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CONCEPTUAL DEVELOPMENT OF AN AUGMENTED REALITY APPLICATION FOR VEHICLE INSPECTION IN KUWAIT

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By

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Chairman : Faieza Abdul Aziz, PhD, PEng
Faculty : Engineering

Automotive inspection is the process of servicing or replacing vehicle components and is very crucial process to ensure that the safety, reliability, drivability, comfort and longevity of vehicles are well maintained. It is very complicated and difficult to teach new workers to carry out inspection task of vehicles, without close instruction and guidance. Many printed instruction manuals which include hundreds of diagrams were difficult and time consuming to follow and interpret. One of the main problem in Ministry of the Interior General Directorate of Traffic, Kuwait is there is no Standard Operating Procedure (SOP) for used vehicle in Kuwait. The procedure they used for used vehicle inspection depends on the insurance companies' checklist: Ain Takaful Insurance, Aman Takaful Insurance and Kuwait International Takaful Insurance. The Ministry of the Interior General Directorate of Traffic Kuwait only issued an inspection checklist for newly registered vehicle. The aim of this research is to develop a standard operating procedure for under hood area for used vehicle inspection in Kuwait as the procedure for used vehicle inspection depends on the insurance company checklists. Furthermore, this research aim is to develop an Augmented Reality (AR) application, to evaluate the effectiveness of AR technology in assisting the task of used vehicle inspection training for the automotive industry. After the main problem in inspection stages have been identified, an AR application was developed using a 3D modeling software, animation software and Unity platform software for this inspection stage. The comparison between two different types of medium which are AR-based instruction and paper-based instruction were carried out. Tracker positioning and orientations were also investigated in order to obtain the best tracking identification. The overall research had taken place at the Ministry of the Interior General Directorate of Traffic Department of Technical Inspection, Kuwait, in order to analyses the effectiveness of implementing AR in automotive inspection compared to the traditional method of manual sheets' inspection. The participants were divided into two groups; Experimental group and expert group. The display of 2D

instruction and rendered 3D model provide an interactive user interface as subject can guide themselves by touching the ‘next’ or ‘previous’ button on the screen. On the other hand, for manual paper based instruction, all the details of the maintenance procedure was written in a proper table format. Experiments to evaluate the effectiveness and acceptance level of AR application in inspection were compared to normal automotive inspection. Based on an overall evaluation, it was found that the developed application does offer benefits in inspection completion time. Results for a mean task completion time from the AR application validation shows that inspection using the AR application is better performed with a 10.72% time reduction compared to the conventional paper manual. It was also found that horizontal tracker placement has attained better measurement accuracy with 20.16% improvement compared to a vertical placement. Meanwhile trackers orientation does not have any significant role in the information feedback time. This work has successfully developed AR application which offers benefits in automotive inspection. Therefore, it was proven that the alternative learning and training method using Augment Application was the most preferred method based on the responses from both control groups.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN KONSEP APPLIKASI REALITI BERPERANTARA YANG DIGUNAKAN DALAM PEMERIKSAAN KENDERAAN DI KUWAIT

Oleh

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Proses pemeriksaan automotif adalah proses penyelenggaraan atau penggantian komponen kenderaan dan merupakan proses yang sangat penting untuk memastikan keselamatan, kebolehpercayaan, pemanduan, keselesaan dan jangka hayat kenderaan dikekalkan dengan baik. Ia merupakan proses yang rumit dan sukar untuk mengajar pekerja baru menjalankan tugas pemeriksaan kenderaan, tanpa arahan dan bimbingan yang teliti. Banyak manual arahan dicetak yang merangkumi beratus-ratus gambar rajah yang sukar dan memakan masa yang lama untuk difahami. Antara masalah utama di Kementerian Dalam Negeri Direktorat Lalu Lintas, Kuwait ialah tiada Prosedur Operasi Standard (SOP) yang digunakan untuk memeriksa kenderaan terpakai di Kuwait. Prosedur yang mereka gunakan untuk pemeriksaan kenderaan terpakai bergantung kepada senarai semakan syarikat insurans iaitu Insurans Ain Takaful, Insurans Aman Takaful dan Insurans Takaful Antarabangsa Kuwait. Kementerian Dalam Negeri Direktorat Lalu Lintas Kuwait hanya mengeluarkan semakan pemeriksaan untuk kenderaan yang baru didaftarkan. Tujuan penyelidikan ini adalah untuk membangunkan prosedur operasi standard untuk di kawasan bawah hood bagi pemeriksaan kenderaan yang digunakan di Kuwait. Ini adalah kerana pemeriksaan kenderaan terpakai di Kuwait hanya bergantung pada senarai semak syarikat insurans.dan tidak mempunyai SOP tersendiri. Tambahan pula, matlamat penyelidikan ini adalah untuk membangunkan membangunkan aplikasi Reality Berperantara (AR) untuk menilai keberkesanan teknologi AR dalam membantu latihan penyelenggaraan di dalam industri automotif. Selepas masalah utama di dalam peringkat pemeriksaan dikenal pasti, aplikasi AR dibangunkan bagi perinkat pemeriksaan ini menggunakan perisian pemodelan 3D, perisian animasi dan perisian platform Unity. Perbandingan antara dua jenis kumpulan terkawal yang berasaskan instruksi AR dan arahan berasaskan kertas manual telah dijalankan. Kedudukan dan orientasi imej pengesan juga dikaji untuk mendapatkan identifikasi pengesanan terbaik. Penyelidikan keseluruhan telah dijalankan di Kementerian

Dalam Negeri Direktorat Jabatan Pemeriksaan Lalu Lintas Pemeriksaan Teknikal, Kuwait, untuk menganalisis keberkesanan pelaksanaan AR dalam pemeriksaan automotif berbanding dengan kaedah tradisional pemeriksaan menggunakan buku manual. Para responden dibahagikan kepada dua kumpulan; Kumpulan iaitu kumpulan eksperimental dan kumpulan pakar. Responden boleh menyentuh butang 'seterusnya' atau 'sebelumnya' pada skrin dan arahan 2D dan model 3D akan terpapar dalam paparan interaktif untuk kaedah bagi responden dalam membimbing melaksanakan tugas. Sebaliknya, bagi arahan berasaskan kertas manual, semua butiran prosedur penyelenggaraan ditulis dalam format jadual. Eksperimen untuk menilai tahap keberkesanan dan penerimaan penggunaan AR dalam pemeriksaan dan penyelenggaraan berbanding latihan penyelenggaraan automotif biasa juga telah diuji. Berdasarkan penilaian keseluruhan, didapati bahawa aplikasi AR yang dibangunkan ini menawarkan faedah dalam pemeriksaan. Hasil untuk masa penyelesaian tugas secara purata dari pengesahan penggunaan AR menunjukkan bahawa pemeriksaan menggunakan aplikasi AR lebih baik dengan pengurangan masa 10.72% berbanding dengan kaedah konvensional menggunakan manual kertas. Ia juga mendapati imej pengesan mendatar mempunyai ketepatan pengukuran yang lebih baik dengan peningkatan 20.16% berbanding penempatan menegak. Sementara itu orientasi imej pengesan tidak mempengaruhi masa bagi maklum balas maklumat. Dalam penyelidikan ini, aplikasi AR yang menawarkan faedah dalam pemeriksaan automotif telah berjaya dibangunkan Oleh itu, terbukti bahawa kaedah pembelajaran dan latihan alternatif yang menggunakan aplikasi Augmented Reality adalah kaedah yang menjadi pilihan responden berdasarkan kaji selidik dari kedua-dua kumpulan kawalan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

3D	Three Dimensional
AR	Augmented Reality
ARMAR	Augmented Reality System For Maintenance And Repair
CAD	Computer Aided Design
Control VR	Without training in VR
DR	Digital Radiography
EEG	Electroencephalogram
EMG	Electromyography
HMD	Head Mounted Display
ICT	Information and Communications Technology
LCD	Liquid Crystal Display
GPS	Global Positioning System
MR	Mixed Reality
PC	Personal Computer
Pre-test	Virtual test
Post-test	Actual (live) test
POI	Percentage of Improvement
QA	Quality Assurance
SD	Standard Deviation
SPSS	Statistics Package for the Social Sciences
TCT	Task Completion Time
Tracker	A system of software and hardware components used to infer the relative position and/or orientation of real objects
VE	Virtual Environment
VR	Virtual Reality
VST	Video See-Through

3D	Three Dimensional
AR	Augmented Reality
ARMAR	Augmented Reality System For Maintenance And Repair
CAD	Computer Aided Design
Control VR	Without training in VR
DR	Digital Radiography
EEG	Electroencephalogram
EMG	Electromyography
HMD	Head Mounted Display
ICT	Information and Communications Technology
LCD	Liquid Crystal Display
GPS	Global Positioning System
MR	Mixed Reality
PC	Personal Computer

CHAPTER 1

INTRODUCTION

1.1 Preliminaries

This chapter describes general background of automotive inspection, the advancement of Augmented Reality (AR), problem faced in automotive inspection and maintenance, objectives and scope of the research work and finally the importance of the study to the engineering community in general and to researchers in particular.

1.2 Research Background

Automotive inspection is the process of examining a vehicle to ensure that it conforms to regulations regarding safety or emission or both. The process is usually mandated by governments in most countries around the world. The purpose is to enhance the safety of motorists when they travel on the road. Examples of automotive inspection are suspension test, brake test, smoke test and others.

Automotive maintenance is the process of servicing or replacing vehicle parts and fluids. It is a crucial process to ensure that the safety, reliability, drivability, comfort and longevity of vehicles are being maintained. Unlike inspection, automotive maintenance can be carried out by anyone. Basic maintenance can be carried out by the owner of vehicle. Advanced maintenance should be carried out by experts in any automotive maintenance outlet in the country as long as the outlet is registered with the Road and Transport Department. Examples of common automotive maintenance are engine oil and oil filter replacement, timing belt replacement and spark plug replacement (Henry, 2013).

Automotive inspection and maintenance often come together as one. Both have a very close relationship with each other. From inspection, the owner or person in charge will be able to identify the condition of a vehicle, whether it is in a good condition or it is in a bad condition. If it is in a good condition, the owner or person in charge can just skip the maintenance process as it will not be necessary. If it is in a bad condition, maintenance process takes place and re-inspection will be carried out after the maintenance process. The cycle repeats until the condition of the vehicle becomes satisfying. Automotive inspection and maintenance are important to ensure the safety of motorists and can also reduce the cost of repair.

From basic to advanced, automotive inspection and maintenance require knowledge and training. In some countries, there are even automotive inspection and maintenance courses offered to public. Some examples of the courses offered are basic car maintenance course, beginner's automotive maintenance course and automotive service course. Nowadays, even the expertise in automotive inspection and maintenance require reference prints, manuals or computers that consist of maintenance procedures, components data and safety information to aid them in their inspection and maintenance process. This causes the inspection and maintenance process to become inconvenient and time consuming as the maintainers need to constantly switch their focus from the process to the artefacts and back to the process again. Furthermore, synthesising inspection and maintenance information from the references to the process further complicate the inspection and maintenance process (Henderson & Feiner, 2007).

Augmented Reality (AR) is the integration of digital information with the user‘s real life environment which overlays new information on top of the existing environment (Prechtel & Münster, 2016). By overlaying new information on top of the existing environment, the user‘s perception of reality can be enhanced. Furthermore, as new information can be displayed virtually in a real life environment, it enriches the user‘s information acceptance. The AR application can be developed by using specific software such as Unity3D, ARToolKit and Vuforia.

Today, AR is being applied into various fields of industry such as education, healthcare, engineering, inspection, maintenance and others. The application of AR in the inspection and maintenance of automotive industry has the potential to solve the issues faced by personnel working in the respective industry as mentioned previously. Furthermore, research conducted by externals also proved that the application of AR in training and in the educational field is far more effective compared to the traditional training and education system that uses verbal and artefacts as delivery media (Gangadharan et. al, 2007).

As a summary, the application of AR in the inspection and maintenance of the automotive industry can aid maintenance personnel in their inspection and maintenance process by simulating a step-by-step procedure.

1.3 Problem Statement

Technicians in workshops today have mountains of data and information for diagnostics and repair. But it is not accessible where it is really needed: on the car itself. The worker must search for the information, and then manually check to see if he can assess the problem and repair what is not functional. The worker must refer to a printed drawing of the testing body, with the inspection parts marked on the testing body drawing. The worker has to locate the matching parts on the drawing and the body manually to perform the inspection. Furthermore, different subsets of parts are inspected on different car bodies with a pre-determined sequence and this costs a lot of time and use of manual guide. The manual method for inspecting faulty component in vehicles involves trial and error processes which are inefficient, stressful, time consuming and this leads to high cost of maintenance (Obodoeze et. al, 2018).

In 2015, many people were injured in work accidents every year at the Ministry of the Interior General Directorate of Traffic, Kuwait. At least five accidents happened each month in the workplace while performing car maintenance and inspection, and some of them were quite serious (Mahmoud, 2015). This situation caused fear to the worker especially the newly joined staff as they do not have experience working and handling the car inspection before performing the real inspection.

Kuwait vehicle inspection centre is divided into five lines (which are for new car, used car, taxi, motorcycle and lorry). One of the main problem in Ministry of the Interior General Directorate of Traffic, Kuwait is there is no Sandard Operating Procedure (SOP) for used to inspect vehicle in Kuwait. The procedure they used for vehicle inspection depends on the insurance companies' checklist: Ain Takaful Insurance, Aman Takaful Insurance and Kuwait International Takaful Insurance. The Ministry of the Interior General Directorate of Traffic Kuwait only issued an inspection checklist for newly registered vehicle. Clearly documented SOPs are crucial where employees can help and coach each other when learning new processes, rather than relying on a managers' instruction. Having an SOP will give employees the opportunity to redirect their peers when tasks are not being performed correctly. As each line of inspection only consist of five engineers to give instruction to mechanics, this process decrease productivity and time consuming for engineers due to time retraining employees and reminding them of what needs to be done on a daily basis (Mahmoud, 2015).

Data from Project Director – Planning and Development and the mechanical engineer of the Ministry of the Interior General Directorate of Traffic, Kuwait, found that under hood area uses more time in comparison with the other inspection points due to different under hood area checklist from different insurance companies and there is no standard time for each inspection point. Accordingly, this inspection point increases the flow time in the inspection lanes (Mahmoud, 2015).

Inspection and repair operations are among potential areas that can be used as subject matter for application of AR. These activities are mostly done manually by skilled workers following a rigorous procedure in documenting and carrying out inspection works in a relatively static and predictable environment. Manual process means that the operator needs to physically navigate tasks in car inspection and this can be extremely time consuming. Improving worker satisfaction and productivity especially in repetitive production tasks are major concerns for management as these tasks are monotonous, boring, fatiguing, and demotivating and consequently affect satisfaction and productivity (Shikdar and Das, 2003).

Precise user tracking is one of the key issues in Augmented Reality (AR) since it determines the immersive quality and credibility of the augmentations. Virtual objects have to be rendered from a virtual camera perspective that is identical with the current vantage point of the user. To implement augmented reality in automotive inspection, visual tracking plays a major role in the car parts image identification, the system deduces the pose of the camera based on observations of what it sees. In an unknown environment, this is challenging; it takes some time to collect enough data to be able to deduce the pose and then the calculated pose estimation easily drifts over time (Gao, 2017). As the environment is unknown to the system, the system selects the orientation of the coordinate axis at random, which may be inconvenient for inspection workers.

The needs to implement Augmented Reality (AR) in inspection of vehicles become obvious where AR enrich user with the information required which overlaid useful computer-generated information to the real-world environment. Interactive 3D technology is a flexible way to represent and experience safely complex, potentially hazardous processes or environments regardless of the geography or industry.

1.4 Research Objective

The overall objective of this work is to design an augmented reality system to help the vehicle inspection process to be more organized and to speed up the overall process of inspection.

The specific objectives are:

1. To develop a basic Standard Operating Procedure (SOP) for under the hood inspection.
2. To develop an augmented reality application for inspection and maintenance in automotive industry.
3. To evaluate the effectiveness and acceptance level of the developed augmented reality application.
4. To determine the effect of marker position and orientation on tracking identification time.

1.5 Signifance of Study

In the race that auto brands carry out to take competitive advantage over the rest, several are considering to add AR technology not only in their advertising campaigns, but also in the physical cars. The advancement of technology has birthed many innovative creations in several fields, one of them being the automotive industry (Schwab, 2017). Thus, a large digital display would be created in order to show all the information. The technology has proven to be popular in the automotive industry, adding another dimension to vehicles that will likely change the driving experience.

Furthermore, it also has the potential of making driving safer, as digital displays can highlight risks in the environment and also warn of potential distractions or unsafe driving habits. Several automotive companies have published various new AR systems that are still being tested. As AR grows, it is shown that it is not all focused on tablets or smartphones, but the devices could have place in this automotive field, as long as they are integrated in a safe way (Cook et al., 2017).

AR technology was applied successfully in certain use cases in industries, and its major application areas include: servicing and maintenance, design and development, production support, and training. By developing a live-diagnosis using Augmented Reality, workers can have;

- Live-diagnostics with visual representation of the results
- Information is available in real-time directly on the vehicle
- Workshop technicians can directly present their customers with diagnostics
- Less time required, because all the information on the tablet is available

1.6 Scope of Work

The overall research is done in Kuwait under the Ministry of the Interior General Directorate of Traffic Department of Technical Inspection to analyse the effectiveness of implementing AR in automotive inspection compared to the traditional manual sheets inspection for the automotive industry. Thus, the scope of work is focused on the development of the AR environment for automotive inspection. Firstly, the main problem has to be identified and a basic SOP for the main problem is developed. Then AR application is developed using a 3D modeling software, animation software and Unity platform software. Series of experiments are performed to evaluate the effectiveness and acceptance level of the AR application in inspection and maintenance compared to normal automotive maintenance training. Finally the effect of marker position and orientation on tracking identification time was evaluated.

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Conference

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