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Review Article

A Review on the use of Augmented Reality to Generate Safety Awareness and Enhance Emergency Response

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Abstract

Augmented reality applications annotate real world with computer generated graphics. They make the surrounding environment interactive by overlaying digital 3D models or some plain text information over and around the tangible objects in its radius. Augmented reality finds its uses in many diverse fields; one such field is discussed in this paper: Safety. This review paper has conducted a study on various existing augmented reality systems that have been successful in implementing a way to provide the user with the knowledge pertaining to safety practices or parting knowledge to the user when it comes to learning how to react in case of emergencies. The ARLIST project (F. Pretto et al, 2008) focused on enhancing Life Support training by projecting audio and visual content on manikins in an attempt to provide a realistic scenario for the trainees. To generate safety awareness in an earthquake prone country-Japan; an augmented furniture falling simulation was implemented by generating 3D furniture models onto strategically placed markers in real environment. An in-car augmented reality system was designed for averting possible collisions with surrounding environment and pedestrians and A computer-vision based tracking method was used to realise an augmented reality application that could enhance the safety for jobs involving physical danger (like construction jobs) backed by a method of information presentation. The paper concludes with establishing the need for a comprehensive system that incorporates both safety awareness and safety training instead of just one of these pair of features.

Keywords: *Augmented Reality (AR), safety, markers, image recognition, emergency, and graphics.*

1. Introduction

Augmented reality is a technology through which a user's real time view is enhanced by superimposing computer generated graphics on the viewing screen in real time. In marker based augmented reality, contextual digital information and animations are tied to an augmented reality marker in the real world. When the application receives digital information from a known marker, it begins to execute the marker's underlying connected functionalities and generates the respective 3D models. Augmented reality is an emerging technology and has found applications in various fields such as medical, defence, tourism and most recently in human safety.

Accidents occur when the correct safety measures are not taken during emergency situations. Millions of dollars are spent on safety drills and other trainings imparted. These include teaching the general population about fire hazards, earthquake emergency response, how to perform CPR and how to apply first aid etc. Such a vast range of activities require sizeable investments that could otherwise be utilised in other fields. As for the knowledge that needs to be imparted with respect to safety, the cost of the same can be reduced dramatically with the use of augmented technology.

Augmented reality applications are cheaper and more efficient ways to enhance human safety. The user simply needs to use an AR system which could be embedded into a supporting hardware like a smartphone. There is no prior safety knowledge that the individual should possess before making use of the system as the application will train the user in safety practices right from the basics. There is also no professional prerequisite for the use of the system itself.

This review aims to critically analyse a set of AR systems that have been implemented to enhance the safety awareness and emergency response in people and derive a set of ideal parameters that can be used to set the basis for a much improved and comprehensive system.

Some existing systems that provide safety training and/or help in emergency response are the electronic triage tags for Disaster relief training (H. Kojima *et al*, 2011) which provides a dynamically changing patient

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vitals tag to keep the medical training exercise interactive and responsive by having the trainee staff respond to the changing conditions with nimble actions. This was done priory through the means of paper written information, an immersive and engaging environment OpenSim (Perera *et al*, 2013) used to create a specialized training Environment to simulate several disaster scenarios and wireless sensors, the latter of which helped management personnel and generic users to enhance their skills by associating with wireless technologies for data collection (Perera *et al*, 2013) and to deploy innovative solutions towards disaster management. The ARP virtual reality system (Y. w. Chow *et al*, 2005) that improves and consequently reduces the rotational latency offered by existing HMDs (Head mounted displays) and also renders high quality, detailed realistic scenes that increase user's imersivity and hence optimize the training simulation.

This review deals with the study of systems that achieve the required functionalities through an augmented reality approach. In Section 2 a set of 4 such systems have been discussed in detail

Outdoor Augmented Reality for Direct Display of Hazard Information (Y. Mizuno *et al*, 2004) emphasizes the need for providing on-screen safety information to help the people with professions that are based outdoors and exposed to physical harm due to their surroundings. In the indoors, the precise registration is realized by using the markers (Mayasuki Kanbara *et al*, 2002). In the outdoors, the registration methods which use sensors, such as GPS and a gyroscope, have been proposed (Taro Odashima *et al*, 2002; Kiyohide Satoh *et al*, 2002; Miguel Ftibu *et al*, 2002). However the accuracy is greatly influenced by the performance of the sensors. This is accomplished by realizing a tracking method (based on texture mapping) over the sensor method which is cost ineffective and can be quite unsuitable when it comes to wearable systems due to its size and weight.

Earthquake furniture falling simulation (N. Yamashita *et al*, 2012) is an android application that simulates the disturbances that take place during the event of an earthquake. 3D furniture models are rendered onto the screen of the android device once the camera senses the markers. The frequency and the Richter scale factors are inputted initially and subsequently those parameters adjust the scale of the simulation. A set of tests and a questionnaire are used to analyse the learner's knowledge.

In-Car Augmented Reality System on Improving Safety of Younger and Older Drivers (Wai-Tat Fu *et al*, 2013) the use of AR in vehicles that would enhance safety of drivers is mentioned in this paper. Preexisting AR systems and their impact on safe driving is analysed and are studied with respect to how AR systems could avert collisions. An AR System is proposed by the researchers and is explained in brief and its effect on the driving skills of a set of subjects is carefully studied. The ARLIST (F. Pretto *et al*, 2008) project focused on enhancing Life Support training by projecting audio and visual content on manikins in an attempt to provide a realistic scenario for the trainees. The trainer inputs the initial parameters of the training session. The simulation responds to the trainee's inputs and changes accordingly to simulate real biological cues. The simulation concludes with the generation of a log file that summarises all the actions taken by the trainee. The trainer uses this log to analyse the trainee's performance.

Lastly, Section 3 concludes this review by summarising the studied systems on the basis of results derived and their critical analysis.

2. Previous Works in the field

2.1 Outdoor Augmented Reality for direct display of hazard information. (Y. Mizuno et al, 2004)

Introduction

With augmented reality, it becomes possible to display the virtual object, which a computer generates, on the scenery and objects in the red world usually viewed through a camera equipped device. With this technology, it is possible to perform various things, such as guidance, notes attachment to buildings, the scene simulation in the outdoors and indoors. In order to realize these features, it is necessary to display a virtual object in an appropriate place. The basis of that lies in the problem of registration-how to obtain the precise relationship? In the indoors, the precise registration is realised by using the markers'). In the outdoors, the registration methods which use sensors, such as GPS and gyroscope, have been proposed.

A highly efficient sensor is expensive and becomes unsuitable for a wearable system in respect to its size or weight. In this research, we aim to reduce the risk in the work accompanied by danger and offer the safe work environment by realising the tracking method, which are depended on the texture tracking which is not dependent on a sensor (provides high accuracy and real-time processing in outdoor environment).

Brief Description

In order to display the position of piping correctly, the precise registration between the real world and the virtual world is important. The relationship between the camera and the real objects needed for registration is described by the transformation matrix (Y. Mizuno *et al*, 2004). Many feature points are extracted from the templates. In the process of the registration, it is considered that template matching (Y. Mizuno *et al*, 2004) is performed on these dl feature points and adopt only the feature points where tracking was successful.

The conditions of the feature point selection are shown below.

(1) The selection conditions which are common regardless of the order of selection (selection of a candidate point)

A) When the feature points is projected on an observation screen coordinate system by using the transformation matrix calculated with the previous frame, it is reflected in the image.

B) The resolution of the object in an observation screen coordinate system is contained in the scope of resolution of the texture which is prepared in advance.

(2) Selection of the first point - It is most distant from the center of an image.

(3) Selection of the second point - It is most separated from the first point.

(4) Selection of the third point - The area of the triangle which is constituted with the first and second points becomes the maximum.

(5)Selection of the fourth point - The area of the quadrangle which is constituted with the first, second and third points becomes the maximum.

(6) Selection of the fifth point - It is chosen as the registered order.

In such an environment, it is necessary to treat information of two or more plane simultaneously. The tracking of two or more planes is made possible by calculating the relationship between multiple target planes and describing the transformation matrix of those coordinate systems in advance.

By using template matching, an area similar to a template is detectable from the image. However the size and angle of feature points dynamically change, because a tracking object can move in 3-dimensional space in this research. Therefore, in having created the template in advance, template matching becomes difficult.

Tracking is realised by repetition of a series of processing in which registration is performed by template matching. A transformation matrix is obtained, the positions of the feature points in the following image are predicted using the obtained transformation matrix, templates are generated, and they match around the prediction positions.

The tracking method is divided roughly into what is depended on image processing, and what is depended on sensors, such as a gyroscope and GPS. This research examines the tracking method using the natural feature points based on computer-vision.

Limitations

1. No explicit system has been discussed in this study. It delves into a method or idea of implementation.
2. It focuses more on the scanning of environment rather than displaying information on the screen.

Strengths

1. There is an emphasis on the need for on screen information
2. Lays out the difference between indoors and outdoors sensors quite clearly.
3. Provided a coordinate transformation matrix for real world to camera transformation
4. Well detailed conditions for feature selection is mapped out.
5. Different types of planes have been considered as well to avoid limitation of the usage in actual environment.

2.2 A Learning Support Environment for Earthquake Disaster with A Simulation of Furniture Falling by Mobile AR (N. Yamashita et al, 2012)

Introduction

A furniture falling augmented simulation software (N. Yamashita *et al*, 2012) was designed by a group of individuals from Wakayama University, Japan. Naosuke Yamashita, Hirokazu Taki and Masato Soga (N. Yamashita *et al*, 2012) felt the need to provide a learning support environment for emergency response during an earthquake. Earthquakes are a common occurrence in the country of Japan with close to 10000 of them occurring in a year (N. Yamashita *et al*, 2012). Such a huge number of this disastrous occurrences required the citizens to be aware and ready to respond in case of an earthquake scenario, especially if it's particularly high on the Richter scale.

Yamashita and team felt the need to address this learning experience in a more dynamic way as opposed to the static learning and memorising from books or from Video movies. And so they took an augmented approach and carried out a comparative study between the augmented simulation and a simple video playback.

Brief description

1) The experiment Methodology consisted of splitting a test set of 10 learners in 2 groups:
Experimental group and control group (N. Yamashita *et al*, 2012). While the control group were witness to an earthquake simulation in a cg environment (which provides a singular view of the environment) on a computer terminal the experimental group were exposed to an augmented simulation of Furniture falling as viewed through an android terminal.

2) The setup of the environment was similar in both cases with the earthquake effect set at level 6.0 on Japanese seismic scale frequency 1 Hz, maximal acceleration 320 gal and peak Acceleration time as 5 seconds. The furniture consisted of a general household collection such as a TV set, table and bookshelf along with a bed and a sofa each with 0.5 static and 0.6 dynamic friction coefficient. For the experimental group a 4mx4m experimental room with AR markers placed at strategic locations was provided where the 3d Cg model of life size furniture was rendered on the learner's android terminal through an application interface designed with the help of 'Unity 3'.

3) The test methodology followed the conduction of a set of 2 tests pre and post which were performed before and after the simulation and in the same manner in both the experimental

And control groups. The first Question was based on the learner's ability to estimate safety and danger zone and the second was to measure the learner's ability to cope with the earthquake scenario if he/she ever faces one in real life. Between these 2 tests the learners learned general precaution points in case of an earthquake by reading technical books and going through specialist's answers.
4) A questionnaire of 5 questions gauging the knowledge and the skill acquired by the learners after the experiment was carried out and the answers were recorded and analysed.

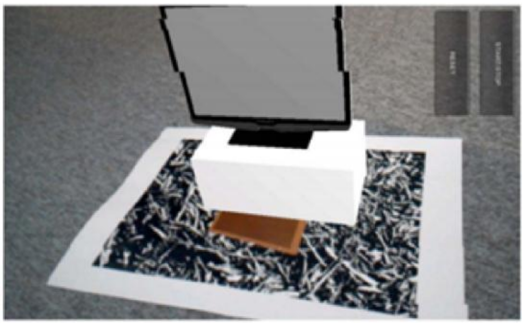

Figure 1: Furniture by Augmented Reality. (N. Yamashita *et al*, 2012)

Results and Inferences

After mapping the percentage of the answers of the pre and post-tests in a table consisting of correct, incorrect and 'NO' responses (N. Yamashita *et al*, 2012) and figuring in the bonus (unanticipated answer in free discussion) and collating the results of the survey tests into a table the following results and inferences were made:-
1) The ability to identify the safety and danger zones in the case of the control group was greatly reduced after the experimentation while the same in the experimental group increased appreciatively. The number of no answers (N. Yamashita *et al*, 2012) remained almost the same in the experimental group between pre and post-tests while that of the control group increased.
2) Though the ability to prepare for an earthquake scenario was increased in both the groups the slope was much higher for the experimental group. The no answers again remained unchanged but the bonus increased greatly. The bonus refers to the learner gleaming at an original answer to the preparation for the earthquake disaster so this shows that the learner was able to improve his/her understanding of the earthquake disaster.
3) Through the questionnaire it was seen that the learners themselves did not believe they had gained the skills through the pre and post-tests pointed to the contrary.

This system was able to prove that an augmented learning towards safety practices leads to a higher understanding since the leaner is able to analyse the experiment space from all angles and depth and hence is able to make good judgements, nimble decisions and develop understanding of the Overall scenario.

Limitations

1) The simulator is limited in its ability to spread earthquake safety awareness since it is completely based on an indoors scenario. It provides no information or directives for survival once the person is outside the 4 walls.
2) If the system is being tested on the basis of its ability to spread awareness through AR approach the inclusion of bookish learning into the testing mechanism is a questionable approach.
3) At the end of the session, the learners were not convinced that they'd learned anything yet the results showed a different picture. This is a conflicting situation. The success of a system is greatly measured by its effectiveness to the consumer.
4) The set of furniture figured into the testing process is of a very common sort and could easily be replaced in the real world scenario by a different piece and will render the person helpless to control the situation.
5) The results displayed that the number of 'NO' answers which were indicative of the ability of a learner to recognize the safe and danger zones remained the same before and after the test. Which proves a degree of ineffectiveness of the system.

Strengths

1) A learner learns better when he/she is able to analyze the affected space from all angles and depth.
2) Learner gets a chance to gleam at an original idea when it comes to safety due to a sandbox environment to analyze.
3) The ability to prepare for an earthquake improves in an appreciable manner in the learners.
4) The system is based on an android device making the production cost quite cheap. An android device is quite affordable and portable so it adds to the strength of this AR system.
5) The simulation can be customised to match the different scenarios with varying order of Richter scale values.

2.3 Effects of an In-Car Augmented Reality System on Improving Safety of Younger and Older Drivers. (Wai-Tat Fu et al, 2013)

Introduction

Augmented reality is being used in several systems nowadays. The use of AR as an in-car system is rare. Road crash victims, their families, friends and other caregivers often suffer adverse social, physical and psychological effects. That is why it might be interesting to analyse the use augmented reality it this sector. Augmented reality is being used as an in-car system by many leading luxury car manufacturers and defence automobile manufacturers.

Brief Description

Driver Distraction and CAS (J.D. LEE et al, 2002)

In-vehicle collision avoidance systems (CAS) (J.D. LEE *et al*, 2002) could be effective in reducing the negative impact of age-related cognitive and motor decline. These systems use augmented signals on screens to alert the driver. Either visual (lights in head-up or head-down displays), audio (monotonic sounds), or haptic/tactile signals are triggered to alert drivers when potential critical events are detected. These signals, however, do not indicate a clear picture of what may happen or what is the current situation. As a result, drivers have to divide their attention between the alert signal and conditions on the road. This may put an extra workload on the driver. We can conclude saying how the CAS (J.D. LEE *et al*, 2002) is effective in alerting the drivers of potential collision but the ultimate aversion has to be taken by the driver himself based on judgement, immediate instinct or gut feeling.

Augmented Reality Systems (ARS) (P.A Hancock et al, 2003)

The main difference between see-through augmented reality sys- tems (ARS) (P.A Hancock *et al*, 2003) and traditional CAS (J.D. LEE *et al*, 2002) was that warning signals from ARS overlap with real physical objects. ARS provides signals which are relative to the lead stimulus (a lead car or pedestrian). This system therefore also guides the driver towards possible measures that can be taken. Focus of ARS is on Safe Driving and not just alerting possible collisions (P.A Hancock *et al*, 2003).

Current use of AR in vehicles

There are two types of augmented reality currently in development or in use. One of these types is displaying critical information (F. Zhou *et al*, 2009). Critical (or less critical but distracting) information is in most cars visible on different places. Looking at the speedometer and navigation for instance distracts the driver and is a moment where the driver is not looking what happens in front of him. With the help of augmented reality this critical information can be seen while looking at the road ahead. As for inattention, perceptual errors and decision errors can be reduced with the help of augmented reality (F. Zhou *et al*, 2009). Some examples are micro-vision displaying for instance speed and navigation information or the Opel insignia, with the 'Opel eye' which recognizes road signs and displays it (F. Zhou *et al*, 2009).

The other type can be seen as an extension of the drivers view. General Motors is experimenting with a system where the side of the road is displayed on the windscreen. The use of this system might reduce the number of single vehicle accidents in darkness or foggy weather.

Pedestrian recognition is another example. BMW has a system where infrared cameras detect humans and displays a warning sign and the thermal images on a LCD screen

Figure 2: An augmented reality system that indicates merging traf-fic. The graduated display indicates relative speed of lead car and direction of merging (Wai-Tat Fu *et al*, 2013)

System proposed by researchers for AR Systems in vehicles

The alert zone of the vehicle's system begins from the front of the host vehicle and extends to a range of about 100 meters. The 100m range is based upon technology constraints. The width of the alert zone approximately covers the two side lanes, as the average lane width is about 3.5m.

When an object (e.g., a lead car) is detected in the alert zone, the ARS is turned on. The system then continuously calculates the time to collision (TTC). When TTC reaches 80 seconds, one colour block will be shown on the windscreen. Subsequently, when TTC decreases to each of the next critical points of 60, 30, 15, and 10 seconds, additional colour blocks will be added to the display. The system continuously recalculates (once every 1/60 second) the TTC, the rate of change of the number of colour blocks on the display affords the perception of the rate of change of relative speeds of the current and lead car (e.g., when the number of blocks is not changing, the speeds of the current and lead cars are about the same; but when colour blocks are added quickly, the lead car is moving much slower than the current car).

Conclusion and Critical Analysis

Most of the accidents are caused by errors of the driver especially distraction, perceptual errors and decision errors. The augmented reality already used in cars is primarily displaying information on the windscreen or an extension of the drivers view on an LCD screen or dashboard. There is no data whether these systems reduces the number of accidents. 'The offset hypothesis' predicts that such systems might even result in more reckless driving.

The ARS did not make drivers to adopt a safer driving strategy. The ARS drivers kept an even safer distance with the lead vehicle and managed to significantly reduce forward collision by having much fewer braking events (when the lead car was within the alert zone) than without the ARS. Although drivers were able to reduce forward collisions with the ARS, their response times to braking events were actually slower than when they did not have the ARS. This suggested that drivers were actively maintaining a close distance with the lead car with or without the ARS, and utilised the ARS progressive alert signals to respond slowly to braking events.

2.4 An Augmented Reality Environment for Life Support Training (F. Pretto et al, 2008)

Introduction

In medical education, Life Support training (LS) is conducted by simulating emergency situations. Students and trainers practice patient care procedures in simulated scenarios using anatomical manikins (C. Strandridge, 1999). These manikins have several resources incorporated in them to facilitate for such training, such as pulse, arrhythmia and auscultation simulator. However this method has certain drawbacks. For example, automatic feedback to the students as a consequence of their actions on the manikin, images such as facial expressions and body injuries, and their combination with sounds cannot be simulated.

The main goal of the ARLIST (F. Pretto *et al*, 2008) project is to update the training environment currently used for LS training by introducing image and sound resources into the training manikins. Using these tools one can simulate some aspects such as facial expressions, skin color changes and various types of skin injuries through image projection over the manikin body, and also play recorded sounds like cries of pain or the groans of an injured person.

Brief Description

The ARLIST project

First, the clinical response during emergency situations were analysed and grouped into two categories (Sound and Visual). The sound category includes:

- Cardiac and Pulmonary sounds.
- Endotracheal and Nasogastric tube sounds.
- Some words or short sentences like the patient's name, complaints etc.
- Responses to the evaluation of the alert state.

The visual signs category includes:

- Facial expressions
- Body injuries.
- Skin colour changes.

The simulation is managed using Patient Simulation Control Tool (PSCT) (F. Pretto *et al*, 2008). It is a software in which the instructor is able to configure all the possible signs or feedbacks provided by the manikin. The software can also register all the trainee actions during the training session. The original anatomical manikins are used and new resources are added.

To represent the most important sound signs, an instrumented waistcoat with push buttons and audio connectors is developed. They emit some physiological sound when pressed such as cardiac auscultation, pulmonary auscultation etc. They are connected to the computer and when one of the buttons is pressed the signal transmitted to the computer. The PSCT (F. Pretto *et al*, 2008) receives the signal and plays the appropriate sound on the adapted stethoscope and on speakers installed in the back of the manikin neck.

On the visual side, this project implements facial expression, skin color and body injuries.
It allows the trainee to look at the patient and recognize the level of consciousness, evaluate the clinical state from the skin color and perceive the presence of injuries.

The image exhibition is made using a projector mounted on a metal structure especially designed for the project. The facial expressions are automatically synchronized with sounds in order to provide more realism to the simulation.

In order to guarantee that the images of facial expressions and body injuries are projected in the right place, even if the manikin has been moved, AR Toolkit registration library is used. It is an open source facial animation system written in C++ language and is responsible for the facial expression production (http://expression.sourceforge.net)

Figure 3: The physical environment for ARLIST. (F. Pretto *et al*, 2008)

Limitations

1) System requires the use of a camera and a projector to be placed over the manikin. These somewhat bulky

pieces of hardware though reasonably portable can still be hard to maintain and replace due to their elevated costs.
2) Since all the features including the visual projection, audio cues and camera detection always have to work in tandem or in synchronisation, a noticeable lag or aberrant behaviour of any the outputs can impair the training process.
3) A complete set of all facial expressions, audio input and skin colour are impossible to comprehend or record. Hence the training is lacking in a certain unmeasurable degree.
4) The system only provides training for medical trainees to enhance their skill set and leaves a large slice of the general population out of the equation. If the same could be provided for general safety awareness involving multiple applications in the same field, this system could be quite ideal.

Strengths

1) Life support training through the use of ARLIST (F. Pretto *et al*, 2008) provides a more realistic training experience and is also a good exercise for working under pressure.
2) Instructor can decide upon the parameters to be tested during training and design the experiment accordingly. Thus, an extensive set of training exercises can be covered within the sample space of the system.
3) The trainee gets immediate feedback from his/her actions and can learn to respond to the same nimbly and deftly.
4) A detailed report of the result of the trainee training process is compiled into a single log file which makes it easy to keep track of the trainee's progress. And can also be analysed to set the future training tests.

Conclusion

We conducted literature survey on four research studies that were based on the use of augmented reality technology in safety. Each study successfully implemented a system that either help increase safety awareness among people or are simply professionally educative as in the case of the ARLIST (F. Pretto *et al*, 2008).

Template matching is a well-accepted technique to detect the environment but there is still problems regarding processing since it may not be able to process object that have a complex relationship with each other.

The earthquake simulation was very effective in providing a close representation of how a real earthquake would pertain but it was restrictive in its ability to provide any directions for safety outside the room. The learners were also not convinced of their gained knowledge.

The study of the AR System present in cars was important as it exposed the possible limitations of AR due to human action and instinct. Preexisting systems proved to be visually appealing but effective in reducing the number of collisions. The proposed system had a major focus on safe driving rather than collision aversion.

The ARLIST (F. Pretto *et al*, 2008) has helped enhance life support training by making the system more interactive. Yet the system requires bulky hardware components and is limited to a small percentage of population which are in the medical field.

Although all the systems are quite effective in achieving their objectives, society demands a comprehensive system that can collate all these different aspects of safety like emergency response, knowledge of a protection device and application of first aid.

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