UNIVERSITI PUTRA MALAYSIA

VIRTUAL TRAINING IN MOBILE PLANT FOR TURBOCHARGER IN OIL AND GAS INDUSTRY IN KUWAIT

MAJED GH A H ALSHAMMAR

VIRTUAL TRAINING IN MOBILE PLANT FOR TURBOCHARGER IN OIL AND GAS INDUSTRY IN KUWAIT

By

MAJED GH A H ALSHAMMAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

April 2019

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

VIRTUAL TRAINING IN MOBILE PLANT FOR TURBOCHARGER OIL AND GAS INDUSTRY IN KUWAIT

By

MAJED GH A H ALSHAMMAR

April 2019

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

Virtual maintenance training or virtual reality (VR) in the industrial and energy industry has been a topic of discussion inside recent years. All major oil and gas companies in recent years have advocated design and develop virtual maintenance training system for the greater benefit of the humanity and the environment focusing on sustainable development. Oil and gas industry often requires people to work in hazardous environments, these environments are constantly increasing in size and complexity as companies look for new more cost effective ways of doing training and maintenance. In this project, a head-based fully immersive virtual reality application is developed in Unity 3D for virtual reality training in industrial equipment maintenance for oil and gas industry. The overall research is done at Kuwait Oil Company (KOC) in which to analyse the crucial part that affecting the production line in oil and gas industry. Turbocharger is an essential link in the oil and gas market, helping industries reduce turnaround times and increase productivity across all spheres of operation. The scopes of works are focused on the development of turbocharger parts. The aim of this project is to design and develop virtual reality (VR) system for turbocharger maintenance training in oil and gas industry, evaluate the efficiency of the implementation of training through the Virtual Reality (VR) system and compare between the process performances data in conventional method. Virtual Reality (VR) application development of a turbocharger has been done by using 3D modelling software, animation software and Unity platform software. The effectiveness of the developed VR training platform was also studied. Experiments were done to evaluate the effectiveness and acceptance level of a virtual reality application in inspection and maintenance compared to conventional turbocharger maintenance training. Validation on this developed virtual reality maintenance training application is done based on five aspects which are functionality, reliability, usability, efficiency, maintainability and portability. VR software developed was evaluated by 20 experts in the oil and gas industry. Result from app validation shows that the functionality aspect offer the best value with 56% and followed

by usability with 52%. Respondents verified that they gain beneficial input and experience in VR training platform compared to the manual maintenance method. The results obtained from this study, support the application of learning and training method of using VR system for a particular assembly task and the implemented is expected to highly benefit the industries and maintenance sectors. The possibility of implementing this technology, especially in industrial and maintenance sectors would lead and benefit both organizations in training new procedure or task.

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

LATIHAN VIRTUAL DI DALAM WOKSYOP BAGI TURBOCHARGER UNTUK INDUSTRI MINYAK DAN GAS DI KUWAIT

Oleh

MAJED GH A H ALSHAMMAR

April 2019

Pengerusi : Faieza Abdul Aziz, PhD, PEng
Fakulti : Kejuruteraan

Latihan penyelenggaraan maya atau realiti maya (VR) dalam industri perindustrian dan tenaga telah menjadi topik perbincangan yang hangat dalam beberapa tahun kebelakangan ini. Kebanyakan syarikat minyak dan gas utama dalam beberapa tahun kebelakangan ini telah menganjurkan reka bentuk dan membangunkan sistem latihan penyelenggaraan maya untuk manfaat yang lebih besar dari manusia dan alam sekitar yang memberi tumpuan kepada pembangunan mampan. Industri minyak dan gas seringkali menghendaki orang ramai untuk bekerja dalam persekitaran yang berbahaya, persekitaran ini sentiasa meningkat dalam saiz dan kerumitan. Oleh sebab yang demikian, syarikat giat mencari cara yang lebih efektif untuk melakukan latihan dan penyelenggaraan. Dalam projek ini, aplikasi sebenar realiti maya berasaskan kepala dibangunkan dalam Unity 3D untuk latihan realiti maya dalam penyelenggaraan peralatan industri untuk industri minyak dan gas. Penyelidikan keseluruhan dilakukan di Kuwait Oil Company (KOC) di mana untuk menganalisis bahagian penting yang mempengaruhi garisan pengeluaran dalam industri minyak dan gas. Turbocharger adalah pautan penting dalam pasaran minyak dan gas, membantu industri mengurangkan masa pemulihan dan meningkatkan produktiviti dalam semua bidang operasi. Skop kerja difokuskan pada pembangunan bahagian turbocharger. Matlamat projek ini adalah untuk merekabentuk dan membangunkan sistem realiti maya (VR) bagi latihan penyelenggaraan turbocharger dalam industri minyak dan gas, menilai kecekapan pelaksanaan latihan melalui sistem Realiti Maya (VR) dan membandingkan antara proses prestasi data dalam kaedah konvensional. Pembangunan aplikasi Virtual Reality (VR) bagi turbocharger telah dibangunkan dengan menggunakan perisian pemodelan 3D, perisian animasi dan perisian platform Unity. Keberkesanan platform latihan VR yang maju juga dikaji. Eksperimen dilakukan untuk menilai tahap keberkesanan dan penerimaan aplikasi realiti maya dalam pemeriksaan dan penyelenggaraan berbanding latihan penyelenggaraan turbocharger konvensional. Pengesahan mengenai aplikasi latihan pemeliharaan realiti maya yang dibangunkan ini

dilakukan berdasarkan lima aspek iaitu cara ia berfungsi, kebolehpercayaan, kebolehgunaan, kecekapan, pemeliharaan dan kemudahalihan. Perisian VR yang dibangunkan dinilai oleh 20 pakar dalam industri minyak dan gas. Hasil dari pengesahan aplikasi menunjukkan bahawa aspek cara ia berfungsi menawarkan nilai terbaik dengan 56% dan diikuti dengan kebolehgunaan dengan 52%. Responden mengesahkan bahawa mereka mendapat input dan pengalaman yang bermanfaat dalam platform latihan VR berbanding dengan kaedah penyelenggaraan manual. Keputusan yang diperoleh daripada kajian ini, menyokong penerapan kaedah pembelajaran dan latihan menggunakan sistem VR untuk tugas pemasangan tertentu dan yang dilaksanakan diharapkan dapat memberi manfaat yang besar kepada sektor industri dan penyelenggaraan. Kemungkinan pelaksanaan teknologi ini, terutamanya dalam sektor perindustrian dan penyelenggaraan akan membawa dan memberi manfaat kepada kedua-dua organisasi dalam latihan prosedur atau tugas baru.

ACKNOWLEDGEMENTS

"Firstly, all thanks and praise to Allah that he bless me to complete my higher education and I dedicate my greatest love to all my family including my mother who always supplicates and asks Allah to help and bless me to fulfil the requirements of the thesis and gain the degree, my wife who encourages me to gather the PhD award and my kids who make me smile during my study, finally, my thanks to my government for providing me the opportunity and support to obtain this degree."

I take this opportunity to sincerely express my gratitude to Associate Professor Ir. Dr. Faieza Abdul Aziz for chairing my committee and advising this research. I am grateful to her for spending time with me and helping me. I am indebted to her for her whole-hearted support, enthusiasm and inspiration throughout my graduated study.

I am grateful to Prof. Ir. Dr. Mohd Khairol Anuar Mohd Ariffin and Dr. Rizal Zahari for the valuable advice and suggestions provided to me during the progression of my study and for their participation in my committee.
I also thank all other faculty members who helped me prepare this thesis.

My special appreciation and acknowledgement dedicated to my supervisor, Associate Prof. Ir. Dr. Faeiza Abdul Aziz for her continuous support, invaluable guidance, patience and motivation throughout my period of completing the Ph.D. study. I would like to extend my appreciation to my supervisory committee, Prof. Ir. Mohd Khairol Anuar Mohd Ariffin and Dr. Rizal Zahari for their advices and assistance during this period of study.

THANK YOU

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:

Faieza Abdul Aziz, PhD
Associate Professor Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd Khairol Anuar Mohd Ariffin, PhD
Professor Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Rizal Zahari, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: _____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: _____

Signature: _____
Name of Member of Supervisory Committee: _____

Signature: _____
Name of Member of Supervisory Committee: _____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

2D	Two Dimensions
3D	Three Dimensional
AR	Augmented Reality
CAD	Computer Aided Design
CATIA	Computer-Aided Three-Dimensional Interactive Application
CBM	Condition Based Maintenance
EEG	Electroencephalogram
FEED	Front End Engineering Design
HMD	Head Mounted Display
HVAC	Heating, Ventilation and Air Conditioning
KOC	Kuwait Oil Company
NASA	National Aeronautics and Space Administration
GPS	Global Positioning System
MOW	Matching Objects and Words
NURBS	Non-Uniform Rational B-Splines
OSVR	Open Source Virtual Reality
OTS	Operator Training Simulator
Pre-test	Virtual test
Post-test	Actual (live) test
SD	Standard Deviation
SDK	Software Development Kit
SPSS	Statistics Package for the Social Sciences
TCT	Task Completion Time
TROV	Telepresence-controlled Remotely Operated underwater Vehicle
VE	Virtual Environment
VR	Virtual Reality
VRC	Virtual Reality Centers
2D	Two Dimensions
3D	Three Dimensional
AR	Augmented Reality
CAD	Computer Aided Design
CATIA	Computer-Aided Three-Dimensional Interactive Application
CBM	Condition Based Maintenance
EEG	Electroencephalogram
FEED	Front End Engineering Design
HMD	Head Mounted Display
HVAC	Heating, Ventilation and Air Conditioning
KOC	Kuwait Oil Company
NASA	National Aeronautics and Space Administration

CHAPTER 1

INTRODUCTION

1.1 Preliminaries

This chapter provides a brief overview of the research presented in this thesis. The background work of this research area is first reviewed. The research statement, objectives and hypotheses are then outlined. Finally, the layout of the remaining structure of the thesis is presented.

1.2 Research Background

Interactive 3D technology is a flexible way to represent and experience safely complex, potentially hazardous processes or environments regardless of the geography or industry. Virtual Reality, can be described as translation of environing information into mental image. That helps explain complex ideas simply, because virtual way of perceiving information is more convenient and simple for human beings. With Virtual Reality technology, engineers are able to analyse risky scenarios and minimize potential incident-prone areas, with safe virtual environments; the ability to make and learn from mistakes while performing complicated procedures and instructions is a hallmark of the way to designs training and educational solutions. Within this 'learning by doing' approach, a user can quickly identify a problem, ask questions, or receive just-in-time mentoring about any consequences of his actions. The objective of all operators training is to improve a skill set as rapidly and effectively as possible. The realism associated with Virtual Reality training greatly accelerates learning and skill acquisition. In fact, the combination of VR and traditional training has been proven (Kozlak et al., 2013).

A great advantage of the virtual training platform is that it can be separated from the real world in space and time and in such a way it does not disturb the work operations, and there is no need to physically build expensive training areas (Montecucco et al., 2014). It could be argued that the greatest benefit of AR and VR training scenarios and exercise play is that it can be stored digitally. This allows an evaluation to be carried out more effectively with the ability to view individual elements of the exercise. The ability of these platforms to support data and video capture of time and critical action elements is an invaluable tool for the analysis of the individual and the training provider itself. This can be used to more accurately gather lessons learned and develop corrective actions necessary for the after-action review process.

Oil and Gas are the most important commodities in the world. The industry has become more complex than ever before. This is due to the growing demand for oil and gas, the complication of production conditions, the reduction in the

number of skilled workers, tough security regulations, and desire to cut costs and improve production rate. New technologies can provide a proper solution to these challenges. Virtual Reality here is a bridge between industry complexity, hi-tech innovations and increase of business value.

Due to today's heavy competition environment, oil and gas companies have to employ new emerging technologies to increase productivity, reduce production costs, improve product quality, and shorten lead time (Ji., 2002). With the increasing improvement of science and technology in equipment, the structure of device is becoming more and more complex, leading to a higher cost and longer training spend. The application of Virtual Reality (VR from now on) technologies in training processes has been shown as an interested topic in the industrial environment.

In first place, VR technologies try to provide realistic representations of real world, so they are shown as a cheaper solution to currently training based on real mock-up models. In second place, the use of Computer Aided Design (CAD) has become generalized in the industrial environment last years. This implies that 3D models are available and so, a lot of work is ready in order to build VR environments. Finally, 3D representation of the model and interactivity with it seems to be a more natural learning media than plain documents, blueprints or fixed videos, making interaction between the student and the model richer (Oliveira et al., 2007).

VR technologies involve several knowledge fields, allowing different levels of implementations which fit to different user requirements. So, VR systems can run on a VR stereoscopic cave with a haptic interface or can be run in a simple desktop computer driven by a mouse. It all depends on the intended actions to be carried out. Independently of the chosen environment, which will determine the level of user immersion in the system, the interaction and simulation of the models is a very powerful tool from early design stages to final customer training systems. Note that these last features of VR systems, interactivity and simulation, are what make them different from directly using the CAD tools. There is a third feature of VR systems to take into account: simplicity. A VR tool, within the context stated above, must be very simple and usable by non-special trained personnel. By the fact of being working with a realistic model and using an intuitive interface (just the user hands) the user has the sensation of being almost in the real world (Oliveira et al., 2007).

1.3 Problem Statement

Upstream oil and gas is the segment of the petroleum industry that finds and extracts crude oil and natural gas via a network of wells and pumps. Some of the major challenges to this industry are the inefficiencies and equipment failures that occur when wells are operated in a less than optimal way as well as the production that is temporarily stalled as parts and equipment fail and await repair. Turbochargers are easily defected in short time interval of time

because Turbochargers have a high infant mortality rate, meaning they often fail early in their functional lives. This is primarily due to dirt and foreign contamination left in the chambers after rebuild or installation.

Turbochargers is easily defected in short time interval of time due to excessive boost pressure, increased exhaust gas temperature that can affect the turbocharger in a number of ways, including problems with efficiencies, oil leaks, carbonization of oil within the turbo and exhaust gas leaks from the turbo, so they need to be maintained four times a year. The preventive and corrective maintenance schedules of turbocharger include removing the bearing parts manually which involves high-risk tasks; accidents involving high temperature parts maintenance can be lethal. A study conduct by Pantelidis (2010), stated that 20 – 25 % (Gavish et al., 2015) of mistakes made by the learner or trainee using the real thing could be devastating and demoralizing to the learner, harmful to the environment, capable of causing unintended property damage, capable of causing damage to equipment, and could be costly.

The replacement of turbocharger parts requires four to six highly skilled technicians which can be costly. Furthermore, the effects of unplanned shutdowns or changes to schedules can have a profound impact not only on the company operating the facility but also on the wider economy. In case of power loss in pipeline due to turbocharger shut down, pipeline station become out of control and will suffer risk of production loss (Islam et al., 2017).

Due to the rapidly changing technology used in the oil industry, providing adequate training programs to enhance employees' capabilities to handle day-to-day activities plays an essential role in the entire energy sector. According to a recent survey conducted by Society of Petroleum Engineers, the majority of the survey's participants indicated that appropriate training was critical to employees' development. In particular, approximately 60 percent of the respondents indicated that technical training is the most vital training needed in the oil and gas industry, followed by management/finance training, and soft-skills development training. As a result, oil companies have increased the percentage of their budget spent on training and development programs in order to retain and reward most qualified employees (SPE Research, 2012). For example, in 2012, ExxonMobil spent $88 million to train its 76,000 employees, a 10 percent increase from 2011. Going forward, oil companies are expected to continue to increase spending related to training programs in order to enhance employees' operational and business skills (Exxonmobil, 2012).

Interactive 3D technology is a flexible way to represent and experience safely complex, potentially hazardous processes or environments regardless of the geography or industry. With VR technology, engineers are able to analyze risky scenarios and minimize potential incident-prone areas, with safe virtual environments; the ability to make and learn from mistakes while performing complicated procedures and instructions is a hallmark of the way to designs

training and educational solutions. A safety application was developed by i3D for Oil and Gas industry. This 'learning by doing' approach, a user can quickly identify a problem, ask questions, or receive just-in-time mentoring about any consequences of his actions (Kozlak et al., 2013). The objective of all operators training is to improve a skill set as rapidly and effectively as possible. The realism associated with Virtual Reality training greatly accelerates learning and skill acquisition (Banaszek et al., 2017).

1.4 Research Objective

The overall objective of this work is to design a virtual reality system to assist technicians in inspection process to be more organized and to speed up the overall process of an inspection.
The specific objectives are:

1. To identify the component which cause less efficiency in mobile plant workshop.
2. To develop a virtual reality training system for workshop maintenance.
3. To evaluate the effectiveness of virtual reality training for turbo charger maintenance in oil and gas industry compared to normal training courses.

1.5 Signifance of Study

As oil and gas companies continue striving to find better ways to meet a growing demand for clean, reliable, and affordable energy, virtual reality and 3D visualization provides a path to success. Oil and gas companies are leading the way in creating virtual decision-making centres including collaborative team rooms, integrated operations centres, and advanced training facilities designed to enable new ways to discover, collaborate, and share information. Leveraging advanced visualization technology ensures:

- Streamlined operations and reduced costs
- More precise and accurate placement of drill sites
- Consistent training and safety procedures

By considering safety in every action, oil and gas companies see positive impacts in cost savings, increased retention, and a positive public opinion. However, ensuring consistent training requirements can be challenging to maintain among changing oil and gas technicians, expensive training exercises, and disruptions to everyday on-site work. Virtual reality and 3D simulations allow employees to be trained safely off-site without disrupting normal work routines in consistent and safe environments. This translates to enormous cost savings, improved accuracy, and reduced risk.

1.6 Scope of Work

The overall research is done at Kuwait Oil Company (KOC) in which to analyze the important parts that affecting the production line in oil and gas industry. Main problem in turbo machinery work plant that has been identified as turbocharger thus the scope of works are focused on the development of turbocharger parts. Turbochargers are used in transportation and energy production to improve overall engine performance. Turbochargers work as a high-performance, and low-cost energy recovery solution for low-pressure systems that reduces the required boost to high-pressure pumps thereby minimizing energy consumption. After the main problem has been identified, the Virtual Reality (VR) application development is been done by using 3D modelling software, animation software and Unity platform software. In addition, as industrial compressors they play an important role in the oil and gas industry. Lastly experiments are done to evaluate the effectiveness and acceptance level of virtual reality turbocharger maintenance training in oil and gas compared to normal conventional turbocharger maintenance training.

REFERENCES

Agrawal, R., Kadadi, A., Dai, X., & Andres, F. (2015, October). Challenges and opportunities with big data visualization. In Proceedings of the 7th International Conference on Management of computational and collective intElligence in Digital EcoSystems (pp. 169-173). ACM.Andreatta, P. B. (2010). A typology for health care teams. Health care management review, 35(4), 345-354.

Alliance Insurance Agency (2017). Oil and Gas Insurance Information, Oil and Gas Insurance retrieved from: https://www.allinsgrp.com/oil_and_gas/

Arbon, I. M. (1995). The compression of fuel gas for turbines, engines, and boilers in cogeneration plants. Transactions-American Society of Mechanical Engineers Journal of Engineering for Gas Turbines And Power, 117, 67-67.

Azadeh, A., Ebrahimipour, V., and Bavar, P. (2010). A fuzzy inference system for pump failure diagnosis to improve maintenance process: The case of a petrochemical industry. Expert Systems with Applications, 37(1), 627-639.

Baines, N. C. (2005). Fundamentals of turbocharging. Training, 2014, 12-02.

Banaszek, D., You, D., Chang, J., Pickell, M., Hesse, D., Hopman, W. M., ... & Bardana, D. (2017). Virtual reality compared with bench-top simulation in the acquisition of arthroscopic skill: a randomized controlled trial. JBJS, 99(7), e34.

Banish, G. (2007). Engine management: Advanced tuning (Vol. 135). CarTech Inc.

Barreira J., Bessa M., Pereira L., Adao T., Peres E. and Magalhaes L. (2012). Learn Words in Different Languages: Case Study: Learning English Names of Animals in Elementary School," 7th Iberian Conference on Information Systems and Technologies (CISTI), Madrid, 20-23 June 2012, pp. 1-6.

Berg, L. P., & Vance, J. M. (2017). Industry use of virtual reality in product design and manufacturing: a survey. Virtual reality, 21(1), 1-17.

Bernard, F. (2003). A history of CATIA by former CEO of Dassault Systèmes. Dassault Systems.

Blackley, D. J., Retzer, K. D., Hubler, W. G., Hill, R. D. and Laney, A. S. (2014). Injury rates on new and old technology oil and gas rigs operated by the largest United States onshore drilling contractor, American Journal of Industrial Medicine, Vol. 57, No. 10, pp. 1188-1192.

Bowling, A. (1997). Research Methods in Health. Buckingham: Open University Press.

Bowman, D. A., & McMahan, R. P. (2007). Virtual reality: how much immersion is enough?. Computer, 40(7), 36-43.

Boyce, M. P. (2011). Gas turbine engineering handbook. Elsevier.

Bretheim, J., and Bardy, E. (2012). A Review of Power-Generating Turbomachines. In Proceedings of the 2012 ASEE North Central Section Conference, American Society for Engineering Education.

Burns, N., and Grove, S. K. (1997). The Practice of Nursing Research Conduct, Critique, and Utilization. Philadelphia: W.B. Saunders and Co.

Cain, G. M., and Deliac, E. P. (2006, January). Facilitating Risk Management in EandP Using Data Visualisation and Collaboration Tools. In Intelligent

Energy Conference and Exhibition. Society of Petroleum Engineers.
Charara, S. (2016). Explained: How does VR actually work. Wareable Haettu, 14.
Chun, D., Kern, R., & Smith, B. (2016). Technology in language use, language teaching, and language learning. The Modern Language Journal, 100(S1), 64-80.
Chryssolouris, G., Mavrikios, D., Fragos, D., & Karabatsou, V. (2000). A virtual reality-based experimentation environment for the verification of human-related factors in assembly processes. Robotics and Computer-Integrated Manufacturing, 16(4), 267-276.
Curran, K., and George, C. (2012). The future of web and mobile game development. International Journal of Cloud Computing and Services Science, 1(1), 25.
Dale, B. E. (2003). 'Greening'the chemical industry: research and development priorities for biobased industrial products. Journal of Chemical Technology and Biotechnology, 78(10), 1093-1103.
Dalvi, S. (2015). Fundamentals of Oil and Gas Industry for Beginners. Notion Press.
Dansie, J. (2013). Game Development in Unity: Game Production, Game Mechanics and the Effects of Gaming.
Dassault Systèmes, (2011). Dassault Systèmes Introduces V5R21". Retrieved from: www.3ds.com.
De Bruyn, H. J. (1996). Current corrosion monitoring trends in the petrochemical industry. International journal of pressure vessels and piping, 66(1-3), 293-303.
Devold, H. (2013). Oil and gas production handbook: an introduction to oil and gas production. Lulu. com.
Dixon, S. L., and Hall, C. (2013). Fluid mechanics and thermodynamics of turbomachinery. Butterworth-Heinemann.
Dodd E. J. (2004). Visualization and Collaboration for the On Demand Upstream Petroleum Enterprise. IBM, Toronto, CA.2004 retrieved from: http://www.epmag.com/item/Virtual-Reality-Simulation-Improves-Offshore- Training-Safety_98496.
Dopkin, D., and James, H. (2006). Trends in visualization for EandP operations. First Break, 24(3), 55–59.
Eckardt, D. (2013). Gas Turbine Powerhouse: The Development of the Power Generation Gas Turbine at BBC-ABB-Alstom. Walter de Gruyter.
Erin C. (2015). How NASA uses virtual reality to train astronauts. Retrieved from: http://www.techrepublic.com/article/how-nasa-uses-virtual-reality-to-train astronauts/.
Evans, A., Romeo, M., Bahrehmand, A., Agenjo, J., and Blat, J. (2014). 3D graphics on the web: A survey. Computers and Graphics, 41, 43-61.
Fair, A. (2011). U.S. Patent Application No. 13/092,213.
Ferry, B., Kervin, L., Cambourne, B., Turbill, J., Puglisi, S., Jonassen, D., & Hedberg, J. (2004, December). Online classroom simulation: The next wave for pre-service teacher education. In Beyond the comfort zone: Proceedings of the 21st ASCILITE Conference (pp. 294-302). Perth: Australian Society for Computers in Learning in Tertiary Education.
Franchi, J. (1994). Virtual reality: An overview. TechTrends, 39(1), 23-26.
Franchi, J. HOW DOES VIRTUAL REALITY WORK?.

Freina, L., & Ott, M. (2015, April). A literature review on immersive virtual reality in education: state of the art and perspectives. In The International Scientific Conference eLearning and Software for Education (Vol. 1, p. 133). " Carol I" National Defence University.
Fritz, M. (1990). Eyephones, datasuits, and cyberspace. CBT Directions, 28(2), 11-17.
Funk, M. (2016). Augmented reality at the workplace: a context-aware assistive system using in-situ projection.
Gartner, I. (2015). Gartner's 2015 hype cycle for emerging technologies identifies the computing innovations that organizations should monitor. Gartner Web site.. Published http://www. gartner. com/newsroom/id/3114217. Updated.
Gary, J. H., Handwerk, G. E., and Kaiser, M. J. (2007). Petroleum refining: technology and economics. CRC press.
Gay, G. (1994). At the essence of learning: Multicultural education. Kappa Delta Pi, 1601 West State Street, Post Office Box A, West Lafayette, IN 47906-0576.
Giertsen, C. (2003). Visualization-Does it make a difference?. Journal of petroleum technology, 55(02), 38-38.
Gorla, R. S., and Khan, A. A. (2003). Turbomachinery: design and theory. CRC Press.
Gore, R. A. (1993). Reality or Virtual Reality-The Use of Interactive, Three-Dimensional Computer Simulations at Trial. Rutgers Computer and Tech. LJ, 19, 459.
Grantcharov, T. P., Kristiansen, V. B., Bendix, J., Bardram, L., Rosenberg, J., and Funch-Jensen, P. (2004). Randomized clinical trial of virtual reality simulation for laparoscopic skills training. British Journal of Surgery, 91(2), 146-150.
Hardisty, J. (2009). The analysis of tidal stream power. John Wiley and Sons.
Hartman, J. (2007). Turbocharging performance handbook. MotorBooks International.
Hayward, V., Astley, O. R., Cruz-Hernandez, M., Grant, D., & Robles-De-La-Torre, G. (2004). Haptic interfaces and devices. Sensor Review, 24(1), 16-29.
Heywood, J. B. (1988). Internal combustion engine fundamentals (Vol. 930). New York: Mcgraw-hill.
Hickman, D. A., and Schmidt, L. D. (1993). Production of syngas by direct catalytic oxidation of methane. Science-New York Then Washington-, 259, 343-343.
Hobday, M. (1998). Product complexity, innovation and industrial organisation. Research policy, 26(6), 689-710.
Islam, R., Abbassi, R., Garaniya, V., & Khan, F. (2017). Development of a human reliability assessment technique for the maintenance procedures of marine and offshore operations. Journal of Loss Prevention in the Process Industries, 50, 416-428.
Ismael H. F. dos Santos (2012). A Collaborative Virtual Reality Oil and Gas Workflow. The International Journal of Virtual Reality, 2012, 11(1):1-13
Jahromi, H. N., Fontes, D., & Cochrane, R. A. (2017). Future liquefied natural gas business structure: a review and comparison of oil and liquefied natural gas sectors.
Jezernik, A., & Hren, G. (2003). A solution to integrate computer-aided design

(CAD) and virtual reality (VR) databases in design and manufacturing processes. The International Journal of Advanced Manufacturing Technology, 22(11-12), 768-774.
Johns, C., Nunez, D., Daya, M., Sellars, D., Casanueva, J., and Blake, E. (2000, June). The interaction between individuals' immersive tendencies and the sensation of presence in a virtual environment. In EGVE (pp. 65-74).
Johnson, Z. (1999). There Are No Upper Bounds, Only Leading Edges with RealityCenter. In Conference Guide of the 1999 High Performance Visualization and Computing Summit Oil and Gas.
Karabay, S., and Uzman, I. (2009). Importance of early detection of maintenance problems in rotating machines in management of plants: Case studies from wire and tyre plants. Engineering Failure Analysis, 16(1), 212-224.
Kerszenbaum, I., & Klempner, G. (2016). Large Turbo-Generators: Malfunctions and Symptoms. CRC Press.
Kidnay, A. J., Parrish, W. R., and McCartney, D. G. (2011). Fundamentals of natural gas processing (Vol. 218). CRC Press.
Kommers, P. A., and Zhiming, Z. (1998). Conceptual support with virtual reality in Web–based learning. International Journal of Continuing Engineering Education and Life Long Learning, 8(1-2), 184-203.
Koźlak, M., Kurzeja, A., and Nawrat, A. (2013). Virtual reality technology for military and industry training programs. Studies in Computational Intelligence, 481, 327–334. http://doi.org/10.1007/978-3-319-00369-6_21
Koźlak, M., Kurzeja, A., and Nawrat, A. (2013). Virtual reality technology for military and industry training programs. In Vision Based Systemsfor UAV Applications (pp. 327-334). Springer International Publishing.
Kratz, S., & Ferriera, F. R. (2016, August). Immersed remotely: Evaluating the use of Head Mounted Devices for remote collaboration in robotic telepresence. In 2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN) (pp. 638-645). IEEE.
Kumar, G. R., Srinivasan, P., Shastry, K. G., and Prakash, B. G. (2001). Geometry based triangulation of multiple trimmed NURBS surfaces. Computer-Aided Design, 33(6), 439-454.
Kyriakides, S., and Corona, E. (2007). Mechanics of offshore pipelines: volume 1 buckling and collapse (Vol. 1). Elsevier.
Li, H., Chan, G., & Skitmore, M. (2012). Visualizing safety assessment by integrating the use of game technology. Automation in construction, 22, 498-505.
Likert, R. (1932). A Technique for the Measurement of Attitudes. Archives of Psychology, 140, 1–55.
MacKinnon, C., and Matthews, D. (2003, January). Subsea Worksite Visualisation-A Step Change in Offshore Operations. In Offshore Technology Conference. Offshore Technology Conference.
Mainwaring J. (2012) EYESIM: The Future of Training is Virtual Reality. Retrieved from:http://www.rigzone.com/news/oil_gas/a/122264/EYESIM_The_Future_of_Training_is_Virtual_Reality
Mavrikios, D., Karabatsou, V., Fragos, D., & Chryssolouris, G. (2006). A prototype virtual reality-based demonstrator for immersive and interactive simulation of welding processes. International Journal of Computer

Integrated Manufacturing, 19(03), 294-300.
McLellan, H. (1996). Virtual realities. Handbook of research for educational communications and technology, 457-487.
Mohana Z., Musae I., Ramachandran M. A.and Habibi A. (2012). Ubiquitous Medical Learning Using Augmented Reality Based on Cognitive Information Theory, Advances in Computer Science, Engineering and Applications, Vol. 167, 2012, pp. 305- 312.
Mokhatab, S., and Poe, W. A. (2012). Handbook of natural gas transmission and processing. Gulf professional publishing.
Muhanna, M.A. (2015).Virtual reality and the CAVE: Taxonomy, interaction challenges and research directions. Journal of King Saud University - Computer and Information Sciences. http://dx.doi.org/10.1016/j.jksuci.2014.03.023
Murray, J. W. (2017). Building Virtual Reality with Unity and Steam VR. CRC Press.
Nawsheen, S. (2016). LPG bottling terminal plant of Orion group: at Mongla Khulna (Doctoral dissertation, BRAC University).
Nice, K. (2000). How turbochargers work.
Norman, D. A. (1990). The Problem of Automation: Inappropriate Feedback and Interaction, not Over Automation. Philosophical Transactions of the Royal Society of London, B Biological Sciences 327(1241):585-593.
Omura, G. (2006). Mastering? 3D Studio VIZ? 3. John Wiley and Sons.
Oinas-Kukkonen, H., & Harjumaa, M. (2018). Persuasive systems design: key issues, process model and system features. In Routledge Handbook of Policy Design (pp. 105-123). Routledge.
Payne, T. (2010). Offshore operations and maintenance: a growing market. Petroleum economist, 77(1).
Pedraza, J. M. (2015). The Role of Oil in the Regional Electricity Generation. In Electrical Energy Generation in Europe (pp. 65-210). Springer, Cham.
Raposo A. B., Corseuil E. T. L., Wagner G. N., Santos I. H. F. and Gattass M (2006). Towards the Use of CAD Models in VR Applications. In Proc.ACM SIGGRAPH Conf. VR- Continuum and its Applications in Industry,VRCIA, 67-74.
Ribeiro, C. G., and Furtado, a. T. (2014). Government Procurement Policy in Developing Countries: The Case of Petrobras. Science Technology and Society, 19(2), 161–197. http://doi.org/10.1177/0971721814529874
Richmond, P. (2016). Virtual Reality in Plant Design and Operations. News and Information for Chemical Engineers, 34(4), 352-358.
Roadcap, G. S. (1990). An evaluation of wellhead-protection area delineation methods as applied to municipal wells in the leaky-confined carbonate-bedrock aquifer at Richwood, Ohio (Doctoral dissertation, The Ohio State University).
Russo, E. E. R., Raposo, A. B., Fernando, T., and Gattass, M. (2004). Workspace Challenges for the Oil and Gas Exploration and Production Industry. In Proceedings of CONVR 2004-4 th Conference of Construction Applications of Virtual Reality (pp. 145-150).
Samuely, A. (2015, November 13). Hyundai modernizes car owner's manual with augmented reality spin. Retrieved from Mobile Marketer: http://www.mobilemarketer.com/cms/news/software-technology/21686.html
Santos, B. S., Dias, P., Pimentel, A., Baggerman, J. W., Ferreira, C., Silva, S.,

& Madeira, J. (2009). Head-mounted display versus desktop for 3D navigation in virtual reality: a user study. Multimedia Tools and Applications, 41(1), 161.
Saravanamuttoo, H. I. H., Rogers, G. F. C., and Cohen, H. (2001). Gas turbine theory. Pearson Education.
Schaefer, S., and Warren, J. (2004). Teaching computer game design and construction. Computer-Aided Design, 36(14), 1501-1510.
Seymour, N. E., Gallagher, A. G., Roman, S. A., O'brien, M. K., Bansal, V. K., Andersen, D. K., & Satava, R. M. (2002). Virtual reality training improves operating room performance: results of a randomized, double-blinded study. Annals of surgery, 236(4), 458.
Sheridan, T. B. (1992). Telerobotics, automation, and human supervisory control. MIT press.
Shiratuddin, M. F., and Thabet, W. (2011). Utilizing a 3D game engine to develop a virtual design review system. Journal of Information Technology in Construction–ITcon, 16, 39-68.
Slatt, R. M., Thomasson, M. R., Romig, P. R. J., Pasternack, E. S., Boulanger, A., Anderson, R. N., and Nelson, H. R. J. (1996). Visualization technology for the oil and gas industry: today and tomorrow. American Association of Petroleum Geologists Bulletin, 80(4), 453–459. http://doi.org/10.1306/64ED880E-1724-11D7-8645000102C1865D
Slobounov, S. M., Ray, W., Johnson, B., Slobounov, E. and Newell, K. M. (2015). Modulation of cortical activity in 2D versus 3D VR environments: An EEG study, International Journal of Psychophysiology, Vol. 95, No. 3, pp. 254-260.
Sousa, M. C. (2012). Interactive Modeling, Visualization and Visual Analytics Challenges for Smart Oil/Gas Exploration and Production. Department of Computer Science, University of Calgary.
Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. Journal of communication, 42(4), 73-93.
Sudiro, M., and Bertucco, A. (2009). Production of synthetic gasoline and diesel fuel by alternative processes using natural gas and coal: Process simulation and optimization. Energy, 34(12), 2206-2214.
Telford, S., Mazhar, M. I., and Howard, I. (2011, January). Condition based maintenance (CBM) in the oil and gas industry: an overview of methods and techniques. In Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia.
Thompson, L. (2013). Unity* 3D Touch GUI Widgets. Retrieved from: https://software.intel.com/en-us/articles/unity-3d-touch-gui-widgets
Tongpradith, T. (2014). Product management: visualization technology and 3D simulator of Aker Solutions (Master's thesis, University of Stavanger, Norway).
Van Basshuysen, R., & Schäfer, F. (2004). Internal combustion engine handbook-basics, components, systems and perspectives (Vol. 345).
Waltemate, T., Gall, D., Roth, D., Botsch, M., & Latoschik, M. E. (2018). The impact of avatar personalization and immersion on virtual body ownership, presence, and emotional response. IEEE transactions on visualization and computer graphics, 24(4), 1643-1652.
Webster, R., & Dues Jr, J. F. (2017, June). System Usability Scale (SUS): Oculus Rift® DK2 and Samsung Gear VR®. In 2017 ASEE Annual

Conference & Exposition.
Webb, G. D. (1981). Inspection and repair of oil and gas production installations in deep water. Ocean Management, 7(1-4), 313-326.
West, A., and Hubbold, R. (2001). System challenges for collaborative virtual environments. In Collaborative Virtual Environments (pp. 43-54). Springer London.
Wiener, E. L. and Curry R. E. (1980). Flight-deck automation: promises and problems. Ergonomics 23(10): 995-1011.
Wolfe, R. H., and Liu, C. N. (1988). Interactive visualization of 3D seismic data: A volumetric method. IEEE Computer Graphics and Applications, 8(4), 24-30.Ackermann, T., & So, L. (2000). Wind energy technology and current status : a review, *4*.
Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 40(8), 792-823.
Zare, A., Aminlou, A., Hannuksela, M. M., & Gabbouj, M. (2016, October). HEVC-compliant tile-based streaming of panoramic video for virtual reality applications. In Proceedings of the 24th ACM international conference on Multimedia (pp. 601-605). ACM.

BIODATA OF STUDENT

Majed Ghanem Al-Shammar is a researcher from Universiti Putra Malaysia. He graduated in B. Eng. Production Engineering and Quality Management from Slovak University of Technology (Slovakia), obtained his Master in Engineering "Engineering Management" from Universiti Putra Malaysia. Currently, he is working as Senior Engineer Plant Overhaul in Kuwait Oil Company (KOC), Kuwait. He has more than 22 years' experience in the Oil and Gas field. He handles various types of Generators, Compressors maintenance, supporting Drilling Workover and some other Oil Production areas.

LIST OF PUBLICATIONS

Journal

Shammar, M., & Aziz, F. A. (2018). Virtual Reality Application in Oil and Gas Industry. Journal of Fundamental and Applied Sciences, 10(5s), 746-752.

Aziz, F. A., Alshammar, M., & Ariffin, M. K. A. (2018). Using Virtual Reality for Equipment Maintenance in Oil and Gas Industry. Journal of Computational and Theoretical Nanoscience, 15(4), 1090-1094.

Conference

Shammar, M., & Aziz, F. A. Virtual Reality Application in Oil and Gas Industry. 2nd Progress in Continuing Engineering Education and Life Long Learning International Conference 2017 (CEELLIC 2017).

UNIVERSITI PUTRA MALAYSIA

STATUS CONFIRMATION FOR THESIS / PROJECT REPORT AND COPYRIGHT

ACADEMIC SESSION : Second Semester 2018/2019

TITLE OF THESIS / PROJECT REPORT :

VIRTUAL TRAINING IN MOBILE PLANT FOR TURBOCHARGER IN OIL AND GAS INDUSTRY IN KUWAIT

NAME OF STUDENT: MAJED GH A H ALSHAMMAR

I acknowledge that the copyright and other intellectual property in the thesis/project report belonged to Universiti Putra Malaysia and I agree to allow this thesis/project report to be placed at the library under the following terms:

1. This thesis/project report is the property of Universiti Putra Malaysia.
2. The library of Universiti Putra Malaysia has the right to make copies for educational purposes only.
3. The library of Universiti Putra Malaysia is allowed to make copies of this thesis for academic exchange.

I declare that this thesis is classified as :

*Please tick (√)

☐	**CONFIDENTIAL**	(Contain confidential information under Official Secret Act 1972).
☐	**RESTRICTED**	(Contains restricted information as specified by the organization/institution where research was done).
☐	**OPEN ACCESS**	I agree that my thesis/project report to be published as hard copy or online open access.

This thesis is submitted for :

☐ **PATENT** Embargo from _____ (date) until _____ (date)

Approved by:

_____
(Signature of Student)
New IC No/ Passport No.:

Date :

_____
(Signature of Chairman of Supervisory Committee)
Name:

Date :

[Note : If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization/institution with period and reasons for confidentially or restricted.]