



**INVESTIGATION ON EARLY AUTONOMOUS VEHICLE
MANOEUVRE INFORMATION TO MOTION SICKNESS
SYMPTOMS USING ROAD TEST METHOD**



MASTER OF SCIENCE IN MECHANICAL ENGINEERING

2024



Faculty of Mechanical Technology and Engineering

INVESTIGATION ON EARLY AUTONOMOUS VEHICLE MANOEUVRE INFORMATION TO MOTION SICKNESS SYMPTOMS USING ROAD TEST METHOD

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

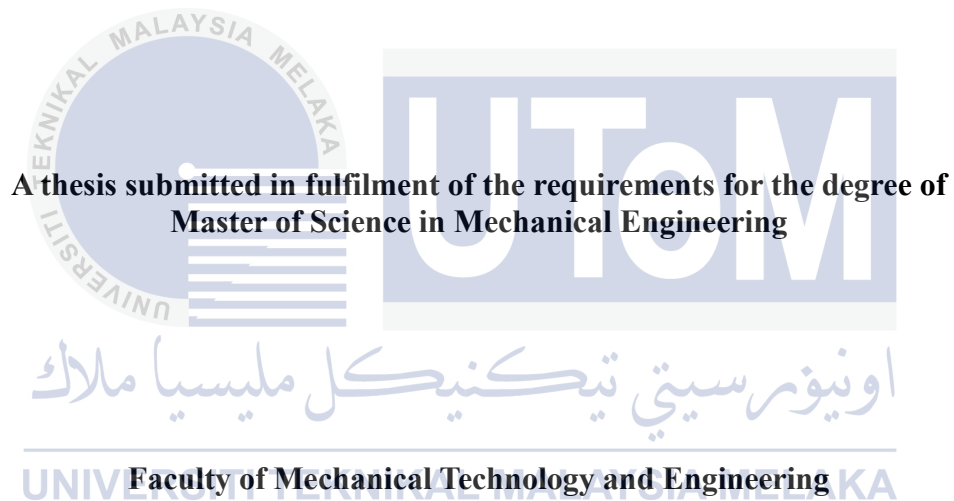
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Master of Science in Mechanical Engineering

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**INVESTIGATION ON EARLY AUTONOMOUS VEHICLE MANOEUVRE
INFORMATION TO MOTION SICKNESS SYMPTOMS USING
ROAD TEST METHOD**

MOHAMMAD IZHAR BIN SULAIMAN



2024

DECLARATION

I declare that this thesis entitled “Investigation on Early Autonomous Vehicle Manoeuvre Information to Motion Sickness Symptoms Using Road Test Method” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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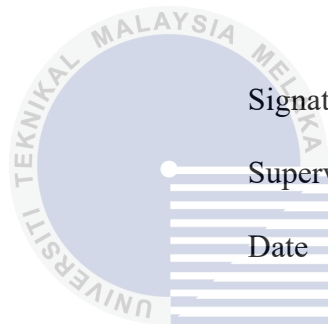
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APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.



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اونيورسيتي تيكنيكل مليسيا ملاك

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DEDICATION

To my beloved mother, Rusnah Binti Shadar Khan, and my families.



ABSTRACT

The development of autonomous vehicles has been started by various automakers. Once available for the masses, this technology allows all passengers to engage in non-driving related activities, such as reading books, watching movies, and playing video games, as studied in various countries before, except for Malaysian passengers. One of the concerning issues regarding the benefits is the development of motion sickness. It is a type of sickness that exists among passengers of various transportation, with an increased chance of getting the symptoms when they remove the focus from the vehicle's trajectory. Hence, this thesis was completed to determine the severity of motion sickness based on the vehicle's motion (predictable and unpredictable motion) and to develop prototypes that can reduce motion sickness symptoms among autonomous vehicle users while engaging in non-driving related activities. In addition, the most preferred non-driving related activities among Malaysian passengers were also studied to fill the gap in the study. The motion sickness studies were performed in a real-road environment with controlled conditions using an instrumented vehicle as the real-road autonomous vehicle simulator. On the other hand, the preferred non-driving related activities among Malaysians were conducted by distributing an online questionnaire over six months. The results showed that the unpredictable motion induced higher motion sickness compared to the predictable motion. Furthermore, the top three non-driving related activities that were preferred among Malaysian passengers were found to be "listening to music", "interacting with others", and "calling and texting". The developed prototypes using audio and visual modalities that were tested on real-road were able to supply the early trajectory of the vehicle to the passengers, hence improving their situation awareness. The ability to predict the vehicle's trajectory contributes towards mitigating motion sickness levels. This thesis shows that the information on the vehicle's trajectories is important for the passengers, especially when their focus is removed while engaging in non-driving related activities. In addition, automakers should consider embedding tested prototypes that increase passengers' situation awareness to minimise motion sickness symptoms. Meanwhile, the completed data on the preferred non-driving related activities can be a guideline for autonomous vehicle production that is suitable for potential Malaysian users.

**KAJIAN TERHADAP MAKLUMAT PERGERAKAN AWAL KENDERAAN
SWAPANDU KEPADA SIMPTOM MABUK PERJALANAN MENGGUNAKAN
KAEDAH UJIAN JALAN RAYA**

ABSTRAK

Teknologi kenderaan swapandu telah mula dibangunkan oleh pelbagai pembuat kereta. Setelah ia tersedia untuk pengguna, kenderaan ini membolehkan penggunaan dalam aktiviti yang tidak berkaitan dengan pemanduan, seperti membaca buku, menonton filem, dan bermain permainan video, seperti yang telah dikaji di pelbagai negara sebelum ini, kecuali Malaysia. Walau bagaimanapun, salah satu isu yang membimbangkan mengenai kelebihan ini adalah mabuk perjalanan. Ia adalah sejenis gejala yang wujud dalam kalangan penumpang pelbagai pengangkutan, terutama bagi mereka yang mengalihkan tumpuan daripada laluan pergerakan kenderaan. Oleh itu, tesis ini disediakan untuk menganggarkan tahap mabuk perjalanan berdasarkan pergerakan kereta (gerakan yang boleh diramal dan tidak boleh diramal). Selain itu, ia juga untuk membangunkan prototaip yang boleh mengurangkan gejala mabuk perjalanan dalam kalangan pengguna kenderaan swapandu semasa melakukan aktiviti yang tidak berkaitan dengan pemanduan. Di samping itu, aktiviti yang tidak berkaitan dengan pemanduan paling digemari dalam kalangan penumpang di Malaysia juga turut diselidik untuk mengisi jurang dalam kumpulan data tersebut. Kajian mabuk perjalanan dilakukan dalam persekitaran jalan sebenar dengan keadaan terkawal menggunakan kenderaan berinstrumen untuk mengimitasi kenderaan swapandu sebenar. Sementara itu, sebuah kajian untuk mengenal pasti aktiviti yang tidak berkaitan dengan pemanduan telah dijalankan dengan mengedarkan soal selidik atas talian dalam tempoh enam bulan. Keputusan menunjukkan bahawa mabuk perjalanan lebih parah dalam gerakan yang tidak boleh diramal berbanding yang boleh diramal. Selain itu, tiga aktiviti yang tidak berkaitan dengan pemanduan yang paling digemari di kalangan penumpang Malaysia ialah “mendengar muzik”, “berinteraksi dengan orang lain”, dan “menelefon dan menghantar pesanan ringkas”. Tambahan pula, prototaip yang dihasilkan melalui kaedah audio dan visual yang telah diuji di atas jalan sebenar mampu membekalkan maklumat haluan awal kenderaan kepada penumpang, seterusnya meningkatkan kesedaran situasi mereka. Keupayaan untuk meramalkan haluan kenderaan menyumbang kepada pengurangan gejala mabuk pergerakan. Tesis ini menunjukkan bahawa maklumat tentang haluan kenderaan adalah penting bagi penumpang. Selain itu, pembuat kereta swapandu harus mempertimbangkan penggunaan prototaip yang telah diuji untuk mengurangkan gejala mabuk perjalanan ini. Sementara itu, data mengenai aktiviti yang tidak berkaitan dengan pemanduan paling digemari di kalangan penumpang di Malaysia juga boleh dijadikan garis panduan untuk pengeluaran kenderaan swapandu yang sesuai untuk bakal pengguna Malaysia.

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere acknowledgement to my supervisor, Dr. Nidzamuddin Bin Md. Yusof, from the Faculty of Mechanical Technology and Engineering, Universiti Teknikal Malaysia Melaka, for his crucial and endless support, supervision, and encouragement towards the completion of this thesis.

Next, I would also like to express my gratitude towards my co-supervisor, Dr. Juffrizal Bin Karjanto, also from the Faculty of Mechanical Technology and Engineering, Universiti Teknikal Malaysia Melaka, for his additional support and knowledge to complete this thesis.

In addition, I would also like to thank Ts. Dr. Abd. Fathul Hakim Bin Zulkifli, a senior lecturer from Universiti Tun Hussein Onn Malaysia Pagoh, for his support in the journey of this thesis, especially in the experimental works. Also, Mr. Mohamed Ihsan Sabri Bin Mohamed Nazar, a lab technician at Universiti Tun Hussein Onn Malaysia Pagoh, for his assistance and supervision in the experimental works.

Last but not least, a special thanks to the Ministry of Education and Universiti Teknikal Malaysia Melaka (UTeM) for the financial support to realise the completion of this thesis. Also, thank you to everyone who has been involved directly or indirectly towards the success of this thesis.

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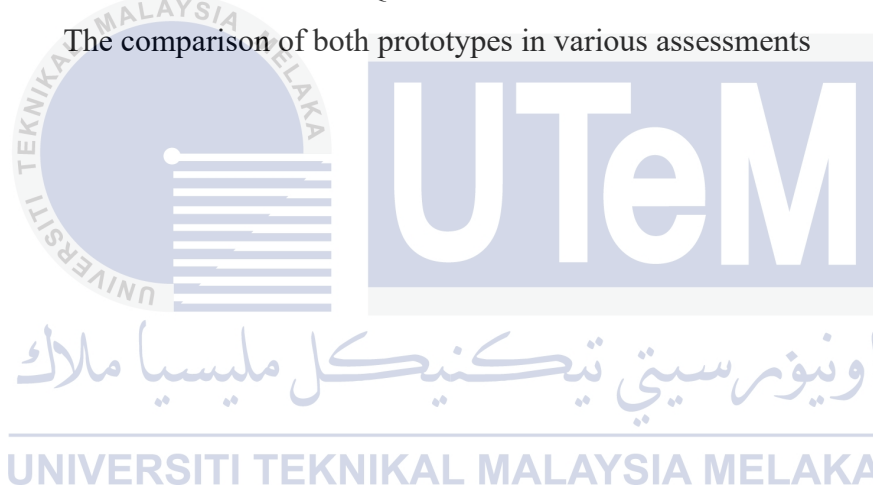
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LIST OF ABBREVIATIONS

ADAS	-	Advanced Driver Assistance System
AR	-	Autoregressive Modelling
AUTOAccD	-	Automatic Acceleration and Data Controller
BASt	-	<i>Die Bundesanstalt für Straßenwesen</i> (The Federal Highway Research Institute)
ECG	-	Electrocardiogram
FFT	-	Fast Fourier Transform
HF	-	High Frequency
HRV	-	Heart Rate Variability
LF	-	Low Frequency
MISC	-	Misery Scale
MSAQ	-	Motion Sickness Assessment Questionnaire
MSDV	-	Motion Sickness Dose Value
MSSQ	-	Motion Sickness Susceptibility Questionnaire
NDRA	-	Non-Driving Related Activity
NHTSA	-	National Highway Traffic Safety Administration
Pnn50	-	Percentage of Successive Normal Sinus RR Intervals more than 50 ms
PSD	-	Power Spectral Density
RMSSD	-	Root Mean Square of Successive Differences
RSME	-	Rating Scale Mental Effort
SAE	-	Society of Automotive Engineers
ULF	-	Ultra Low Frequency
VLF	-	Very Low Frequency

LIST OF PUBLICATIONS

Journal Publications

Sulaiman, M. I., Yusof, N. M., Karjanto, J., Hassan, M. Z., Sulaiman, S., Jawi, Z. M., and Kassim, K. A. A., 2023. Non-Driving Related Activities Inside an Automated Vehicle Among Malaysia Passengers. *Automotive Experiences*, 6(3), 452–465. <https://doi.org/10.31603/ae.9152> (Scopus-indexed, Q2)

Sulaiman, M. I., Yusof, N. Md., Karjanto, J., Hassan, M. Z., Sulaiman, S., Jawi, Z. M., and Kassim, K. A. A., 2023. Motion Sickness Mitigation Through Audio Modality Prototype. *Journal of Mechanical Engineering and Technology (JMET)*. (In reviewing process)

Conference Publications

Sulaiman, M. I., Yusof, N. Md., Karjanto, J., Hassan, M. Z., Sulaiman, S., Jawi, Z. M., and Kassim, K. A. A., 2022. Proof of Concept for Visual Modality Prototype in Mitigating Motion Sickness in Automated Vehicle. *5th International Conference on Automotive Innovation & Green Energy Vehicle (AiGEV)*.

Sulaiman, M. I., Yusof, N. Md., Karjanto, J., Hassan, M. Z., Sulaiman, S., Jawi, Z. M., and Kassim, K. A. A., 2023. Development of Motion Sickness Between Predictable and Unpredictable Motion: A Real Road Study. *The 9th International Conference & Exhibition on Sustainable Energy and Advanced Materials*.

CHAPTER 1

INTRODUCTION

1.1 Background

Autonomous driving technology is becoming more reliable with the invention of various Advanced Driver Assistance Systems (ADAS) levels. A lower level of ADAS, such as blind-spot detection, lane departure warning, and front vehicle movement, helps alert drivers about the surrounding activity. On the other hand, higher-level ADAS will enable the vehicle to move by itself and remove the need for a human driver, known as autonomous driving. Thus, all users of the vehicle will be considered as passengers. Furthermore, more than 10,000 articles related to autonomous technology were published from 1969 to 2017 (Gandia et al., 2018). With this technology becoming a reality each day, various preparations must be completed before a matured version arrives. One of the critical preparations is the user's comfort.

Since all users inside the autonomous vehicle become passengers, past studies show that passengers of any vehicle tend to engage in non-driving related activities, such as reading, texting, or using a phone (Hecht et al., 2020; Yoon and Ji, 2019). However, most aforementioned activities need a partial or complete focus level, eventually removing the ability to predict the vehicle's future manoeuvre. Hence, the inability to predict the future trajectory leads to motion sickness (Kuiper et al., 2020).

Motion sickness (or carsickness) is a sickness due to the forces of a moving vehicle that often affects the passengers, giving symptoms such as nausea, headache, and vomiting. Various theories have been developed to explain motion sickness. However, the two (2) leading theories that have been most accepted are the sensory mismatch and the postural instability theories (Reason and Brand, 1975; Stoffregen and Smart, 1998). The sensory mismatch theory suggests motion sickness is due to the sensory organs' various inputs not synchronising. Meanwhile, the postural instability theory suggests that the motion sickness occurred because of the passenger's posture effect (especially the head roll angle) due to the lateral force of the vehicle. Furthermore, motion sickness is also related to low-frequency forces (below 0.5 Hz), as frequencies larger than that contribute to physical discomfort rather than cognitive discomfort (Turner and Griffin, 1999; Donohew and Griffin, 2004). Various attempts to solve the problems based on both theories were studied, one of which is by improving situation awareness (Petersen et al., 2019; Nini, 2020; Endsley, 2021).

Situation awareness is a concept where the vehicle's users are aware of their current situation and collect the information to predict the near future while engaging in their focus-required activities (Endsley, 2021). Currently, passengers who develop motion sickness symptoms pause their non-driving related activities to look at the outside view of the vehicle. By looking at the surroundings, passengers can anticipate the vehicle's path to regain situational awareness (Diels and Bos, 2016). Even though motion sickness can be reduced by this simple method, the progress of their activities will be interrupted depending on the time needed to reduce the symptoms.

This study explored improving situation awareness by providing information on current and future vehicle trajectories for passengers who engaged in non-driving related activities using auditory and visual modalities. Besides, the effectiveness of the solutions to mitigate motion sickness was also studied.