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REVIEW ARTICLE - ENGINEERNG TECHNOLOGY

Augmented reality in smart cities: applications and limitations

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Abstract. Intro: This paper presents an advance overview of utilizing Augmented Reality (AR) in smart cities. Although, Smart cities contain six major aspects (mobility, economy, government, environment, living, and people), this paper focuses on three of them that have more potentiality in using virtual assistant (mobility, environment, and living). **Methodology:** Presenting a state-of-the-art review studies undertake between 2013 and 2017, which is driven from highlighted libraries is the aim of this research. After exact examine, 15 emphasized studies are chosen to divide the main aspects while 120 selective articles are supporting them. These categorizes have been critically compared with an aim, method and chronological perspectives. **Results:** First of All, Environmental issues (Museums industry) attract the most attention of researchers while the living issues (maintenance) have lower significant compare t latter and mobility (indoor-outdoor navigation) attract the least. Moreover, a close connection between academic and industry fields is going to be created. **Conclusions:** it has been concluded that, because of economic advantages, utilizing AR technology has improved in the tourism and maintenance. Moreover, until now, most of studies try to prove their concept rather than illustrate well stablished analytic approach. Because of hardware and software improvement, it is essential for the future studies to evaluate their hypothesis in a real urban context.

Keywords: Augmented reality, smart cities, mobile device, smart environments, living and mobility.

1. Introduction

An Augmented Reality (AR) system can be defined as a coincident combination between a real world and virtual objects – which can interact in real time –and has three-dimensions virtual object registration [1-3]. Recently, the human perception of the environment has changed a lot with modern technology. AR is the most prominent technology in this regard, it adds virtual information to real environments and effects on user cognition [4, 5]. AR augments virtual intangible information to the tangible world. Day to-day, this combination affects on how we live. It can be useful and popular because AR apps recently are well progressive in hardware and software [6].

The vast population migrates from rural to urban in recent years; moreover, it will continue for some further decades [7]. During this growth, cities face different obstacles and issues. Smart city concept can be a great idea to overcome with them. As a whole, smart cities try to enhance and to improve the novel interaction between citizen and their city. Internet of Things (IoT) is the main feature of smart cities. It connects devices, sensors, and people together. Consequently, a new window to observe the information and connections created by IoT is essential. AR technology creates an intuitive, contextual and immersive way to depict and superimpose various data in urban context. Due to the fact that every city has its own population, demographic and geographic status, the concept of smart cities does not have a single and distinguishable definition. On the other hand, smart cities have common aspects within different cities. These similar demands are excavated by Giffinger [8, 9] that is adopted in various studies [10] with different aims and strategies. As a conclusion, Torres-Sospedra summarized all of the aspects of these factors: Smart Governance, Smart People, Smart Economy, Smart Environment, Smart Living and Smart Mobility [11]. These factors contain the main component of smart cities concept [6]. This review of the literature highlights the implementation of AR technology in smart cities with thanks to smartphone development. The following questions show the special issues of this review:

- In what subjects, AR can be used in smart cities?
- Which aspects of smart cities have more potentiality in the industry?
- What equipment is needed in smart cities AR application?

The next two sections of the paper are devoted to provide definition of AR as well as examples. In the Following, a review of literature of studies that have used AR in smart cities is offered. In the last section, we discuss the findings of the review of the literature alongside implications and recommendation for future research.

1.1 Definition

Milgram presents AR as "reality – virtually continuum" that encompass real and virtual environment [12]. Adding virtual information to the real environments with a computer is another definition of AR [13]. Superimposing information to the real environment can be a great advantage in smart cities. The major objective of smart cities is to connect everything together and to people. Consequently, AR technology can help citizens to have an instant and immersive connection with everything around them.

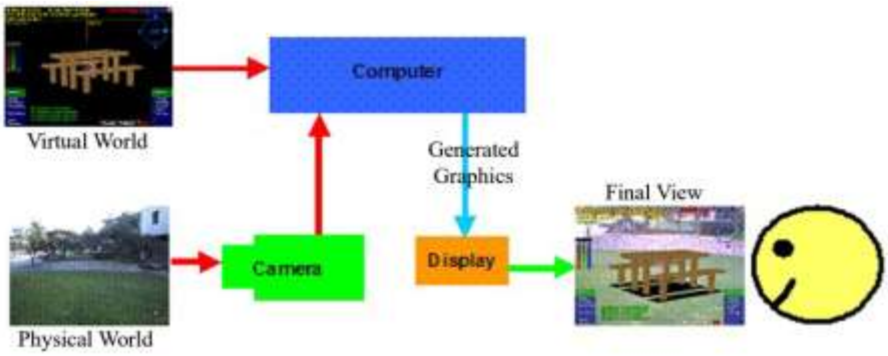

Figure. 1. The process of AR, Source: [3]

Real objects can also be removed using AR technology which is named as Diminish Reality while Azuma [14] has called it sub-component of AR. Marketing, an illustration of a 3D form of manufacturing products and design really are the main component of AR [13]. AR is adding real world with virtual elements. It is great virtual help for designing issues within a team of them. It can help urban designers to visualize and assess urban design in real and interactive platform [15]. AR uses in diverse fields. Its benefits have been widely using in architecture and urban design studies [16, 17]. Interior experience is also in high demand.

Many studies show European almost pass 90 percent of their daily activities in indoor spaces [18]. Also, its benefits have been demonstrated in interior design [19]. Some studies focus on using AR in built environments; however, Wang [20] find out that most of them just present a new concept and cannot adapt themselves to industrial demands. Currently, AR apps is trying to approach toward industrial condition and focus on the commercial sector. Enormous progressive in hardware and software in AR architecture and engineer are widely used in solving architectural issues [6]. By 2050, almost three-quarter of earth population will concentrate in an urban context. Consequently, a quick improvement is essential in the economy, creativity, and environments [21].

1.2 Smart Cities Structure

Using sensor and all communicable technologies in cities with the aim of enhancing quality, effectiveness and procedure life is the unique acceptable definition of smart cities. Nowadays, Smart cities and AR can open new windows in the life of the citizens and can solve some problems caused by rapid urbanization. It also helps authorities to make better choices; what's more, it creates new business opportunities. Navigation is another field of utilizing AR in cities. Most of the studies present and examine their navigation application on the university campus and conclude positive respond [22]. Currently, some academic and industrial illustration declare a great enthusiasm in implementing AR into tourism industry [4]. Furthermore, the people declare great acceptance with using AR technology in tourism industry [4, 23]. AR introduces new applications; furthermore, people use this technology and their apps for evaluation user experience. Some studies have concentrated on both views[24]. By 2020, smart growth is one the most priorities that encompass augmented reality project to combine sounds and videos to real world [18]. On the other hand, Salvini disagreed with too much use of technology in urban context [25]. Google Glass along with AR is one the most prominent technologies that creates interactive interaction with the city [26]. More specifically, the designer uses Holones to actualize and to cooperate their concepts [27]. AR is more than just adding info to the real world. It growth to social interaction and changes the way people behave each other in a certain place [28]. The implication of AR in architecture starts from education to real and professional usage [29].

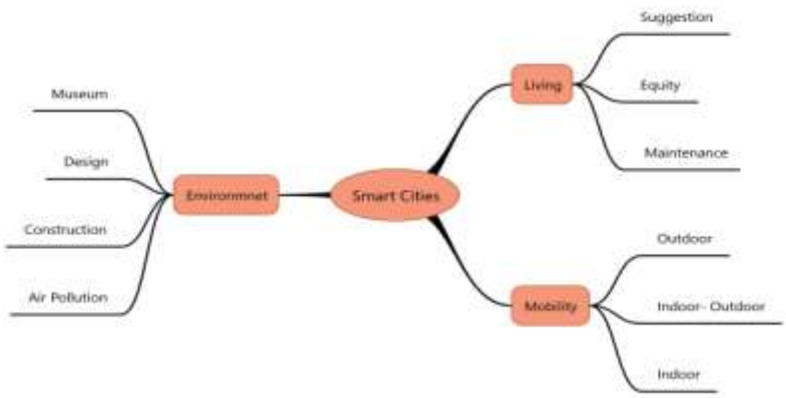

Figure. 2. Smart cities sections and components, Source: Authors

2. Methodology

This paper establishes a literature review with three main keywords of "Augmented Reality and/or Smart Cities", "Augmented Reality Smart Cities" and "Augmented Smart Cities" in the period of Jan, 2010 to May, 2017 from the database of Science Direct, Google Scholar, Taylor and Francis and IEEE. We only consider those articles that have a high level of innovation and industrial adaptation perspective. Selected articles produce an application for smartphone or tablets within their process or as a conclusion. Also, as it can be seen in figure 1, the Smart Cities selection studies are divided by three main sections and ten components.

2.1 Environment

Museum

Heritage building is usually damaged by natural and some other factors. Cognition of demolished heritage building is sometimes difficult for tourists. They, therefore, need a visual assistant to complete their imagination. Consequently, Younes [30] presented a method to reconstruct missing part of heritage buildings; additionally, this method enhances the cognition of tourism with AR. Moreover, many other studies use AR in museum industry. There are some examples which can be mentioned for better understanding of this concept. First of all, ancient objects and art crafts have been simulated for any later interaction by 3D reconstruction[31, 41]. Furthermore, using AR leads to giving information about historic graffiti [42]. Last but not least, it can enhance the time consumption of paintings visitors [43] or create an interaction with them [44]. AR in the museum can also be used to give POIs suggestion to visitors [45]. Han et al. [46] have used AR in robotic tour guide to augment multimedia elements as virtual 3D objects, movie clips, or sound clips to real artifacts in a museum. Also, Kundu[47] used AR in indoor navigation. Moreover, Thon [48] proposed a AR serious game in historical places to enhance tourists interaction. The combination of AR in museum is also interested for the various researchers [46-51]. In this way, Novotny[49] declares that AR can be used widely in education and entertainment. For example, Blanco-Fernandez [50]creates an app (REENACT) to augment battles for learning aim. Wojciechowski [51]also used it in learning progress. More specialty, Barry [52]employed AR in Natural History Museum in London to illustrate extinct species like dinosaurs. Takahashi [53]used AR for child visitors to Gamagori Museum of Earth, Life and the Sea. Besides visual, Damala [54]also includes voice augmentation. The methodology of superimposing virtual objects on real museum environment is divided into two parts of the indoor and outdoor environment. For indoor spaces, Rattanarungrot[31] proposes a marker-less methodology tracking system. While Choi [55]used beacon for marker-less indoor navigation ; moreover, Jevremovic [56]used marker base QR code. Afif [57] investigated on rapid movement in outdoor spaces, while Han [58]used GPS for navigation in this spaces [58]. Finally, Gutierrez [42] employed a questionnaire for analyzing the functionality of production.

To sum up, various studies show a positive conclusion from the implementation of AR in museum industry [59]. By the way of illustration, Younes [30]decided to test their application to extend their case studies in other historic sites, The beneficiary of AR in both tourism and historic teaching is also reported. Moreover, Cianciarulo [60]declared many visitors come to the museum just to try AR and interestingly the results were very positive especially among the kids. From a location focus, the benefits of AR was tested in Oslo and London. The results showed a positive outcome [43, 61]. Kourouthanassis[62] also investigate functional system properties, user emotions, and adoption behavior and get a positive. Along with user satisfaction, the economic beneficiary is also significant for the future of this technology in the tourism industry. Dieck[63] demonstrated the economic beneficiary for stalk holders to implement AR in museums in the UK. With popularizing this pervasive technology in tourism industry [59], we can bring history to our daily life [64].

Design

Cirulis [32]presented a new app to depict a 3D of the virtual building which can be seen from different angles and distances. Hui[65] presented an app that located virtual decoration in interior space. Vassigh[66] proposed and provided an app that created an opportunity for Architecture, Civil, and Mechanical Engineering students in outdoor augment BIM, Ruwanthika[67] put the virtual model on a house plan, while Cho

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[68]facilitated and enhanced to putting single 2D images on building façade. Furthermore, for this aim Redondo[69], presented a new practice (MLAR) to put architecture virtual model in real view. Further efforts have been done. Fonseca[70], what's more, tried to implement virtual architectural model and projects in a real environments. In another study, Redondo[71] employed AR architecture and planning models. In conclusion, Cirulis [32]found that using AR in designing filed can have some advantages for authorities, planner, and architects companies, municipal and markets. Also, Hui [65]concluded that because the customer can have an interaction with a virtual illustration; consequently, it helps them for a better decision making. In academic achievement, Redondo[69] concluded that this system can be useful in the depiction of virtual architecture and urban design projects, construction project, heritage studies and enhance public participation. Fonseca [70] found that AR can lead to the academic achievement; additionally, it can noticeably enhance the student motivation. Also, Oleksy[72] showd a positive correlation between game satisfaction, social interaction, and place attachment.

Construction

Vert [21] produced an AR application that enable citizens to recognize the owner of under-construction building around their point of interests and recognize, how the building will be formed. Similar researchers also focused on using AR in construction, for example, Kim[73] proposed an app that illustrat construction project in the real environment. Moreover, Behzadan [74]put virtual objects in an augment scene. Kirchbach[75] introduced an application for an intuitive information on construction sites. Behzadan[76] ,furthermore, produced multi-function app that can superimpose virtual animation in a real construction building. Additionally, he [77]presented an AR app to illustrate virtual construction components in both indoor and outdoor spaces. Moon [78] enhanced the recognition of workers from construction site by an AR app. Lee[79] used the same method to decrease the errors in a construction site. Zhou [80] ,moreover, applied the benefits of AR in the construction of tunneling site. Because of rapid and diverse studies in this field, Gruber [81]presented a global and standard platform for any further AR studies in construction sites.

Vert and Vasiu [21] utilized GIS location system to illustrates virtual data on real under construction building. In constrast Kim[73] used GPS and marker base AR methodologies for indoor construction sites. In a combination of both Behzadan [82]tracked user location in indoor space with Wireless Local Area Network (WLAN) and outdoor space with GPS. Gheisari [83]had a different view. He exchanged registration and location tracking systems with a semi AR panorama view. Kim [73,84] decided to facilitate choosing construction methods to reduce design and operating errors with AR technology.

Air Pollution

Because of rapid urban growth, environmental factors become important in recent years. Pokric and Andres [33, 85] presented a novel apps to enhance citizen awareness about climate conditions of cities. Furthermore, Xiaojun [86] evoked IoT to track environmental issues. After the data captured from an online resources, Pokric [33] formed the results in an AR maker-less avatar, which citizen can observe and have an interaction with it. Maia [87]presented an app, that aid non-programmer users to build the location-based AR games.

There are many various methods to collect air conditions, for example; Pokric and Dutta [33, 88]preferred wireless sensor network (WSN), Boubrima[89] used WSN because of its cost beneficiary and autonomy, Rushikesh and Vong [90, 91]used RFID technology, Manna[92] proposed a complex system of RFID and WSN. Moreover, the level of collecting the data is divers between researches and methods, to some extent; Siregar [93]collected dust, humidity, light intensity and level of sound voice, Baralis [94] not only collect data about the air pollution but also gather meteorological and traffic data and pollutant concentration. Manna [92]

,additionally, detects pollutant vehicles in town and analyze its pollution type. Dutta [88]declared that his system is capable of collecting gass, smoke, and the pollutions dada.

Rushikesh [90] tested the feasibility of his app with 19 users and got the positive results. Pokric[33] not only presented the app to examine group and observe the usability but also asked an open comment. The beneficiary of depicting air conditions data with AR technology is confirmed by Pokric[33] and he believes it will be more effective in entertainment and education domains. The effectiveness of the Pokric app has demonstrated in both indoor and outdoor spaces [33].

2.2 Living

Suggestion

Depicting the available properties in augmented perspective was the aim of Macedo [34]. In short, Macedo presented an app that illustrates the real estate classified ads in an augmented perspective to enhance decision making quality. In similar interest, Balduini[35] presented an android AR application to shows the rating of nearby restaurants. Customer shopping behavior was also studied by Pantano [95] in an AR system. Furthermore, customer behavior has been studied by Wafa [96].

Collecting the data is a diverse issue. First of all, Macedo [34] created a website, and asked the users to upload their information, pictures, and location. Balduini [35]collected and analyzed 200 million tweeters within 3 years that showed positive, negative and neutrally opinion about a restaurant services. Kourouthanassis[62], additionally, analyzed emotional attributes of user in AR app. Because of rapid and divergent growth of studies in this field, finally, Georgiou [97]presented a standard questionnaire for measuring immersion in future AR app. Rese[98] showed the level of good satisfaction with using AR technology among shopping mall costumers. Furthermore, Dacko [99]showed the same benefits for retailers costumers.

Equity

The main aim of smart cities is to offer the same level of facilities to all citizens. Consequently, some researchers tried to utilize AR technology to facilitate disabilities activities in smart cities. Oliveria [100] proposed a navigation system that calculates and facilitats rout suggestion for disabilities. Rashid [36] declared that the design of shopping and library shelves do not let disabilities freely interact with items. So he created a system, with RFID technology, that enable disabilities to detect the availability and location of items in the shelves [36]. Lee [101]invented an app to help elderlies to have a better mental 3d orientation skills. Covaci[102] created a novel assistant app for cognitive disabilities. Burke [103]also stablished an app that use AR technology to help people with stroke disease. An innovative app help disabilities by translating pics intro sound, this app has been created by Hrytsyk [104]. Furthermore, Mirzaei [105]presented an app that helps deaf disabilities by converting voice of speaker into readable text on AR display. Alongside of physical disabilities, AR can also helpful for mental health. AR can helpful for treatment of physiological stress disease [106]. Vinumol [107]produced an application that augments marker base text book with graphic presentation and sound for disabilities. Colpani and Homem[108] combined gamification with learning process for disabilities.

Maintenance

Maintenance is one the most operational field in using AR. The aim of this content is to enhance the efficiency of industrial maintenance [37, 109] and decrease the time consumption and error during the process

[110-112], by putting contextual or animated virtual content on the specific equipment [37, 113]. Various studies choose this well growing topic. To some extend; Lima[114] focused on maintenance of vehicles by the help of AR. Neges [115]employed AR in maintenance of pipelines. Benbelkacem[111] also helped repairer to enhance their capability and decrease the risk of the accident. As it can be observed, employing of AR in learning maintenance has a great potentiality. For isntance, Fiorentino[116] presented an AR app that trains maintain and assembly skills. Abramovici [117] produced and app that not only helped maintainer to repair the machine but also create an opportunity for AR based team collaboration.

Yew[118], furthermore, used AR in remote maintenance with robots. Programming knowledge is known as the most crucial issue in using AR, accordingly, in Erkoyuncu [37] study an app is crated, which let technicians use AR in maintenance while they don't have a previous programming knowledge. Ramirez[119] produced a program which let companies to create their AR maintenance app without the need of programming skills. In this section, most of researcher end up their studies with applied application but an exact examine cannot be observe. Schall and Garza [38, 120]demonstrated that using AR take a shorter time than a paper guide. Ramirez confirmed the same results and declared that using AR in maintenance is 30% faster than traditional paper guide [121]. Also, Benbelkacem [111]showed time-saving and flexibility features. Also it should be mentioned that, maintainer which educated by AR, present a better performance compare to those who educate with normal paper guide. Because of AR complexity procedure in maintenance, Palmarini[123] believed that solo text illustration is more feasible.

2.3 Mobility

Outdoor

Huang[39] used AR in outdoor pedestrian navigation by introducing a new approach. This method combined GIS and virtual objects registration. Siu[124] , moreover, presented an outdoor AR navigation for firefighters. Abdi[125] created a novel system to illustrate marker-less traffic sign and weather condition to drivers. Similarly, Yoon[126] focused on analyzing using AR in car navigation. He [127]had a wide view in the close future, and proposed a system to caution the driver about unseen obstacles and proposed a visual and audio warning system by the help of AR. likewise, Jaeyong [128] suggested a new concept for illustration the naval information in AR format. The most prominent problem in outdoor tracking is the accuracy of location. Therefore, Li [129]enhanced the accuracy of GPS for his purpose. In an outdoor tracking system, Azuma[130] presented a new tracking method in outdoor spaces with using beacons. It should have mentioned that using PGS and IU equipments in the outdoor environment, may cause some errors[39]. The introduced AR GIS system by Huang and Shi [39, 131]showed a practical and successful registration in an outdoor environment. Consequently, there is great demand in research that implements object tracking in outdoor spaces [39]. A full biography of tracking methods can be found in Daponte research [132].

Outdoor-Indoor

Torres-Sospedra[11] tried to present a method for both indoor and outdoor navigation. Weng[133] presented and upgraded an algorithm to enhance rotation, scaling and translation of objects in AR markerless system. The app allowed users to locate him/herself on campus and interact with the environment to find a point of interest (POIs)[11]. Afif [57]cautioued that fast motion can interrupt this markerless system. Therefore, it can be observe that AR tracking system is an essential issue [134].

Indoor

Subakti [40]focused on the indoor navigation system and proposed a marker-less AR app (ENGFIGATE) to navigate fresh students in the smart campus. Kundu[47] proposed a novel AR indoor navigation system for a wheeled robot which can use in museum and shopping malls. Some researchers has fresh view in indoor navigating, for example, Mahadik [135]presented an indoor navigation system in the library to help borrowers to find the proper book and navigation him/her to the shelves. Kuo[136] proposed an AR indoor positioning system that can track user location and their angles of vision to create a high adaptability space . The accuracy of user position is satisfactory but will it should improve in future studies in the context of smart cities [40]. Subakti [40]compared the AR indoor navigation system with tradition way finding methods and found that AR is more feasible and beneficiary.

3. Discussion

After categorizing smart cities in sections and components, this study tries to collect all applicable articles on each part. Finally, 116 highlighted researches found. These articles summarized and then critically analyzed. In this section, we aim to deepen the knowledge of Augmented Reality in “Smart Cities” content by analyzing the number of articles that have been allocated to each section and components. This quantitative analysis can help us to recognize the degree of importance, potentiality and gaps in each parts. As it can be observe in Figure 3, a comprehensive analysis to illustrate the potentiality and gaps in each major sections of smart cities is presented. Environment section attracts the most attention of researchers by more than half of all articles by 52.5% (61 articles). The living section that usually relates with the everyday life of citizen has acceptable but lower degree of attention by 31% (36 articles). Only 16.3% of whole articles focus on mobility issues. So it cannot attract the researchers’ attention (19 articles).

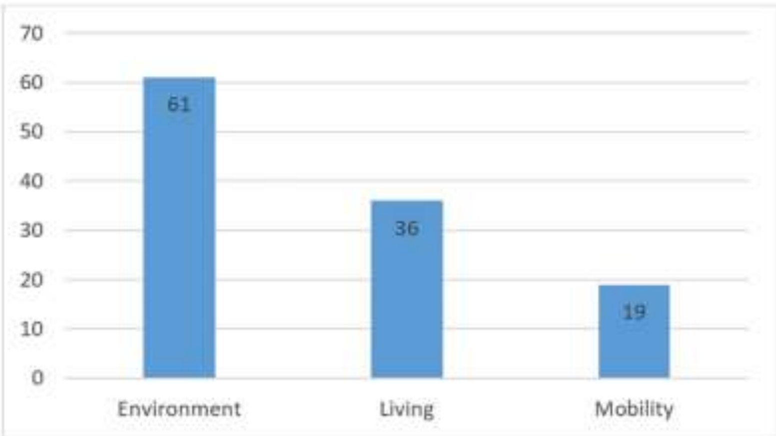

Figure. 3. Number of articles in Smart Cities sections, Source: Authors

After the sections analyze, now it is time to have a deeper look their components and find their attraction for researchers. Although table 2 give us a meaningful information about the potentiality in Environment, less attention on Living and gap of knowledge in Mobility sections, the component does not necessarily obey this categorize. In this part the number of articles that allocate to each component sort and analyze without the consideration of their main categorize. As it can be notice in Figure 4, the most attractive component in all three main sections is “Museum” that allocates almost a quarter of all consideration 22.4%. The next well flourish component is “Maintenance” with 14.6%. With a closer look, it can find that museum and maintenance can attract 40% of all attention. The main reason of this attention can find in economic advantages. Built environment components such as “Construction” 11.2% and “Design” are another well industries also use advantages of AR in their aims. Environmental factors is also become important in recent years and “Air pollution” located 9.4% of whole articles (the same as “Design” component), and it shows the growing concern of about this issue. As it can hypothesis, those components that have a less economic perspective, also, has a less attraction in AR. For instance “Outdoor mobility and equity” 8.6%, “Suggestion” 7.7%, “Indoor” 4.3%, “Outdoor-Indoor” 3.4%.

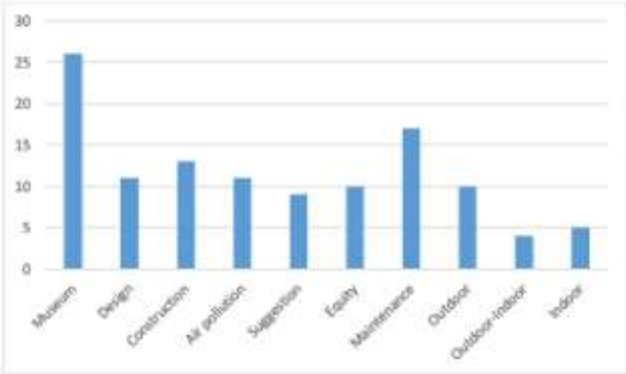

Figure. 4. Number of articles in Smart Cities components, Sources: Authors

3.1 Chronological Analyze

Although some valuable information can be attain with analyzing the number of articles based on sections and components, but to verify its outcome a chronological analysis is indispensable. This method is helpful to understand, investigate and track the growth of each component in recent years. As it can be observe in table 5, although “Museum” contains most of the studies in all times but “Maintenance” has more improvement in last years and attract the most attention in 2017. “Suggestion” and “Construction” together has the third stage. On the other side, in mobility section, the combination of Indoor-Outdoor navigation did not attract any attention in 2017. From Figure 5, some new interesting information can be extracted, only 15 researches have been done in 2011 and before that, and it seems that 2012 is a millstone and starting point in AR studies. This growth became faster in 2013 and improve each year to 2017 that is the most published year.

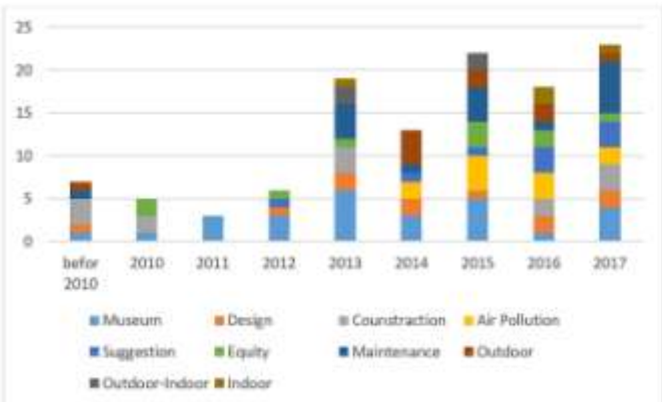

Figure. 5. Number of articles based on year of publication, Source: Authors

With keep the above information in mind, some major finding can be inference:

As compare to other components, Museum and Maintenance have received most of the attention in smart cities domain. 116 articles were identified as the AR work in Smart Cities between 2010 and 2017. Most of the articles for AR in smart cities were published in following journals: "Automation in Construction", "Computers in Industry", "Computers in Human Behavior" and in IEEE conferences. Most of the reviewed papers successfully implemented their concepts in a control group and environment. Which implies that the AR technology has matured enough to come out academic shelf and prepare for a practical and professional environment. The majority of articles focused on proofing their concept and concluded their successful implementation rather than illustrate the pros and cons of their ideas by worthy detail.

4. Conclusion

This review details the wide variety of smart cities applications for which AR systems are now being developed and tested. The published studies mostly use control environment toward testing the feasibility or proof of concept. This kind of approach is acceptable in the early stage of starting a system, but after years of investigation in AR, it is time to implement it in the real urban environments. This is applicable if the researcher or developer is fully familiar with the scientific rationale behind their app. Although some researchers try to use AR in real urban content, many of research area is remain unexplored and several questions remain unanswered and feasibly of the app are under question. Based on this gap, it can conclude that smart cities have great potentiality for vast studies to implicate AR in Smart Cities and as result connecting this two technology requires much more innovative attention.

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