The Use of Augmented Reality in Collaboration Within the Construction Industry

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Abstract. Site visitation is a crucial aspect of civil engineers' job scope as it provides them with first-hand construction data. However, due to the recent COVID-19 pandemic, construction site visitations are restricted, making the tasks of a civil engineer impossible to achieve. The main objective of this research is to find out and suggest a remedy to the problems commonly faced by civil engineers through the help of Augmented Reality (AR). Hence, the study's objective is to analyse AR's functionalities and suggest its best application to communicate spacious awareness via visual feedback for civil engineers. For maximum usability, an integrated software suite is proposed that provides access to AR worksites, measured data, and allows peer communication. This addressed the whole spectrum of problems faced by civil engineers with the switch to remote working. However, with the COVID-19 pandemic, the limitation of this project is that testing could not be executed to determine the efficacy of the said solution. Furthermore, the proposed solution has limitations, such as requiring pre-constructed infrastructure in applicable construction sites. Therefore, regular quality assurance (QA) and quality control (QC) are required to ensure proper functionality. In the future, AR LiDAR sensors could be a possibility as it provides increased accuracy of AR measurements which is critical in engineering.

1. Introduction

COVID-19 pandemic has evolved into a global crisis that has brought many problems and impacts to businesses, governments, and societies worldwide. No industry is immune to this crisis, and the construction industry is no exception. Among them, civil engineers are seriously affected. The ongoing pandemic has hindered their daily engineering duties. Before that, civil engineers could physically inspect construction sites to ensure that the site is constructed in accordance with design specifications and safety standards. Therefore, they were able to collect first-hand data on-site to create and modify the blueprint according to the actual situation. With a good understanding of the on-site project, civil engineers could organise and brief a team of engineers about the project very well in order to make sure that all the members know the project’s details. Also, they were able to manage projects and assign tasks accordingly to ensure that site workers perform tasks with high productivity. The main challenges they face due to the COVID-19 pandemic are as mentioned below.
1.1. Challenges faced by civil engineers

1.1.1. Inaccessible site visitation. Civil engineers play a vital role in project construction because the activities carried out in construction projects are highly dynamic. Therefore, they need to follow up on the development of the project at all times to avoid unnecessary construction mistakes. However, as the pandemic worsened, the government issued a lockdown restriction prohibiting site visitation, so this affects civil engineers to physically visit the sites to perform project monitoring and construction inspections. Therefore, they cannot check and ensure whether the building is in accordance with the technical design and construction drawings and compliance with safety regulations.

1.1.2. Lack of Communication. Another issue civil engineers face is that they are unable to meet and communicate effectively with other site personnel to obtain the latest project’s information. Insufficient communication has become an obstacle for civil engineers to work simultaneously as on-site construction personnel. As a result, they are not able to monitor the project in real-time and conduct a thorough analysis. Hence, they cannot provide timely and accurate guidance and technical advice to site workers, resulting in a team of engineers being unable to perform their work effectively. It is difficult for civil engineers to brief and distribute day-to-day work to site workers. Furthermore, with a severe lack of collaboration and interaction within the engineering team, civil engineers are not able to deliver the projects on time, on budget, and meet quality expectations.

1.2. Consequences

The challenges and impacts mentioned above may lead to unnecessary construction mistakes. According to information is taken from the Department of Safety and Occupational Safety and Health (DOSH) database, the lack of supervision was the third leading cause of accidents in the construction site during the investigation of 30 fatal accidents [1]. Table 1 shows the causes of accidents with their frequency, percentage, and rank.

| SN | Accident Causes                                           | F | %  | Rank |
|----|-----------------------------------------------------------|---|----|------|
| 1  | Failure to follow safe work procedures or non-compliance with them | 8 | 22.22 | 1<sup>st</sup> |
| 2  | There is a lack of or a scarcity of PPE                  | 5 | 13.89 | 2<sup>nd</sup> |
| 3  | Edge protection is lacking                              | 3 | 8.33  | 3<sup>rd</sup> |
| 4  | Inadequate oversight                                    | 3 | 8.33  | 3<sup>rd</sup> |
| 5  | Failure of the material                                 | 2 | 5.56  | 5<sup>th</sup> |
| 6  | Worker’s unsafe act                                     | 2 | 5.56  | 5<sup>th</sup> |
| 7  | There is no indication of a hazard                       | 1 | 2.78  | 7<sup>th</sup> |
| 8  | There is no warning notice                              | 1 | 2.78  | 7<sup>th</sup> |
| 9  | The aperture on the floor is not covered                | 1 | 2.78  | 7<sup>th</sup> |
| 10 | Failure of the equipment                                | 1 | 2.78  | 7<sup>th</sup> |
| 11 | Working conditions are hazardous                        | 1 | 2.78  | 7<sup>th</sup> |
| 12 | Causes that have been overlooked                        | 8 | 22.22 |      |
|    | TOTAL                                                    | 36 | 100.00 |    |

In addition, the progress of the project may also be delayed. This result can be proven from real data. Figure 1 [2] shows the AIA survey, which found that two-thirds of responding construction firms reported that the operation of projects has slowed down or completely stopped due to the COVID-19 pandemic.
This paper aims to analyse the problem faced by civil engineers during this pandemic and to propose a solution to close the gap between civil engineers and construction project sites by further scrutinising the capabilities of augmented reality to facilitate remote working. Therefore, the objective of this research is to suggest optimal applications of augmented reality (AR) by conceptualising a program that remedies the problems faced by civil engineers. Furthermore, significant functionalities are included, such as communication features in an all-in-one platform for civil engineers to carry out their tasks.

Having understood the objectives, the developed system named Smart Construction Solutions (SC Solutions) focuses on AR technology and other mentioned features catered for communication purposes, which will be discussed in the following sections.

Section 2 includes the literature review of augmented reality and related works of augmented reality in other industries. Section 3 discusses the proposed system of SC Solutions. The module description, system architecture as well as tools for implementation are elaborated in detail. In section 4, the paper discusses the implications of the system. Finally, the paper is concluded in section 5 with research limitations and future research.

2. Literature Review
The literature on augmented reality and its related works will be reviewed in this section of the paper.

2.1. Augmented Reality
Augmented reality (AR) is a digital simulation in which computer-generated images or objects are superimposed over real-world surfaces [3]. The data that flows to the computer through the Internet is used to enhance the content [3]. The technology is known as augmented reality because the data put on the real-world surroundings is augmented and observed through augmented reality devices such as AR glasses, smartphones, tablets, and HoloLens. Augmented reality will be implemented for on-site construction projects to monitor and document project progress [4] by connecting the technology to the users’ devices to perform construction tasks remotely. The aim of applying augmented reality would be to gain indoor-outdoor setting of visualised design models, layout analysis using several layers of data, and enhanced quality inspection made possible by integrating BIM [5].
Three leading technologies that power augmented reality are Simultaneous Location and Mapping (SLAM) [6, 7], depth tracking [8], and image processing [9]. SLAM Maps an entire space or object and then uses augmented reality Image Simulation to project the image on a screen [6, 7]. However, the majority of today’s augmented reality SDKs have built-in SLAM so that developers do not have to start from scratch in developing augmented reality simulations. Depth tracking measures the physical properties of an object from the camera sensor [8]. This will be useful in developing the augmented reality system, especially when it comes to measuring the properties of an object in terms of height, width, and depth. Finally, image processing is used to power augmented reality, where the augmented reality program generates the image’s final render and displays it on the device’s screen [9]. These three technologies allow the augmented reality application to provide an interactive reality for the user. Alternative AR tools such as Vuforia Software Development Kit (SDK) and QCAR (Qualcomm Company Augmented reality) were used in successful instances of AR development [10].

However, instead of the various traditional methods in implementing augmented reality, Video Surveillance Technology [11] will be deployed. The intelligence surveillance camera infrastructures built with augmented reality with the three leading technologies mentioned earlier on the construction site. The cameras will be equipped with augmented reality standard functions such as AR video with a geographic tag to view locations around a construction site, AR video & data to show information of an object, AR with GPS to track the movement of a construction tool present on-site, and live plan that ensures a maximised viewing area is essential in a construction site [12]. The augmented reality cameras are then connected to the host application via wireless for users to utilise augmented reality technology remotely. Therefore, doing so further exceeds augmented reality’s capabilities in a remote usage setting; an example is shown in Figure 2.

![Figure 2. Implementation of the augmented reality technique.](image)

2.2. Related Work

2.2.1. Akular AR. Akular AR [13] is an augmented reality platform that is integrated with AutoDesk BIM360. The system provides an intuitive walkthroughs experience for a construction project in real-time geolocated BIM in real size. The system is compatible with mobile devices and tablets that support augmented reality. Akular AR uses marker-based augmented reality experience by requiring devices to scan a QR code that is located on the real-world surface [14]. They have developed an
augmented reality experience that adds realism to the 3D models. The system’s real-time augmented reality environment based on its geolocation will be integrated, similarly with the concept presented in Akular AR.

2.2.2. Arvizio’s Immerse 3D. Arvizio’s Immerse 3D is an augmented reality solution for the AEC industry that includes import, refining, complicated 3D models with LiDAR scans optimisation and hybrid rendering to create and exchange digital twins among several participants [15]. According to a study from the Journal of Engineering Science and Technology (JESTEC), the trilateration localization technique is used to estimate location using a LiDAR system [16]. The solution provides end-users to perform 3D multi-user collaborative assessments, on-site product alignment for AR inspections, and virtual online meetings for shared 3D models in AR using Arvizio’s Immerse 3D business level solution, which features industry-leading hybrid rendering and 3D model optimisation capability. Arvizio’s Immerse 3D allows other components to be incorporated into the augmented reality experience, for instance, documents, pictures, and other design data [17].

Their system works so that multiple users can collaboratively share and interact with 3D models in the augmented reality interface, as shown in Figure 3 [17]. The platform is linked to web meeting sites such as Microsoft Teams and Zoom to accomplish this. As a result, they will study the models in a collaborative environment. This is a valuable point when designing the system based on the concept of collaboration among users.

![Figure 3](https://www.arvizio.io/products/)

2.2.3. Synchro XR. Synchro XR by Bentley uses augmented reality by Microsoft HoloLens to achieve 4D construction modelling [18]. Users of the SYNCHRO XR variant can interact with the templates in a variety of ways. For example, they can make a model that sits on a tabletop or in space, that can be rotated or even cut for a more detailed view, and that has a timeline slider that can move forward and backwards in time [19]. In addition, users observe augmented reality through the HoloLens. Figure 4 [20] shows the workings of HoloLens using spatial mapping that depicts real-world surfaces around the hardware [21].

Synchro XR is also integrated with Synchro Field, which is a construction project management system. This should be seen as a model for the system. The principle can be incorporated into the development of the productivity suite.
3. Module Description

The program SC Solutions contains a total of six (6) features, and the first feature is augmented reality (AR) module construction sites which help engineers visualise any construction site(s). Engineers can search for the construction site using the search feature provided or simply selecting the site through the map interface. Once the construction site is selected, users will be brought to the AR interface where they are able to gain on-site information, perform structural measurements and inspect a construction structure.

The second feature is a project management module. In this feature, there are lists of projects and tasks ready to be tracked. Also, the users can see whether a specific task is completed. If completed, the program automatically calculates the progress and will update the system accordingly.

The third feature is the video conferencing module, where online meetings are generated and organised according to a specific date and time. The program will display proper navigation panels for more leisurely usability purposes for the users.

The fourth feature is a file-sharing function. This module allows users to share and view files with selected peers. This is integrated with google drive, so it is reliable and cost-effective. Users are able to upload any document formats such as CAD drawings, so limitless usage.

The fifth feature is a workspace. This allows users to create a new empty whiteboard and invite co-workers for collaboration. Once a user selects a workspace, the app will show the updated workspace, and there is a navigation panel where users can add/remove charts, notes, and etcetera.

The final feature is text messaging. This feature allows casual communication with co-workers. Photos can be uploaded for reference in conversations.

3.1. System Architecture

SC Solutions provides a desktop and mobile version that clients can choose to install on their devices. The pre-requisites for the desktop version are to have a Microsoft Store (Windows) and Mac App (Apple). Meanwhile, for mobile version is Google Play Store (Android) and IOS APP (Apple). SC Solutions uses the graphical user interface (GUI) to allow clients to operate the software by directly manipulating graphical icons intuitively. First, the GUI integrates the information presented. Then it presents this information to the user by forming a platform where the user can see which functions are
possible without command codes. Augmented Reality enhancements have been successfully applied to mobile applications and will be beneficial here [22].

On the server side, SC Solutions has a database and web server. The database operates a large amount of information by storing, retrieving, and managing data. MySQL is applied as the database server in the application because it is an open-source relational database management system and can run on any platform. Web server is used for responding to the client request by sending the file to the client associated with the requested URL and generating the response by communicating with the database. Web server also functions in supporting the remote server. The remote server port is protected by a firewall to protect the database. The remote server consists of (Search Web Services, Profile Web Service, and Authentication Web Service) all of which are web services. Search Web Service establishes search relationships with other sources (including other websites or custom databases). This gives a single interface for a unified result set to the end-user. Profile Web Service is used to create distinct profile sources to import users’ data (such as name, address, or phone number) defined in the existing user repository in the enterprise. Finally, Authentication Web Service enables authentication of users and assigns appropriate security to documents and objects within the application.

This application depends on Internet connectivity. HTTPS request is done to initiate the system. A Private cloud is used as it is more secure and offers to a select few users and not the public. Furthermore, private cloud ports are protected by a firewall. Hence, it is unable to accept connections directly from the web, which jeopardises users’ security. Web browsers can connect with the application via HTML.

This program has all the essential AR construction site features, work schedule reminder, collaborative workspace, video conference, online messaging, voice call, and file sharing. Application functions are enhanced by JBoss application server. Several subsystems are integrated within SC Solutions, including Google Maps, OneDrive, Microsoft Office, and Augmented Reality SDK. Google Maps helps in locating AR construction sites. OneDrive is used for file sharing. Microsoft Office is used as a business administration tool. Digital content is integrated with information gathered from the real world by AR SDK.

SC Solutions use a cumulation of multidisciplinary technologies such as Voice over Internet Protocol (VoIP), Cloud technology, Instant messaging (IM), Telepresence, Internet, and Augmented Reality (AR). The interaction of these various systems supports each other. Cloud technology is utilised for data storage as it shares information without restriction, irrespective of physical location. VoIP enables online calls via the Internet, and telepresence is used for video conferences. The Internet supports the interconnectivity among these various technologies. Instantaneous messaging through online chat enables users to perform real-time sending and receiving text messages. AR construction site is generated over real-world surfaces, and this is done by a comprehensive integration of information input by Cortex. Figure 5 depicts the proposed system design.
Figure 5. System Architecture for SC Solutions

3.2. Tools

3.2.1. Aspose Tasks. Aspose Tasks for .NET is the proper application because it is capable for any .NET application to read/write MPP/XML files without installing Microsoft Project software [23].
Currently, this .NET is the only component that offers flexibility and stability and also this functionality. Lastly, this Aspose. Tasks for .NET works well with Web Forms and Window Forms.

3.2.2. SlashRTC. Video SDK by SlashRTC [24] provides excellent video quality regardless of the quality of network conditions. The video quality is well optimised, and make sure the video streaming is at the best quality. Furthermore, it is a fully customisable feature that can show multiple different layouts and up to 5 integrated live chats and phone calls simultaneously.

3.2.3. Cortex. Cortex [25] provides a wide range of augmented reality video feed cameras with real-time computational functionalities. Furthermore, providing standard augmented reality functions such as geographical tags that detect on-site objects. According to research made in the Journal of Engineering Science and Technology (JESTEC), OS3D is used to start a virtual environment. This plug-in, however, has certain restrictions, since it does not enable users to change any of the scene's elements [26]. Hence, the use of Cortex was found to be a practical approach. Moreover, augmented reality data display relevant data to the users. Augmented reality GPS provides the flexibility of switching between multiple cameras depending on the field of view. Additionally, Cortex video feed cameras provide a live plan that will detect a wide-range view of a construction site.

3.2.4. Chat SDK. Chat SDK [27] allows users to communicate with each other. It allows users to create a private chat for selected participants, allowing easy creation of communication channels for separate project teams. Chat SDK is supported on two platforms which are iOS and Android, and is scalable as it can support up to 10k users daily. Other than that, Chat SDK also provides numerous extensions to extend Chat SDK's capability for both iOS and Android versions, such as sticker messages, file messages, audio and video messages.

3.2.5. EaseFilter. EaseFilter [28] is a file system filter driver that provides many functionalities such as providing security for the users while entering the files, file access control and security control. It allows users to share or upload the files and even restrict them from accessing them or remove the files even if the files were expired. Also, once the files are uploaded, users can track the files if there is anyone accessed it, when the user accessed them. Other than that, it also provides file protection, file security, and file access control. Furthermore, the users have complete control of the shared files, such as they can modify the content of the files anytime, write/overwrite, remove/replace, or rename/delete the files.

3.2.6. Miro Developer Platform. Miro provides customised tools for users to make workflows based on what the users want. It is capable of enabling multiple users to work together in real-time to unleash creativity to plan projects from unlimited space. Miro is an online collaborative platform for users or teams to work together effectively, using brainstorming ideas and sticky notes to plan and manage their workflows [29]. It also provides some functionalities such as chat and video, presentation, and sharing to make their work easier.

4. Implications of System

4.1. Recommended Solutions of Challenges
The proposed features are explicitly constructed to target the two aspects of challenges faced by civil engineers due to the adoption of remote working.

4.1.1. Lack of Site Information. As stated, visual feedback is most effective in acquainting an individual with foreign environments without being physically present. Hence, Augmented Reality (AR) functionalities are adopted to reconnect civil engineers with their construction sites. Since spatial awareness is always required for work in construction sites, the aim of implementing AR features is to
provide ease of obtaining a range of measurement data commonly taken from construction sites while being supplemented by visual feedback to simulate the environment of being physically on-site. The functions include a User Interface (UI) displaying live video capture of selected areas in site with a large field of view while being manoeuvrable via keyboard controls paired with an overlay displaying available measurements when relevant structures are within the field of view.

4.1.2. Difficulty in Communication with Peers. Although AR features may provide the necessary information, communication is vital for construction projects as such additional features are required to facilitate information exchange between peers. A study conducted by Hubstaff concluded that 46% of remote working difficulties are caused by communication issues [30].

To reflect the common usage of communication, several modes are made available. For formal communication, meetings can be held with selected participants via video conferencing. A scheduling tool is also integrated to schedule and notify future meetings. While voice calls and chat functions are available for mobile communication should the need arise. Finally, brainstorming features such as whiteboards or diagram makers can be utilised in conjunction with meetings for added productivity. Fluid communication can help maximise work productivity and reduce errors, ensuring work is completed according to prescribed timelines.

4.2. Contributions of the System
This system aims to enhance the functionality of AR in its application within the construction industry by supplementing it with additional systems such as the overlay display of measurement information and productivity features into an “all in one” suite for ease of access to civil engineers.

It simulates the day-to-day interactions of civil engineers to assist them in carrying out their job scope in a remote environment. This improves their productivity as inconveniences will not burden them with inadequate information on job sites or difficulty contacting team members. Both issues are solved with solutions. The cost of rework due to misunderstanding and wrong information cost the US construction sector more than $31 billion in 2018, according to a report by Plangrid, a construction solutions provider [31]. This was before the pandemic and the rise in frequency of remote working. However, a major setback is that the proposed system is labour intensive during setup and requires constant maintenance. For the AR-based features to function, equipment such as camera modules must be first be installed at fixed positions in the construction site. As construction continues, the modules may need to reposition, or additional ones may need to be installed, e.g., on every new floor. Hence, regular maintenance of the system’s physical components is still required to ensure its optimal functionality.

In conclusion, the solution remedies problems faced by civil engineers when assigned to construction tasks via remote working. This ensures that their productivity is maintained while reducing common errors to ensure that tasks are completed on time without incurring any potential losses.

5. Conclusion
SC Solutions is designed to reduce the impact of the COVID-19 pandemic challenges on civil engineers. This high-efficient platform allows users to implement various functions under one single application. Visiting and monitoring sites, a general task for civil engineers, can be conducted anywhere, anytime through the program’s highlighted feature AR in the construction sites. It allows civil engineers to obtain first-hand information so that they can give instant feedback and use the supplementary features to communicate with others smoothly. The workspace feature is designed to reduce the possibility of engineering mistakes and project delays by increasing team collaboration. SC Solutions has the potential to revolutionise today’s working environment. This is done by shifting the
trend of traditional working mode into remote working mode. This program will be not only applicable during this pandemic but also has great potential in the future.

In the future, the system has huge potential. It may be modified in the near future as and when the need arises, as it is quite adaptable in terms of expansion. The program will also involve AR LiDAR sensors into the construction site camera to increase measuring accuracy [32]. Finally, the benefits of remote working are not limited to the pandemic and could be adopted in the future for the benefits mentioned above, such as the cost-effectiveness compared to importing foreign workers.

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References
[1] Williams O Samuel, Hamid R Abdul and Misnan M Saidin 2017 Analysis of Fatal Building Construction: Cases and Causes J. Multidisciplinary Eng. Sc. and Tech. 4
[2] AIA n.d. from www.aia.org/pages/6282364-march-2020-special-report-moving-ahead-ch
[3] Ronald T Azuma n.d. A Survey of Augmented Reality Presence: Teleoperators and Virtual Environments 6
[4] Zollmann S, Kulckner S, Hoppe C and Poglitsch C 2014 Augmented Reality for Construction Site Monitoring and Documentation Proc. of The IEEE Special Issue on Applications of Augmented Reality Environments
[5] Chai S Chang, Klufallah M, Kuppusamy S and Aminah M Yusof 2019 BIM Integration in Augmented Reality Model Int. J. of Tech
[6] Reitmayr G, Wagner D, Langlotz T, Mulloni A, Schall G, Schmalstieg D and Pan G Qi 2010 Simultaneous Localization and Mapping for Augmented Reality Int. Symposium on Ubiquitous Virtual Reality
[7] Wang C Chih and Thorpe C n.d. Simultaneous Localisation and Mapping with Detection and Tracking of Moving Objects Proc. 2002 IEEE Int. Conf. on Robotics and Automation (Washington DC) pp 2918-2924
[8] Polcar J, Kopeček P and Martirosov S 2016 Active Camera Positional Tracking for Augmented Reality Applications Proc. of the 27th Int. DAAAM Symposium 2016 (Vienna) pp 0447-0451
[9] Sato Y, Yabuki N, Fukuda T and Michikawa T 2016 A Marker-Less Augmented Reality System Using Image Processing Techniques for Architecture and Urban Environment The 21st Int. Conf. on CAADRIA 2016
[10] Widiati I, Suciat A, Kuswardhana D, Achdiana Y, Mubaroq R Sugeng 2021 Development of Augmented Reality Technology In Vocational School: A Socio-Technical Curriculum Framework J. Eng. Sc. and. Tech.(JESTEC). 16
[11] Sebe I Oner, Hu J, You S and Neumann U 2003 3D Video Surveillance with Augmented Virtual Environments IWVS '03: First ACM SIGMM Int. Workshop on Video Surveillance (California)
[12] Woodward C and Hakkarainen M 2011 Mobile Mixed Reality System for Architectural and Construction Site Visualization Augmented Reality - Some Emerging Application Areas ed Yeh A Ching Nee chapter 6
[13] Akular 2021 from akular.com/blog/2021-02-17-akular-autodesk-the-power-of-augmented-reality-ar-in-construction
[14] Akular 2021 from akular.com/tutorials/
[15] Sprigg S 2021 from www.auganix.org/arvizio-launches-its-immers3d-solution-for-sharing-3d-models-in-ar-within-collaborative-web-meeting-platforms/
[16] Noaman N Mohanad, Qasim M, Ismael Y Omar 2021 Landmarks Exploration Algorithm For Mobile Robot Indoor Localization Using Vision Sensor J. Eng. Sc. and. Tech.(JESTEC). 16
[17] Arvizio 2021 from www.arvizio.io/products/
[18] Fonsati A, Osello A and Marco A D 2021 OpenBIM Methods and Tools for Schedule and Cost Management Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development).
[19] Lauter C 2019 from https://www.spar3d.com/news/vr-ar/hololens-2-and-synchro-xr/
[20] Kloud Blog 2017 from https://blog.kloud.com.au/2017/12/15/hololens-understanding-depth-spatial-mapping/
[21] Khoshelham K, Tran H and Acharya D 2019 Indoor Mapping Eyewear: Geometric Evaluation of Spatial Mapping Capability of Hololens The Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences
[22] Widiati I, Riza S Lala, Danuwijaya A Ari, Hurriyati R, Mubarok R Sugeng 2016 Mobile-Based Augmented Reality for Learning 3-Dimensional Spatial Batik-Based Objects J. Eng. Sc. Tech.(JESTEC)
[23] Docs.aspose n.d. from docs.aspose.com/tasks/net/
[24] SlashRTC n.d. from www.slashrtc.com/video-sdk.php
[25] Cortex Integrated 2019 from cortexintegrated.com/augmented-reality/
[26] Kabtane E Hamada, Adnani E Mohamed, Sadgal M, Mourdi Y 2018 Toward an Occluded Augmented Reality Framework In E-Learning Platforms For Practical Activities J. Eng. Sc. and. Tech.(JESTEC). 13
[27] ChatSDK n.d. from chatsdk.co/
[28] AssureFiles n.d. from assurefiles.com/
[29] Marina 2021 from help.miro.com/hc/en-us/articles/360017730533-What-Is-Miro-
[30] Nevogt D 2019 from https://blog.hubstaff.com/remote-management-problems/
[31] Concrete Construction 2018 from https://www.concreteconstruction.net/business/management/lack-of-communication-and-technology-costs-construction-industry-177-billion-annually_o
[32] Gupta S and Lohani B 2014 Augmented reality system using lidar point cloud data for displaying dimensional information of objects on mobile phones ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences (Riva Del Garda)