this article. In the United States, various service providers promote cable Internet connections that are similar to fibre but offer lower uplink speeds [16].

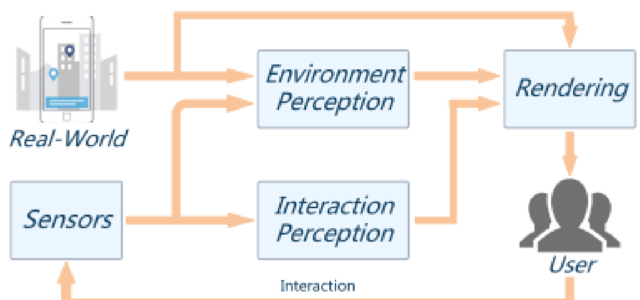

Figure 2 A typical AR procedure.

Figure 2 depicts a typical AR procedure. Constantly, the lens and other sensors are taking readings of the user's surroundings. The acquired data (such as image/video, position, and orientation) is analyzed by the environment perception to enable recognition and perception in the actual world. Meanwhile, the sensors collect data about the user's interactions and process it so it may be used to monitor things [17]. The user's surroundings perception and interaction data are combined in a rendering technique that allows for the natural augmentation of the actual world with digital information.

The present state of mobile networks is very similar: Convergence between mobile and desktop Internet usages has occurred rapidly thanks to the proliferation of 3G and 4G networks [18]. There was a dramatic increase in mobile online traffic to the top 10,000 US sites in 2015, with mobile accounting for 56 percent of all US web traffic. Broadband Internet access and mobile broadband networks have a significant imbalance [19]. Complete Duplex transmission in 5G networks might increase the likelihood of symmetrical bit rates; however, the present tendency appears to favour asymmetric profiles that are dynamically adjusted.

A. Multimedia Protocols

Multiple protocols exist now that were developed mainly for the purpose of transmitting video. Since MAR requires substantial uplink transfers of video, pictures, and data, the protocols used in multimedia networks may provide a suitable model for an AR transport protocol [20]. Below, we go over some of the most often-used protocols of this type:

1. RSVP (Network Control Protocol): is used to reserve resources on a network. Both hosts and routers utilize this protocol to negotiate and exchange QoS assurances for individual traffic flows. A business rationale for mobile broadband carriers might be the ability to give QoS guarantees on specific augmented reality apps, even if this isn't relevant to general expanded reality applications.

2. RTP (real-time Procedure) and RTCP (Real-time Control Protocol): both run on top of UDP. While RTCP provides a layer of Quality of Service, RTP enables the transport of real-time data via UDP. Those protocols include various features that are helpful for augmented reality applications beyond the standard sequential delivery: Firstly, jitter compensation techniques. Synchronization across multiple media formats allows users to access material from a variety of online and offline sources. (3) The programme receives QoS data and uses it to adjust video quality, transmission rate, and other parameters based on the state of the network [21].

3. MPEG-TS (MPEG Transport Stream): also provides stream synchronization, with the possibility of convolving several streams together [22]. Forward error correction (FEC) is included for restoring corrupted or missing frames.

Diffusion-to-Depth (D2D) Multimedia Protocols: It has not been proposed to use D2D communications specifically for the transfer of multimedia data between mobile devices. Different ideas, when applied to mobile ad hoc networks, centre on the task of establishing a connection between two points. Examples include the work of Fu et al., who suggested a form of (TCP)-friendly rate control (TFRC) for multimedia traffic, and H. Luo et al., who expanded on this work to develop a rate control protocol for real-time video streaming [23]. However, MAR applications that require network connectivity will not benefit from these developments.

3.4 ANDROID MOBILE OPERATING SYSTEM

Mobile business applications, in general, should be released on all major platforms to attract the largest possible audience. Consequently, we have made Android-compatible versions of AREA for both phones and tablets . In this part, we'll examine the Android version of AREA and see how it stacks up against the iOS version. While both Android and iOS share AREA's fundamental software design, there are noticeable variances in how well each platform runs the app in practise.

Android packages for use with the Sensor Controller's implementation. Two words: Android and a certain place. We employ hardware [24]. Comparable to its iOS counterpart, the location package includes methods for retrieving the current GPS coordinates and altitude of the device in question. An extra feature of the Android location package is the ability to retrieve a device's rough location via network triangulation. This latter method is useful in particular when a GPS signal is unavailable. There is, however, the caveat that in this situation, the device's present height cannot be calculated. Likewise, the hardware suite has features for polling the magnetic field and the accelerometer. The latter is used to determine device rotation and is identical to iOS's.

Due to the increased mobility of MAR, it is essential that mobile platforms be compact and lightweight so that services may be provided without limiting the users' freedom of movement. Recently, there has been a lot of development in the shrinking and performance enhancement of mobile computing systems. Actually, you can spin the map to change the orientation of your points of interest and your range of vision. Similarly, a layout with child views cannot be rotated in the same manner on Android. This means that the x and y coordinates of POIs need to be calculated in a different method when the Point of Interest Controller gets sensor data from the Sensor Controller. The Sensor Controller's degree of the process is used for point-of-interest placement rather than relying on the device's present rotation to determine their location. After that, we spin the points of interest (POIs) around the geographic centre of the current view. This method still allows us to incorporate all POIs into the map's location display. Finally, when you rotate the POIs, they will no longer appear in the camera's perspective.

It's common knowledge that both iOS and Android receive regular updates. It follows that while creating and releasing a cutting-edge mobile business app like AREA, relevant updates must be carefully examined. Because of its reliance on reliable sensor data, AREA might be adversely affected by even seemingly innocuous modifications to the native libraries it uses. Take the following problem we encountered after an Android system upgrade as an illustration. The sensor framework in the previous version would alert AREA if the data being monitored became suspect. However, the latest mobile OS version rendered several previously-used constants unknown [25]. The problem could only be fixed by switching to a listener instead of a distinct constant. Similarly, the launch of iOS 7 resulted in a new overall UI design. Specifically, several of the user-customized UI components in the live rendition of the Live Guide apps suddenly disappeared or stopped responding to user inputs.

3.5 RESEARCH CHALLENGES

The proliferation of Mobile AR apps has been greatly aided by the development of Web AR. But until the right technologies are developed and made accessible, there are a number of hurdles that must be overcome. We were really encouraged by the actual progress and implementation of Web AR.

1. Effectiveness in Computing: The computation and rendering capabilities of mobile platforms play a vital role in the enhancement of the functionality of Web AR apps, particularly when the personality and collaborative compute outsourced Web AR implementation options are taken into consideration.

2) Network needs are another major issue for Web AR. Because of the limitations of mobile devices in terms of processing power and rendering capabilities, computationally expensive activities are often offloaded to cloud/network edge servers in order to enhance performance and hence the user experience. When used to Web augmented reality applications, the MEC model can further reduce communication latency. However, the expense of deploying an edge computing device means that similar infrastructures are still not widely used in today's 3G/4G mobile networks. To bridge the gap between consumers' already demand for Web augmented reality apps and the compute outsourcing approach under existing mobile networks, it is more practicable to employ presently accessible network technologies like content delivery networks and data centres.

3. Environment observation, interaction perception, and an active Internet connection are required for augmented reality applications over the long haul. The battery life of portable devices is severely compromised by all these power-intensive activities. However, at the moment, the battery can only be used for essential functions. Web augmented reality apps can have a negative effect on mobile devices, which is why consideration of energy efficiency is crucial. Off many multicore CPU chips are currently available for mobile devices, and their lower frequency and voltage mean they consume less power than single-core CPUs. Web augmented reality applications can save energy by distributing their workloads over several processors.

4.) Compatibility of Enabling Technologies: There is a wide gap in the support and compatibility of all forms of Web AR supporting technologies, such as Web Assemblies, WebGL, WebRTC, and so on, across the many browsers available today, from native browsers like Chrome, Firefox, and Safari to built-in browsers like Facebook, Twitter, and WeChat. This not only makes it more challenging to create programmes, but it also impedes the widespread marketing of Web augmented reality apps.

5.) compatibility problem stems from the fact that browsers supporting Web AR have not been standardized. There is currently no way for augmented Reality (AR) software developed for one web browser to run on another browser, as they are all entirely separate at the moment. The W3C group has made some attempts [100] recently, and with the rising interest for the Web AR from users, standardization also needs attention, which calls for a concerted effort from academics and businesses alike.

6) Web augmented Reality has the potential to significantly improve the quality of our experiences in the physical world. Mobile-friendly, lightweight, and platform-agnostic augmented reality apps are in high demand. The release of Google Glass was a watershed moment for the industry, as it not only piqued the public's curiosity but also helped push AR and, more specifically, Mobile AR forward. Even though most Web AR apps now available are only research prototypes, Pokémon GO's success shows that there is a market for and interest in Web AR apps. In our opinion, the proliferation of publicly accessible Web AR development platforms and educational programmes, as well as the proliferation of open-source software, will lead to the creation of a greater variety of Web AR prototype systems and applications. The same is valid for Web AR; it needs game-changing apps for both developers and consumers to realize its promise fully.

Many factors, like the number of major operating systems, the ease of porting code to multiple platforms, performance, and more, go into an author's decision on which tool to use for developing augmented reality technology. Cross-platform engines and toolkits are both viable options; however, their use depends on the nature of the application being built. These kits streamline and expedite the process of creating any software that makes use of augmented Reality. Newcomers to the field of expanded reality technology development may use these pros and cons to make an informed decision about which tool best suits their needs.

4. CONCLUSION

In this paper discussed several directions for designing upcoming multimedia transport protocols to get as close to their requirements, with an emphasis on Augmented Reality, even though the most recent technologies may not be adequate for the most demanding ubiquitous MAR applications. With the massive increase of traffic that MAR offloading will cause, existing and future unlicensed spectrum would be overwhelmed. The future network may provide the performance improvement needed to enable substantial offloading, but it will rapidly be overrun by the demand, especially in the absence of AR-specific congestion control. Presented a synopsis of the problems still being faced and the potential areas for further study in Web AR. Although Web AR is in its infancy, this article will give researchers and developers with recommendations and a reference entry for applying Web AR technology in their Internet mobile apps to deliver a ubiquitous AR experience to the users.

REFERENCES

1. Charland and B. Leroux, "Mobile application development: Web vs native," Commun. ACM, vol. 54, no. 5, pp. 49–53, May 2011.
2. J. G. Andrews et al., "What will 5G be?" IEEE J. Sel. Areas Commun., vol. 32, no. 6, pp. 1065–1082, Jun. 2014.
3. Reznik et al., "Developing software for multi-access edge computing," ETSI, Sophia Antipolis, France, White Paper 20, 2017.
4. Y. C. Hu, M. Patel, D. Sabella, N. Sprecher, and V. Young, "Mobile edge computing—A key technology towards 5G," ETSI, Sophia Antipolis, France, White Paper 11, 2015, p. 1–16.
5. P. Belimpasakis, P. Selonen, and Y. You, "Bringing user-generated content from Internet services to mobile augmented reality clients," in Proc. IEEE Cloud-Mobile Converg. Virtual Reality Workshop (CMCVR), Mar. 2010, pp. 14–17.
6. Z. Sun, A. Purohit, S. Pan, F. Mokaya, R. Bose, and P. Zhang, "Polaris: Getting accurate indoor orientations for mobile devices using ubiquitous visual patterns on ceilings," in Proc. 12th Workshop Mobile Comput. Syst. Appl., 2012, p. 14
7. J. Mellado. Js-ArUco—A JavaScript Library for Augmented Reality Applications—Google Project Hosting. Accessed: Mar. 7, 2018.

8. Heikkinen. (2011). JSARToolKit—JavaScript Port of FLARTOOLKit. Accessed: Feb. 12, 2018.

9. P. H. Kato, M. Billinghurst, and I. Poupyrev, "Artoolkit user manual, version 2.33," Feb. 2000.

10. D. G. Lowe, "Distinctive image features from scale-invariant key points," Int. J. Comput. Vis., vol. 60, no. 2, pp. 91–110, 2004.

11. H. Bay, T. Tuytelaars, and L. Van Gool, "Surf: Speeded up robust features," in Proc. Eur. Conf. Comput. Vis. (ECCV), 2006, pp. 404–417.

12. D.-N. Ta, W.-C. Chen, N. Gelfand, and K. Pulli, "Surftrac: Efficient tracking and continuous object recognition using local feature descriptors," in Proc. IEEE Conf. Comput. Vis. Pattern Recognit. (CVPR), Jun. 2009, pp. 2937–2944.

13. Karpathy. (2014). ConvNetJS: Deep Learning in Your Browser. Accessed: Mar. 23, 2018.

14. M. Hidaka, Y. Kikura, Y. Ushiku, and T. Harada, "WebDNN: Fastest DNN execution framework on Web browser," in Proc. ACM Conf. Multimedia, 2017, pp. 1213–1216.

15. Han and M. Orshansky, "Approximate computing: An emerging paradigm for energy-efficient design," in Proc. 18th IEEE Eur. Test Symp. (ETS), May 2013, pp. 1–6.

16. Q. Xu, M. Todd, and S. K. Nam, "Approximate computing: A survey," IEEE Design Test, vol. 33, no. 1, pp. 8–22, Feb. 2016.

17. S. Mittal, "A survey of techniques for approximate computing," ACM Comput. Surv., vol. 48, no. 4, pp. 62-1–62-33, Mar. 2016.

18. W. Zhang, B. Han, and P. Hui, "On the networking challenges of mobile augmented reality," in Proc. Workshop Virtual Reality Augmented Reality Netw., 2017, pp. 24–29.

19. Xu et al., "Show, attend and tell: Neural image caption generation with visual attention," in Proc. Int. Conf. Mach. Learn., 2015, pp. 2048–2057. (Mar. 2018). WebXR Device API Specification.

20. Acquisti, R. Gross, and F. Stutzman, "Faces of facebook: Privacy in the age of augmented reality," Tech. Rep., 2011.

21. F. Roesner, T. Kohno, and D. Molnar, "Security and privacy for augmented reality systems," Commun. ACM, vol. 57, no. 4, pp. 88–96, 2014.

22. Lebeck, K. Ruth, T. Kohno, and F. Roesner, "Towards security and privacy for multi-user augmented reality: Foundations with end users," in Proc. IEEE Symp. Secur. Privacy, 2018, pp. 392–408.

23. Y. Midak, I. V. Kravets, O. V. Kuzyshyn, L. V. Baziuk, K. V. Buzhdyhan, J. D. Pahomov, Augmented Reality as a part of STEM lessons, Journal of Physics: Conference Series 1946 (2021) 012009. doi:10.1088/1742- 6596/1946/1/012009.

24. Striuk, M. Rassovytska, S. Shokaliuk, Using Blippar augmented reality browser in the practical training of mechanical engineers, CEUR Workshop Proceedings 2104 (2018) 412–419.

25. Lavrentieva, I. Arkhypov, O. Kuchma, A. Uchitel, Use of simulators together with virtual and augmented Reality in the system of welders' vocational training: Past, present, and future, CEUR Workshop Proceedings 2547 (2020) 201–216.