Analysis of 3D Building Construction Applications in Augmented Reality

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Abstract

Construction industry is considered as one of the oldest industries in the world since human came into being and the need of their own space is realized. All this led to make the world a space of many beautiful constructive ventures. As per the requirements of today's world, every industry is recognizing the need for use and adoption of modern as well as innovative technologies due to their benefits and timely production. Now construction industry has also started adopting the use of modern and innovative technologies during their projects but still the rate of adoption is so slow. From design to completion, construction projects take a lot to manage for which technology based solutions have continuously been proposed. These include Computer Aided Design (CAD), building information modeling (BIM) and cloud computing have been proved to be much successful until now. The construction projects are high budgeted, and direly require timely and successful completion with quality, resource and other constraints. So, the researchers observe the need of more clear and technology based communication between the construction projects and its constructors and other stakeholders is required before and during the construction to take timely precautions for expected issues. This study has analyzed the use of Augmented Reality (AR) technology adopting GammaAR, and ARki applications in construction industry. It has been found that both applications are light-weighted, upgradable, provide offline availability and collaborative environment as well as fulfil most of the requirements of the construction industry except the cost. These applications also support different screen size for better visualization and deep understanding. Both applications are analyzed, based on construction's application requirements, usability of AR and ratings of applications user collected from application's platform. The purpose of this research is to provide a detail insight of construction applications which are using AR to facilitate both the future developers and consumers.

Keywords:

Augmented Reality, Building Design Visualization, 3D Building, 3D Construction. Applications

1. Introduction

Construction industry plays an important part in fostering economy all over the world [1]. It is believed that just one successful construction project can produce a great impact on many industries of a country [2]. In today's world, construction projects have not only become more complex as were before but also have to fulfil the modern world requirements as well as to provide better and effective production [3]. Traditional methods presently in use do not fulfil these enhanced requirements; thus one of the fast, efficient and possible solutions is use of information and communication technologies [4]. Froses et al. [5] describes three ages for the use of Information and Communication Technologies (ICTs) in construction industry. The first age is of ICT as the era of development of specific functionality application such as Computer Aided Designs and tools for estimation and constructional analysis. The second era is defined with the use of Emails, websites and document management applications and the third one as the current time in which construction organization look up for the overall package of system which will deal with all problems occurs during construction with the integration of model based method such as Building Information Modeling (BIM) to meet the criteria of upgraded technologies.

Although the BIM method has been instrumental in resolving mostly the issues occurring during construction phase of projects [6]. The most modern studies have however suggested the integrated use of the BIM and AR in the construction industry [7-9]. The AR provides an effective and efficient way of monitoring the construction projects [9]. The AR's interaction with real world environment makes it more efficient and better method for construction industry in comparison of Virtual Reality (VR) [10].

The AR provides best possible visualization of building construction which will give better understanding of model design [8, 11] and also ease of the communication required for a decision change, among all the project stakeholders

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[12]. Problems such as planning, scheduling, budgeting and safety etc. of modern construction can easily be analyzed by using the AR technology [13]. In other studies, the researchers Li et al. [14] have highlighted the use of AR for the safety purpose during construction phase. From planning to operation phases of a construction project, the management of different tasks can easily, effectively and efficiently be handled with the use of AR technology [8]. The AR can also be used for assistance in resolving the scheduling, budgeting, safety, maintenance, progress issues and conducting workers' training [15].

The AR is considered as mature technology, but the need of study to utilize AR effectiveness during construction and specific development for proper implementation in construction industry is still required [8]. For implementation of the AR applications, the integration of virtual objects with real-time environment must be seen effortless [16]. According to some researchers [12], the most important factor in this technology is to ensure its effectiveness from perspective of end user. In recent times, the AR adoption and implementation is getting very slow attention in the field of construction industry [17].

Although the AR adoption and implementation is still at slower pace in the construction industry, the stakeholders particularly the owners of construction organizations have recently shown great interest to invest in the AR methods to be used for future projects [8]. According to a research prediction [7], the future construction industry shall most likely be adopting the use of Augmented Reality (AR) because of its great potential in effective and efficient construction analyses. In comparison of other technologies for visualization of architecture design, the AR receives more user acceptance and proved as most effective reality technology [12]. As study of Sattineni et al. [2] consider the AR as a beneficial factor for construction industry. But to fulfil the modern construction industry demands, more research in the field of related features specifically design for construction industry is required [8].

The focus of present research is to analyze the 3D building construction using the AR applications, which are commercially available and free to use. For this, applications platforms like Microsoft windows app store, Google play and Apple app store have been searched to find the desired application specially the design in order to help in construction project working. These platforms are chosen because they are globally popular and user-friendly platforms for applications. Moreover, after acquiring the applications, their usability is evaluated in terms of AR, that how AR helps in the applications productivity with the help of usability evaluation method and then analyze the user rating of application from application platform which describe the feedback of its consumer.

2. LITERATURE REVIEW

2.1 Construction Overview

Construction is considered as a process consisting of four basic steps in order which result to a physical structure to facilitate the demands of society. These four steps are planning, design, building and operation-cum-maintenance [18]. The requirement for the construction of physical infrastructures increases with the increase in number of people in the world because it is a necessity in the day-to-day life of an individual to have a proper house with all the basic facilities such as affordable utilities, nearby transportation, and managed infrastructure with establish environment and all these are the subdivision of construction [19].

2.2 Construction Success Factors

Like any all other projects, construction projects are designed and completed to must meet the people's requirements of commonly referred to as critical success factors (CSF) which are discuss by [20]. The CSFs in the construction industry are taken as cost, time, quality, stakeholder satisfaction, management, health and safety, technology, organization, safe environment, and resources. All these factors affect the life of construction project and should be considered as important task parameters in prior all construction steps starting from the planning till operation and maintenance. If a construction project is completed on in the planned time within allocated budget and sustain its quality because of proper management during the process it will consider as a success project. In another research it is stated that construction project success is affected because of slow finances, improper management and time taken in authorization of approvals [21]. Besides other parameters like cost and quality, the risk assessment has also been analyzed as an One important factor towards success or failure of construction projects after cost and quality is analyzed by [22] is risk assessment which can lead construction project success to another level if managed properly. Soewin et al. describes the nine performance factors or CSFs with percentage contributions[23] which will affect the performance of construction project and require careful attention to produce a successful project. As shown in figure 1. People is the most important general factor for the performance of a project which basically comprise of teamwork, stakeholder communication, labor co-ordination, proper training and education, and satisfaction of employee, all of this depends upon the collaboration of information among them.

2.3 Technology in Construction

From paper-based traditional method to complete digital exchange of information, construction industry is now experiencing a noticeable shift towards the ICT adoption and implementation due to anticipated successes

and the promising benefits [4]. The need of implementation of innovative technologies like Augmented Reality (AR) in construction industry is still not getting a required momentum –one of the reasons is that not much work has been carried out in this direction to attract the stakeholders [24] and no up-to-mark productivity [25]. To examine the use of technology in construction industry, an analysis is performed by [26] which provide a comparison between expectation of benefits and motivation of implementation of innovative technologies if applied to maintain given factors of construction. The participants of this analysis highly appreciated the implementation of innovative technologies for the management of cost, quality and productivity and consider competitive advantage as most beneficial factor for innovative technology implementation in construction industry.

2.4 Limitations

Construction industry is considered to be at slower pace in case of adoption of the modern and innovative technologies [5, 25, 27] and it is also stated in the research of [28] that in comparison to other fields, construction industry is far behind in adopting the technological inventions until now. According to [5] most of the construction organizations still do not appreciate the benefits which technology solutions have brought in other industries. A survey is performed with 1014 participants from all scales of construction organization by Holt et al. [25] about the technology adoption barrier in construction industry and the participants were asked about the most limiting factor in adoption of newer technology .

In the aforesaid survey, the cost involvement has been found to be the most critical barrier in adoption of technology in the construction industry followed by thinking of the technology as a toy and poor staff support. Lack of leadership interest towards the implementation of technology is also a critical barrier that the construction organizations are still unaware of technology benefits. It has been a well-known finding by the management experts that no new method, policy or technology can be adopted and/or implemented without support and commitment of the top management or leadership of an organization and/or industry. what basically construction industry required in an application, to know the answer to this question, related research is observed here to acknowledge the parameters which are required to develop a specific application which can be used during construction working.

Table 1: Features required for construction application

Authors	Required features for construction application
Rivard et al. [4]	Economical, secure, user friendly, light-weighted, Upgradeable, offline availability with complete tutorials.
Salman et al. [27]	Weather forecasting, collaborative, proper visuals, Help feature.
Holt et al. [25]	New Technology i.e. AR
Yamazaki et al.[29]	Technology integration
Orihuelaa et al. [30]	Field work management.
Forcada et al. [5]	Document management.
Kim et al. [10]	Multi-platform supporter.
Magaba et al. [3]	Tutorials support
Fischer et al. [31]	Project management.

3. Methodology

The methodology adopted for the present study comprises
(1) Selection of AR applications (2) Adoption of CSFs (3) Collection of Data (4) Analyses of the collected Data and (5) Interpretation of Results.

3.1 Data Collection

Finding the right Augmented Reality-based application for building construction is a hustle because none of the famous application store like Microsoft windows app store, Google play and App store by Apple have filters for construction building [27] and most of the Augmented reality applications are registered in gaming, design, and productivity categories. Search of all the available applications in Apple store, Google play and windows app store, which solely deals with building construction and AR, and should be commercially available, as a result found two applications which are specifically design for building construction and using AR for the visualization of their projects. These two applications are GammaAR, and ARki. Analysis and interpretations of results is discussed in section 4 and 5 respectively.

4. Results and Aalysis

We will analyze both applications GAMMA AR and ARki, by comparing the features through construction application parameters, then check usability with the help of heuristic valuation method and then analyze the user rating provided by application store.

4.1 Construction Application Parameters

First, we analyze both of our applications with the help of Table 1 which describes the required features for construction applications define in previous studies.

Table 2: Comparison of GAMMA and ARki as construction application

No.	CSFs / Features	GAMMA AR	ARki
1.	Economical	×	√
2.	Secure	√	√
3.	User-Friendly	×	√
4.	Light-weighted	√	√
5.	Upgraded	√	√
6.	Available offline	√	√
7.	Weather forecasting	×	×
8.	Collaborative environment	√	√
9.	Proper visuals (screen size)	√	√
10.	Maintenance support	√	×
11.	Updated technology use	√	√
12.	Field work support	√	×
13.	Document management	√	×
14.	Multi-platform support	√	×
15.	Complete tutorials for beginners	×	√
16.	Technological integration	√	√
17.	Project management	√	×

Table 1 is giving a general idea of features presence or absence in applications; GAMMA AR provide total 13 features required for construction application and ARki supports 11 of them. Now, we will discuss these features briefly to understand the idea that what more a specific feature required to fulfill the construction application requirements.

4.2 Heuristic Evaluation Method

Now, Heuristic Evaluation Method is applied on given applications to measure the usability of AR in these applications through heuristics with severity rates, which are 0 = No problem,1 = Better if fixed if not then ok, 2 = Minor problem, 3 = Major problem, 4 = Must be fix or provide other way. To perform this method, two evaluators are involved. Each evaluator uses different devices, evaluator 1 use iPhone XS and evaluator 2 use iPhone 11 to evaluate the applications and results of their evaluation are given below:

Table 3: Heuristics severity rate for GAMMA AR and ARki by Evaluators (Ev. means Evaluator).

S. No	Heuristic	GAMMA AR		ARki	
		Ev. 1	Ev. 2	Ev. 1	Ev. 2
1.	Visibility of the system	0	0	0	0
2.	Match between real and system world	2	1	2	1
3.	User control and freedom	0	0	4	4
4.	Consistency and standard	3	4	0	0
5.	Error Prevention	0	0	3	4
6.	Recognition than recall	3	3	0	0
7.	Flexibility and efficiency of	4	4	2	3
8.	Aesthetic and minimalist	0	3	4	3
9.	Error recovery	0	0	0	0
10.	Documentation and help	4	4	0	0

This table no shows the severity rate of evaluators to the specific heuristic of given applications, for GAMMA AR, evaluator 1 indicate 4 out of 10 heuristics as a major issue or need immediate fix and evaluator 2 point out 3 out of 10 heuristics as major problem or in need of immediate fix. In the case of ARKI, evaluator 1 indicate 3 out of 10 heuristics as a major issue or need immediate fix and evaluator 2 point out 4 out of 10 heuristics as major problem .

4.3 User Rating

The last step of our analysis is the user ratings and reviews of applications to measure which application is most desirable for user and why. For this, both applications will analyze with the help of factors required for good user ratings.

Table 4 : Factors effecting user rating of applications

S.no	Factors effecting User Rating	GAMMA AR	ARki
1.	Application size	194.8	249.2
2.	User Interface	Not easy(heuristic result)	Easy(heuristic result)
3.	Application Requirements	1.AR SDK 2.Camera permission 3.Contact info, user content, identity, usage data and diagnostics	1.AR SDK 2.Camera permission 3.No more details provided
4.	Marketing Strategy	Screenshots of different features on platform without details of feature.	Screenshots of feature with title.
5.	Category of Application	Productivity	Art and design

GAMMA AR rated as 3.5 stars out of 5 by 2 users, both users, explain their experience with application in which one user is mostly satisfied with minor issues and expects better version in future but the other one, find it difficult to use the application because of lack of tutorials. On the other hand, ARki rated 5 out of 5 stars by only one 1 user with no review.

As stated above, most of the construction applications used in construction projects do not cover all phases of construction, or only applicable for one task such as building design, scheduling, estimation, and measurements, but for this study, we required applications thoroughly deals all problems of building design and construction and use AR as a solution according to modern requirements. But the number of applications of 3D building construction using AR which are commercially available is so less that any of the analysis method cannot be used in this study, as every analysis method needs a proper data set which is not possible with only two available applications. One of the main reasons of less availability of such applications is the slow adoption rate of AR by construction industry, as s survey is performed by Holt et al. [25] to check the adoption of AR or VR in construction industry companies on which 1014 participants participated and results are as under:

Table 5: Usage of AR/VR in construction companies

Response	No of respondents
Yes	24
No	710
I do not know	208

As it is clearly from above given table that most of the construction organization workers do not have much knowledge or even simple ideas about the AR technology. But it is not something to worry about as it is the fact that AR is a new technology, and it is mostly used for gaming and educational purpose until now. That is the also the reason of lack of methods to check the AR performance in application which limits the results of this study. Both applications GAMMA AR and ARki require devices of updated system and features which is not easy to arrange at student level and both applications in demo version provide a limit for project number and size. Limit of project size makes it more difficult to arrange such project which can fulfil the demands of every feature of application but not exceed the size limit. And, this study only uses the iOS version of GAMMA AR, because ARki is not available for commercial use in android, which limits the data of this study.

5. Conclusion

Technology usage in construction industry can totally change the way of construction working and can provide a great help to reduce the complexity of construction projects. By using innovative technologies, construction industries can increase the effectiveness and productivity of the construction projects. In few years, adoption of technology in construction shows an undeniable progress which will provide great benefits in near future.

Started from the Computer Aided Design (CAD), construction technology is now upgraded to Building Information Modeling (BIM), Cloud Computing and reality technologies in which Virtual Reality (VR) and Augmented Reality (AR) are the popular ones. The CAD changes the way of construction design from traditional paper to digital 3D model, then BIM upgrade this 3D model with the integration of building information in it and Cloud Computing fulfill the demands of construction projects of better and centralized collaboration with huge data storage, and now reality technologies like the VR and the AR totally change the way of project visualization.

Many studies highlighted the potential of AR in construction industry if applied effectively by experts, as it can be a major success for construction working in terms of collaboration, progress controlling, maintenance management, cost and time saving. AR can help all level

workers in construction project such as designer, architecture, engineer, labor, and investor of the project. After AR introduction in construction technology, construction industry is started considering the use of computer applications for the development of construction projects.

This study only considers construction applications which are using AR, but there are many construction applications using BIM and VR present for android, iOS and windows which can also be analyzed in future research. Also, this study does not have a proper feedback from the user of applications which can also be consider in future research. And analysis like qualitative approach and quantitative approach can also be done in future when there are more applications for construction working using AR will introduce. Also, this study does not consider any hardware application of AR used for building construction because of limited resources, which can also be consider in future research.

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