AUGMENTED REALITY SYSTEM APPLICATIONS IN CONSTRUCTION PROJECT ACTIVITIES

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ABSTRACT

The firms in construction industry could not sufficiently adapt the rapidly emerging information technologies in recent years into their corporate structures. Therefore, in an effort to further exploit the benefits of information technology (IT), integration of the experiences and backgrounds of construction industry and the advantages of IT, is one of the most open-ended fields for improvement in this industry. Utilization of IT in the construction sites will positively affect the efficiency, productivity, quality and health & safety issues in the construction sites thus the cost and completion time of the projects. Within this context, augmented reality technology, which brings a new perspective into IT, can be put into the service of construction industry. Augmented reality which has been designed to improve the services in many application domains such as school education, military warfare, military trainings, industrial maintenance, retail and medical, can be defined in the simplest form as augmenting the real world with information from the virtual world. The main aim of this study, which presents an overview of an ongoing project, is to develop an innovative method by making a construction worker, foreman, equipment operator or a site engineer watch a very comprehensive and informative animation which will enable the said staff to perform or supervise all the phases of the activity he or she is in charge for in a more efficient, productive, safer and qualified manner by means of smart glasses using augmented reality systems. In this respect, training material related with the activities in the construction sites will be prepared and with a well-fictionalized scenario, animations exhibiting all the phases and details regarding the related activity (e.g. masonry, formwork and rebar works etc.), method of statement, correct and incorrect applications in comparison-wise manner, will be produced. Therefore, the user will be able to reach the training material, method statements etc. in the animations about the activity he or she is in charge for, enabling him or her to figure out the work as prescribed in the specifications. Basic trainings about the system will be given to target group, i.e. construction workers, foremen, operators, site engineers and managers working in the construction sites to apply the system on sites after all the system was tested. After the testings, to determine the effectiveness of this system, semi-structured interviews and survey questionnaires will be conducted among the mentioned target group. Therefore, the potential benefits of this system to the construction industry can be determined. The main target of this study is to implement an efficient, thorough construction management by orienting the staff in the construction sites to perform efficient, safe and qualified works by means of smart glasses that use augmented reality. There are relatively few studies about the implementations of augmented reality technology in construction. The outputs to be attained in the end of the study have the potential of improvement of time, cost, quality and safety parameters by ensuring a qualified, safe, efficient and productive construction management via augmented reality technology in the construction industry.

KEYWORDS

IT in construction sector, augmented reality, smart glasses, efficient construction management

INTRODUCTION

Insufficiency of existing infrastructure for the increasing population & urbanization and substantial rise in the necessity of power and energy worldwide can be regarded as an indication of investments to be made in those fields for the upcoming decades. In the future 40 years, it is estimated that the approximate total cost of infrastructures will sum up to 70 trillion US Dollars (Armstrong, 2012). Successful completion of infrastructure & energy and power plant projects require a high efficient and well-rounded organization with specialized technical staff.

Information technology (IT) has become a key element of any organizational infrastructure. There is a perception that the level of an organization's dependence on IT in the twenty-first century is similar to the reliance on electricity in the previous century (Alshawi, 2007).

The construction firms could not sufficiently adapt the rapidly emerging IT in recent years into their corporate structures. Therefore, in an effort to further exploit IT, integration of the experiences and backgrounds of construction industry and the advantages of IT, is one of the most open-ended fields for improvement in this industry. Utilization of IT in the construction sites will positively affect the efficiency, productivity, quality and health & safety issues in the construction sites thus the cost and completion time of the projects. Therefore, it has almost become a mandatory situation for the companies to integrate IT into their business environment efficiently to sustain competition within the industry.

In this study, the main objective is to develop a system in which smart glasses will be developed and utilized by making use of augmented reality. The target is to enhance construction management by developing the said system and giving training to the construction professionals about the system. The target group i.e. construction workers, foremen, operators, site engineers and managers working in the construction sites will be introduced to use the system on the jobsite via augmented reality and thus an innovative method will be put into the service of construction companies in order to better execute and accomplish the infrastructure, energy and power related projects which require advanced qualifications.

Wang and Dunston (2007) defined augmented reality as a technology or an environment where the additional information generated by a computer is inserted into the user's view of a real world scene. A simpler definition of augmented reality is given as augmenting the real world with information from the virtual world by Cleveland, Jr. (2011).

This study presents an overview of an ongoing project. In this study, the staff from target group, prior to commencing an activity they are in charge of performing, will watch an informative and comprehensive animation through smart glasses in which all of the phases of that activity in conformance with international best practices, method of statement related to that activity and mistaken and correct implementations in a comparison-wise manner will exist. To accomplish this, augmented reality technology will be used through smart glasses. Accordingly, more efficient, effective, productive, safer and higher quality works will be carried out. For example, by this way a novice construction worker charged in a viaduct construction project not only will be able to learn how to bend and place rebar in the formwork before concrete casting, but also will acquire the awareness of the requirement to use the safety belts while performing pier cap formwork activities over the scaffoldings. Similarly, a hi-up crane operator working in a pipeline project will be able to learn the weight of the pipes to be placed in the trench together with the capabilities and safety aspects of the equipment that she/he is operating, by means of the smart glasses which will augment the real conditions on the job.

Moreover, a foreman working in a housing project will be able to instantly check out the ratio of the plastering materials to be used in the mixture in a building project where high-performance isolation is required and similarly, while pouring concrete in cold weather, a site engineer responsible for concrete works will able to reach immediate data about the technical properties of the set accelerating admixture and the ratio of the admixture to be used with respect to the unit concrete volume through the animations they see through their smart glasses and ensure that the mentioned activities are performed accordingly. By this way, they will not only minimize the risks inherent in the construction activities but also reach the targeted quality standards together with health and safety goals.

Since smart glasses are run by establishing connection with an external monitor, in addition to the comprehensive animations, documents such as drawings, specifications, employer's requirements, conditions of contract, quality execution plan, health and safety goals will be accessible through those smart glasses. Moreover, web browsing and navigation features will be added. Site engineers and department managers will be able instantaneously monitor the specifications and quality standards to check out and supervise the activities on the job by using augmented reality technology through smart glasses. They will also enable the staff to communicate by means of short messages and e-mails in addition to the

above-mentioned innovations of smart glasses in construction sites. In other words, smart glasses will make significant contributions to construction practitioners on site changing according to their responsibilities and authorizations from different levels irrespective of their educational status. One of the most important points in utilization of smart glasses in construction site is its minimization of loss of money and time stemming from the confused staff on the job going back to the office in order to have a look at and make sure that the drawings, specifications and standards etc. are in conformance with the activities performed on the site and then going back to the site with a convinced mindset or making a telephone call with a colleague in the office to ask for the desired data related with a problem encountered on the site. The products of this study have a great potential guiding other sectors such as mining and manufacturing in which efficient project management and productivity are of vital importance.

Augmented Reality blurs the real world with computer generated one by augmenting what we see, hear or smell. Augmented Reality which is far closer to the real world compared to the Virtual Reality enhances the existing reality by adding graphics, audio, haptic feedback and smell into the natural environment without changing its origin (Bonsor, 2001). Augmented Reality can be regarded as the child of Virtual Reality whose most simple and widest definition is simulation of a 3D environment in the computer (Cleveland, Jr., 2011). However, construction industry is one of the leading sectors which do not make use of this promising technology. Ever-growing hardware developments and tracking technologies should motivate utilization of augmented reality based applications in construction industry (Wang & Dunston, 2007).

Having entered 21st century, construction practitioners have a tendency to build much more complex buildings. With building management systems including electro-mechanical systems, buildings seem to have even more complexity. Since there is a need of the specialized construction workers, more and a various set of workers is walking around on the construction site. Additionally, increasing time pressure to construct a building as fast as possible and it becomes evident that it keeps getting more difficult to acquire a clear overview of the work in progress for each of the construction site staff involved. This in turn results in higher costs due to construction failures. Moreover, severe security risks of the building and on the construction site will rise in great deal (van Berlo, Helmholt, & Hoekstra, 2009). To overcome these above-mentioned problems it became necessary to support construction workers by providing them with real-time and accurate information about their ever modifying surroundings and the task in their charge (van Berlo et al., 2009). Here where augment reality steps in. Visual augmented reality presented in the study of van Berlo et al. (2009), can be used in three categories; in situ experience, in situ verification, in situ warning. “In situ experience” enables seeing the real construction site with virtually constructed building superposed in the same place before construction of a building is commenced. Therefore it becomes possible to monitor how the building fits with its surroundings before constructed and how it influences the landscape etc. (van Berlo et al., 2009). Figure 1 exemplifies “in situ experience”.

Figure 1 - Augmented reality applications in construction projects (in situ experience)
(http://www.augmentedplanet.com/2010/08/the-worlds-largest-augmented-reality-project/)

In situ verification is used in order to carry out more effective and accurate inspections of the construction site. A 3D construction map could be projected on top of a construction site and an inspector could then visually check if the intended design is in conformance with how the work was actually carried out. For example the correct placement of reference poles for brick-laying could be checked by this way. This does require a great accuracy (van Berlo et al., 2009). Also a control engineer can check the rebar placement before the concrete works by overlapping the drawings over the real conditions on site to prevent any errors likely to cause failures. Figure 2 is an example of in situ verification with augmented reality.

Figure 2 - Augmented reality applications in construction projects (in situ verification) (Van Berlo et al., 2009).

In situ warning with augmented reality can enhance the occupational health and safety management in great deal by means of a more alarming, interruptive and real-time attention-attracting warnings in order to prevent any accidents (van Berlo et al., 2009).

As seen, utilization of augmented reality in above mentioned 3 categories, conformity of any construction project with its environment can be monitored and assessed before construction phase and in case any revision is required, it can be realized without incurring any costs. Moreover, construction projects can be inspected in terms of parallelism between the intended design and the actual performed work at any stage of construction. Quality and health and safety management of the project can also be improved by means of augmented reality.

Advancements in computer interface design and hardware have enabled developments of augmented reality prototypes and testing applications in architecture, engineering and construction. However, most of them are developed by computer science and/or electric electronic engineering researchers who randomly selected construction and engineering fields as testing scenarios to evaluate the feasibility of their augmented reality concepts. Consequently, further development of those prototypes to field experience has usually been a lacking point (Wang & Dunston, 2007). In order to remove this lacking point, researches could be carried out jointly by researchers from the fields of computer science and/or electric electronic together with architecture, engineering and construction researchers.

Within the scope of this study, 10 prototype construction activities will be selected from the most common activities existing in infrastructure projects (dams, motorways, railways, pipelines, bridges, tunnels, subways, domestic water and sewerage systems, sea outfalls, ports and airports), power and energy projects (hydroelectric power plants, energy transformation plants, nuclear plants and wind energy plants),

housing and residential projects, and industrial plant projects (cement, iron and steel plants). For example, construction activities such as masonry, shuttering works, rebar works, concrete works, plastering works and excavation works will be selected. A database will be prepared for these selected 10 prototype construction activities in which there will be trainings and elaborated methods of statements. This database will be able to provide the target group on site with an informative animation and required data regarding the construction activity at hand. In the animations all phases of the construction activity will be visually described step by step taking quality health & safety issues into account. Therefore, not only erroneous construction activities will be avoided, but also cost efficient project management with prioritized quality and safety aspects will be performed.

In this study, target groups who are charged in ever getting complicated construction sites for performing or supervising an activity will be able to watch an informative, comprehensive animation including training materials, method statements demonstrating all phases in detail about that activity by extracting the related animation from the database. This will be possible by using smart glasses using augmented reality. As a result, construction activities carried out and supervised in a more effective, efficient, qualified and safer manner will create a positive effect in the whole project and lead to a better project management. In addition to the informative and comprehensive animations, documents such as drawings, specifications, employer's requirements, conditions of contract, quality execution plan, health and safety goals will be reached by the user through smart glasses depending on his/her responsibility and authorization. Moreover, smart glasses will enable usage of web browsing and navigation etc. All the services brought by smart glasses using augmented reality will train a newcomer construction worker, foreman, and engineer in a fast and low cost way and will enable him to integrate with the project in a short time. By this technology, experienced target group will also have a chance to improve their performances by correcting the mistaken activities that they have been assuming as correct or they will be able to learn further details and hints without the need of asking anyone but by just watching the animation through smart glasses. Furthermore, the quality and health & safety issues which are regarded as secondary or even lower priority issues in construction sites will be brought to primary importance by means of the said animations in which impressive and recollective scenes exist about health and safety issues. Site engineers and department managers will be able to instantaneously communicate via smart glasses (by short messages and electronic mails) in addition to the above-mentioned smart glasses activities hence improve communication skills within the construction site. In other words, by realization of usage of smart glasses in construction industry will make unique contributions to the target group by enabling reaching information instantly which will minimize losses of time and money.

Consequently, augmented reality system to be developed within the scope of present study will make the construction companies gain an innovation in management of complicated, challenging projects. Therefore, this innovative methodology will bring efficient management insights and accurate skills in strategies to handle cost and time effectively for the construction companies.

Prototype construction activities will be tested in the representative laboratory-construction site which will be founded in Department of Civil Engineering in Anadolu University. Then after the basic tests are completed for utilization of the system, basic trainings about the developed system will be given to target group, i.e. construction workers, foremen, operators, site engineers and managers working in the construction sites to apply the system. After the preliminary applications of the system in the construction sites, in order to determine the effectiveness of this system, semi-structured interviews and survey questionnaires will be conducted among the mentioned target group. Therefore, the potential benefits of this system to the construction industry can be determined.

LITERATURE

Several researchers have common opinion that exploitation of improvements in IT will benefit construction sector to a large extent. Cleveland, Jr. (2011) states that construction engineering is potentially on the verge of significant breakthroughs in efficiency, quality, and safety, facilitated by existing and emerging information technology abilities and adds that it is worth thinking on how to make a transition to

the innovative advantages of IT in construction industry. One of these leading innovations is augmented reality, which brings virtual objects in the same axis with real world and enables monitoring the virtual objects together with the real world where they are relayed (Hammad, Wang, & Mudur, 2009). There is a definition of augmented reality on which many researchers agree which states that augmented reality enriches the real world objects by overlaying virtual objects on the view of the real word objects (Azuma, 1997; Feiner, Maclntyre, & Sleegmann, 1993; Feiner, Webster, Krueger, Maclntyre, & Keller, 1996; Hammad, Garrett, Jr., & Karimi, 2002; Höllerer, Feiner, Terauchi, Rashid, & Hallaway, 1999; Thomas, Piekarski, & Gunther, 1998; Webster, Feiner, Maclntyre, Massie, & Krueger, 1996).

Wang and Dunston (2007) emphasizes that it is very impracticable to train a novice heavy construction equipment operator (excavator, bulldozer, grader, loader, backhoe loader etc.) in real conditions since it will be extremely expensive, logistically difficult, dangerous and hard to control. Instead of impracticable site training, they developed an augmented reality based real world Training System (ARTS) in which heavy equipment operator is trained in real construction equipment with virtual materials and targets in a real construction site. The operator trained by the model of Wang and Dunston (2007) will feel an almost real interaction and sense of existence with visual, auditory or force displays. In that study, novice operator will be trained sufficiently in a low cost and faster way and his/her integration to the industry will be ensured in a safe and quick manner. ARTS can also allow equipment operation training during extreme weather conditions, and trainees have much more time to practice their skills in unlimited scenarios without the pressure of costs. Besides, adverse effects such as noise, dust, mud etc., can be avoided (Wang & Dunston, 2007). Figure 3 represents an example of hypothetical concept illustration of Wang and Dunston (2007).

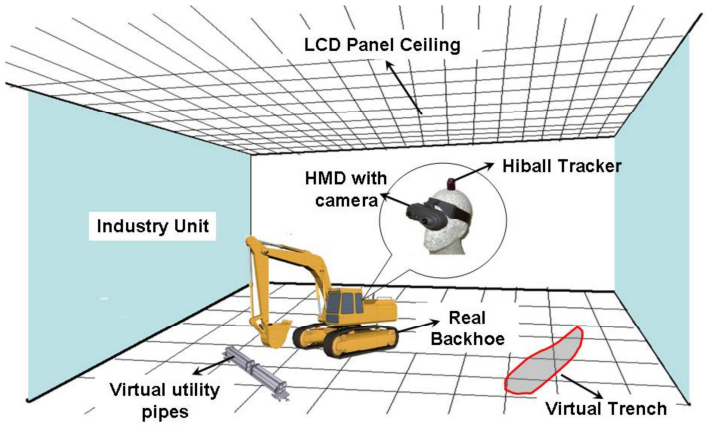

Figure 3 - Hypothetical concept illustration of AR system application in pipe-laying operation training with backhoe (Wang & Dunston, 2007)

During an excavation activity, there is a high risk of damaging the existing buried utilities by accident. Such accidents may cause substantial financial loss to the project and can delay or even cease ongoing construction activities. They also may pose a life threat and often result in accidental deaths (Behzadan & Kamat, 2009). In order to prevent those drawbacks, Behzadan and Kamat (2009) has developed a system in which they integrated Augmented Reality (AR) visualization and the Global Positioning System (GPS) to create real time views of an excavation site in which CAD models of the buried utilities can be accurately superimposed over live video streams of the real world with the yielding views being displayed to the equipment operator in real time. Figure 4 and 5 demonstrate the model developed by Behzadan and Kamat (2009) and another example of augmented reality visualization of buried utilities, respectively.

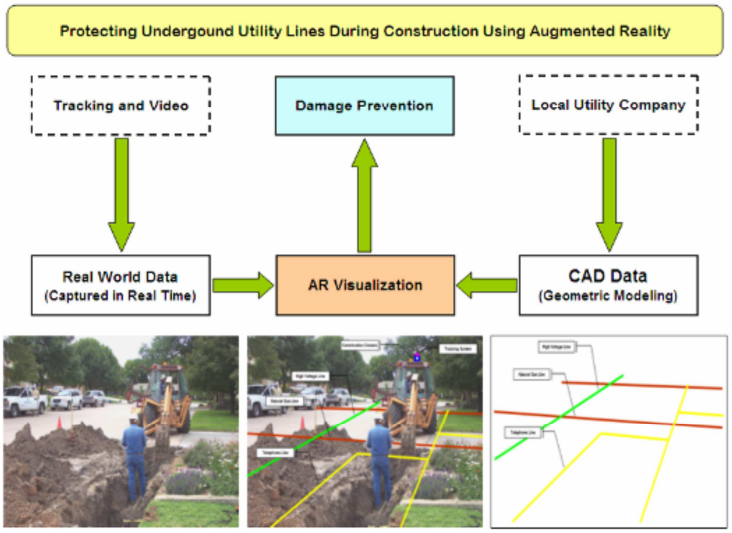

Figure 4 - Data Flow Diagram of the Designed System by Behzadan and Kamat (2009)

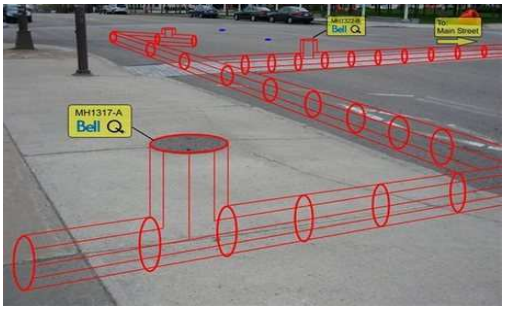

Figure 5 - Example of augmented reality visualization of buried utilities (Puhakka, 2011 available at http://www.scoop.it/t/augmented-reality-news-and-trends/p/248705370/augmented-reality-for-infrastructure-a-first-step-stephane-cote-s-blog-bentley-colleague-blogs-be-communities-by-bentley).

Hammad et.al. (2002) has developed a Mobile Augmented Reality System for Infrastructure Field Tasks (MARSIFT) which will not only allow users to automatically retrieve the required information in real-time based on the location and orientation of the user, but it will also show this information as augmentation to the view of the surrounding real world objects such as roads, bridges, and tunnels. This is realized through a wearable head mounted display equipped with tracking sensors that help register the virtual objects with the real objects in real-time. For example, an engineer inspecting a viaduct will need to know which pier he is dealing with and requires data about the history of maintenance of the said pier. In case of a crack determination in the pier, he will need the rebar configuration and additionally he will need to draw locations of the cracks, take photographs of them and write down an explanation describing the situation. All of these can be executed by means of using MARSIFT through a head-mounted display (Hammad et al., 2002).

Park and Kim (2012) proposed a system for Safety Management and Visualization System (SMVS) in which integration of building information modeling (BIM), augmented reality (AR), location tracking and game technologies has been carried out. A prototype has been developed and tested and as a result of the case study conducted, the outcomes indicated great potential in improvement of determination

of safety risks, in increasing risk perception of workers and in upgrading communication between construction managers and workers in real time (Park & Kim, 2012).

METHODOLOGY

In this study, a system using one of the recent advancements of ever changing technology, augmented reality, will be developed for the service of construction industry which will take effect through smart glasses to be also developed within the scope of this study. By this system to be developed, the domain of this study is composed of activating the efficient, effective, safer and qualified project management in construction sites. Within the scope of this study, 10 activities among the most commonly performed construction activities (e.g. shuttering works, concrete works, rebar works, earthworks, excavation works, etc.) will be selected as prototypes.

In the first phase, training materials, method statements and animations including these data will be prepared. By a screen mounted interior side of the glasses, developed software will be loaded to the operating system and the user will be able to watch the 3 D animations via consoles in hand and listen to the vocal training materials by means of the speaker in the glasses. Any updates in the training materials will be able to recorded SD memory or updated through the server by Wi-Fi connection. Recording the construction activities which the user is performing with a camera positioned on the glasses will facilitate comparison between the users actual performed work with the ideal work exhibited in the animations. In this respect, not only mistakes and non conforming activities will be avoided together with safety risks, but also quality standards in line with international best practices will be achieved. 3 D animation will be watched vocally and important points will be emphasized in written form embedded into the animation. The user can watch the training videos repeatedly and can reach the didactic materials with the username defined to him/her. As a result, target group of this study will ensured to continuously improve themselves in their area of responsibility.

In the second phase, software will be developed in order to use augmented reality technology. In this regard the following software will be utilized; Eclipse (Android software editor), Unity 3 D (Animation Program), Flash Software, Xcode (IOS operating system) and Xcode 4.4 (Software to be developed – IOS operating system). In order to develop the system, following devices will be required; Smart glasses (An illustration is given in Figure 6.), Micro SDHC (32 GB maximum), Mac Book PC and Mac Server. In the third phase, developed software will be applied to the smart glasses. The system will be powered with Android 4.0 have a 400 x 240 pixel resolution screen. Android and IOS software will match up the devices via Wi-Fi and Bluetooth so that short messages and electronic mails will be able to deliver through smart glasses. Moreover, smart glasses can connect an external monitor and all the applications run by the smart glasses will be able to be viewed from that external monitor. This situation will enable augmented reality, navigation, web-browsing and similar useful applications.

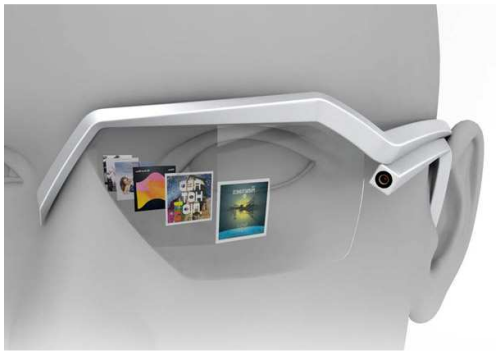

Figure 6 - Illustration of smart glasses to be developed within this study

Other features of the device which can record video 720p are as follows; 1 GHz TI OMAP 4430 CPU, 1GB RAM, inclusive 4GB storage, MicroSD card slot.

Software within the scope of this study will be developed in two main platforms (IOS and Android) and can be integrated with the contents of other sectors such as mining and manufacturing. Figures 7 and 8 exemplify smart glasses & console and camera within the smart glasses, respectively.

Figure 7 - An example given for smart glasses and console to be developed in this study

Figure 8 - Smart glasses camera to be developed in this study

In the fourth stage, prototype construction activities will be tested in the representative laboratory-construction site which will be founded in Department of Civil Engineering in Anadolu University. Animations prepared for the prototype activities will be displayed to the target group.

In the fifth phase basic trainings about the developed system will be given to target group, i.e. construction workers, foremen, operators, site engineers and managers working in the construction sites to apply the system. Trainings will be conducted with the IT departments of the construction companies.

In the sixth phase, after the trainings are completed, testing of the system will take place in order to determine disorders (if any) in the system and re-design the system by removing them.

Seventh phase consists of collecting data during the sixth (testing) phase. In order to measure the efficiency of this system and its outcomes on the staff, semi-structured interviews and survey questionnaires will be conducted among the mentioned target group. The interviews will be analyzed in the Nvivo computer program (used in analysis of data in qualitative research). Questionnaires are going to be analyzed with SPSS program and statistical tests (independent sample t-test, ANOVA).Therefore, the potential benefits of this system to the construction industry can be determined.

RESULTS

In this study, which gives an insight from an ongoing project, the main purpose is to develop a system in which smart glasses will be developed and utilized by construction practitioners on site via augmented reality. The goal is to promote construction management and project management capabilities of construction companies by developing the said system and giving training to the construction professionals about the system. The target group is composed of construction workers, foremen, operators, site engineers and managers working in the construction sites and they will be introduced to use the system based on augmented reality on the jobsite and thus an innovative method will be put into the service of construction companies in order to better figure out and deliver the infrastructure, energy & power, industrial plants and housing projects on time with a safe, standard quality and cost efficient manner which require advanced qualifications. Within the scope of this study, 10 prototype construction activities will be chosen from the most common activities existing in infrastructure projects, power and energy projects, housing and residential projects, and industrial plant projects. For example, construction activities such as masonry, shuttering works, rebar works, concrete works, plastering works and excavation works will be selected. A database will be prepared for these selected 10 prototype construction activities in which there will be trainings and elaborated methods of statements. This database will be able to provide the target group on site with an informative and comprehensive animation and required data regarding the construction activity at hand. In the animations all phases of the construction activity will be visually described step by step taking quality health & safety issues into consideration. Therefore, not only faulty construction activities will be prevented, but also cost efficient project management with highly emphasized quality and safety aspects will be performed.

As a result of this study, from the feedbacks of the target group who tested the prototype construction activities together with the system, it will be understood whether the intended target is attained or not. In case success is obtained, the system will be improved further to cover all the construction activities. For future studies, open learning materials and training videos can be included in the system. Upon integration of additional software, algorithms advanced tracking technologies like Global Positioning System (GPS) and augmented reality improvements in construction management can be carried to one more step forward. Also the system can put into the service of other similar industries such as mining and manufacturing in the future in which efficient project management and productivity are of vital importance.

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