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Driving Simulator Development with Two Degrees of Freedom Motion for Driver Behavior Study

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Abstract – *This paper discusses about the development of a driving simulator with 2 Degree of Freedom (DOF) motion platform as a data collection tool for driver behavior research. The simulator was installed with motion platform, steering wheel, pedals, transmission, screens, computer, simulation software and sound system to record the driving behaviors in simulated traffic environment. Data containing information such as participants' response time, vehicle speed, acceleration, braking, turn signals use and vehicle positioning were collected. This paper also discusses the benefits of driving simulator development for driver behavior research while addressing its challenge and limitation for future improvement. The paper concludes that the driving simulator development can contribute significantly to road safety research specifically in driver behavior study.*

Keywords: Driving simulator, motion platform, driver behavior, road safety

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1.0 INTRODUCTION

In year 2014, 6,674 fatalities were recorded due to road crashes with an average of 18 people were killed every day (Royal Malaysian Police, 2015). Study had shown that human errors are the major contributing factor, which is about 90% of the road traffic accident (Chan, 2007). There are several instruments to study the driver behaviour related issues from road safety perspective. One of the well-known tool is using driving simulator. Driving simulator is a tool that simulate a virtual driving environment, enabling its user to experience a driving environment similar to the actual car (Kang & Abdul Jalil, 2004).

According to documented sources, the first driving simulator was developed about a century ago (Straus, 2005). Back then, the simulator used for assessing the skill and competence of public transport driver in the 1910s. It consisted of a mock up car which was equipped with specified devices to measure driver response to various situations. By the 1960s and 1970s, there were a number of automobile manufacturers, agencies and universities in the United States and Europe which used film approach simulators for studies involving varieties of visual displays and also about 20 researches focuses on driving simulator (Allen et al., 2011).

The advanced interactive driving simulation began in the 1980s, with the development of personal computers with improved imagery. These led to the development of complex and realistic driving simulators, complete with image display, traffic setting, automobile dynamic, real time features and advanced vehicle cabin by the 1990s. Driving simulators are constantly improving with the development of new computer technology (Martin, 2012).

The applications of driving simulator worldwide are commonly for research, driver training and driver rehabilitation activities. However in Malaysia, the applications of simulator are only used for research and training. Both application using three type of simulator are used in Malaysia which are low-cost, medium cost and high cost (Ariffin et al., 2012). A typical development of a driving simulator requires the integration of several subsystem such as control inputs from car cabin, vehicle mathematical model, scenario development, visual display, auditory display, steering feel characteristics, performance measurement and data storage (Eskandarian, 2014). In addition, motion components that has motion platform to resemble actual car movement could be added according to needs (Stall & Bourne, 1996).

The Malaysian Institute of Road Safety Research (MIROS) has embarked on the development of driving simulator with 2 Degree of Freedom (DOF) motion platform at the end of 2015. The simulator, so called MIROS 2 Degree of Freedom Driving Simulator (MiDOF) can be reconfigured easily to suit various driver behaviour research requirement. The purpose of the development project is to develop driving simulator that is more robust as compared to the previous fixed-based mini simulator which is essentially a non-motion set up.

2.0 METHODOLOGY

2.1 Functional Diagram

Feasibility stage of this development project involved the discussion of the types of instrumentation and simulation scenarios suitable to capture the dynamic behaviours of the drivers. The working principal of MiDOF is best represented by several functional block diagrams that interact during simulation process. The interaction between these processes is shown in Figure 1. The driver generates the control inputs from the steering wheel, pedals and transmission that will detected inside the simulator cabin as the primary of the simulator. Vehicle dynamic model is using a systematic algorithm that is to measure, control and integrate the signals on the simulation process.

The vehicle dynamics model and a simulation scenario are used to generate the images in a simulation via the visual display. A scenario guides a simulation by specifying the road environment, existence of other vehicles and the roadway geometry. The simulation scenario is combined together with complex visual object, which acquired from a 2D and 3D database, to generate the complete video image. A video image generator uses the image to update the visual presentation.

The auditory and haptic feedback is also received by the respondent. The haptic response module acquires the inputs from the vehicle control and uses a steering force feedback mechanism to produce the feeling of real car driving. Inputs from steering wheel and pedals will determine the movement of the motion platform. Furthermore, the auditory feedback is produced by modules that conduct sound transformation, generation and presentation. The function of data acquisition and analysis module is to acquire the experimental data and able to conduct the analysis. The data can be recorded as a specified file and displayed during the replay simulation run.

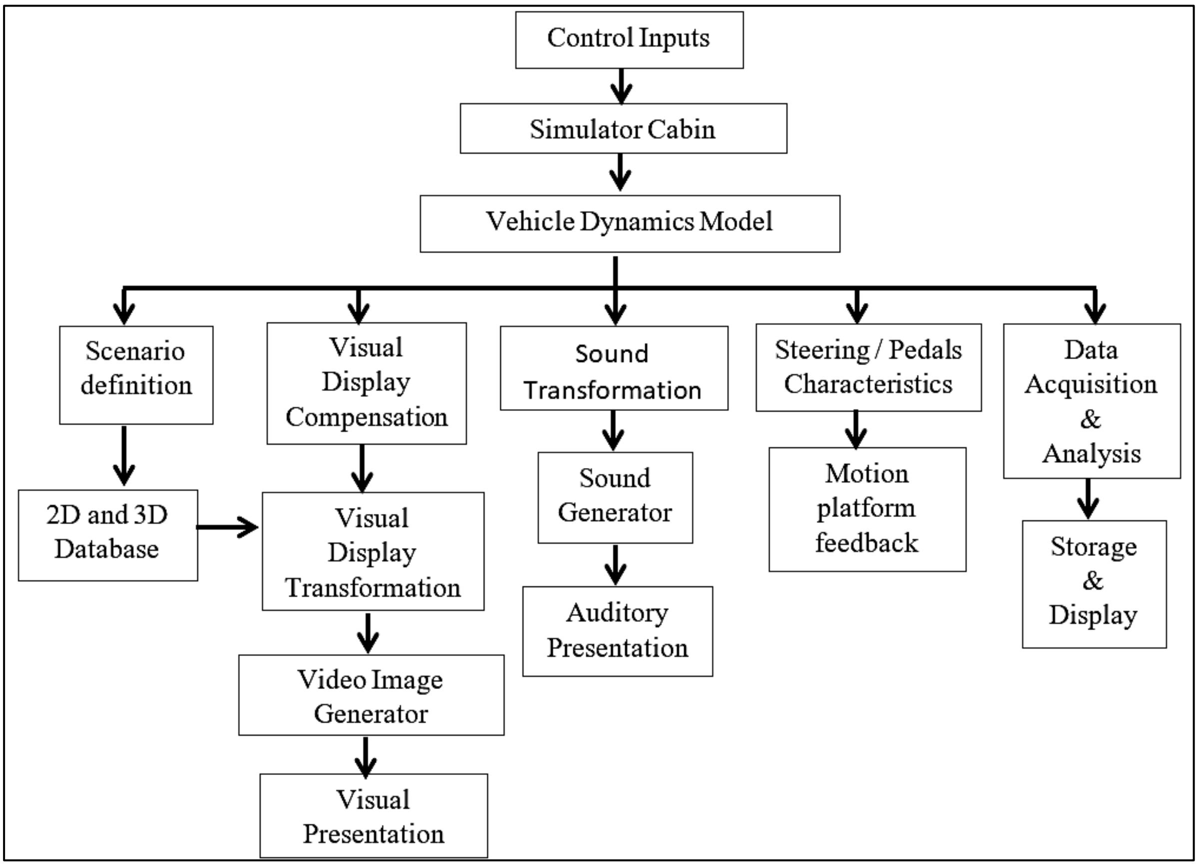

Figure 1: Functional diagram of MiDOF

2.2 Instrumentation setup

One of the most vital features of driving simulator is the ability to capture the dynamic behaviour of drivers robustly in a context of normal driving. Depending on the scale of a simulation study, the selection of specific method of instrumentation are usually determined by the scope and objective of the study. The MiDOF was prepared as a tool to study driver behaviour. The main components of the MiDOF are steering wheel, pedals, transmission, 2 DOF motion platform that consist of roll and pitch axis movement, driver seat, seatbelt, 3 units of LCD monitors, computer, simulation software and sound system. The overview of the MiDOF components are shown in Figure 2.

The MiDOF steering wheel was using Logitech G27 steering wheel. The steering wheel performed two functions, which were to measure the angle of steering wheel rotation and generate a real car feeling, which would be force feedback mechanism and also to move motion platform either to left or right (roll). The steering had a 900 degree wheel rotation. The MiDOF included a desktop computer that controlled and integrated the overall simulator system, in terms of hardware and software.

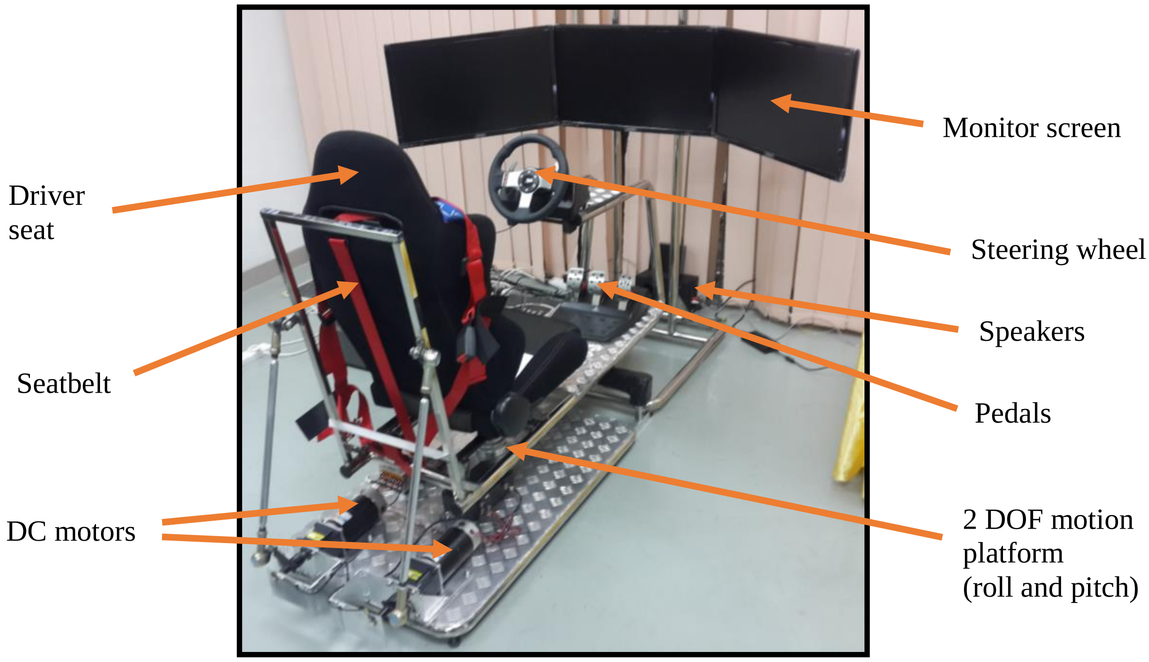

Figure 2: Overview of the MiDOF components

2.3 Output Data

The simulator is capable of produces a wide array of data and can be stored for further analysis of research. Each record in the file is a data of vehicle state including the numerical data that driven by the respondent. The interval between recoded data is specified in term of either time or distance. The system could create a summary file of the event that occurred during the simulation run. Events include time of simulation start, simulation running time, etc. Some of output data that able to record by the software, but not limited to, elapsed time, distance travelled, longitudinal acceleration, lateral acceleration, response time, vehicle longitudinal speed, vehicle lateral speed, lateral lane position, steering wheel angle, brake pedal force, transmission, turn signals use and vehicle positioning data. All the data will be further analysed according to types of driver behaviour study needs.

2.4 Simulation Software

Silab Version 5.0 was used as the simulation software in the development of MiDOF. The software enable user to create a terrain and driving scene according to the study requirement, save the file and modified existing file for other study. The development of the driving scenario was divided into two phase, which are designing phase and programming phase. The terrain and driving surrounding was developed in the designing phase. Important objects like road, junctions and road landscape were created before they were all merged into a completed scene. In the programming phase, the traffic flow and other vehicles locations and movement were programmed according to the study requirement. Researchers can see the results of the experiment that consist of graphs results and data sheet (Ergoneers, 2015). The software interface and example of designated simulation scenario are shown in Figure 3 and Figure 4 respectively.

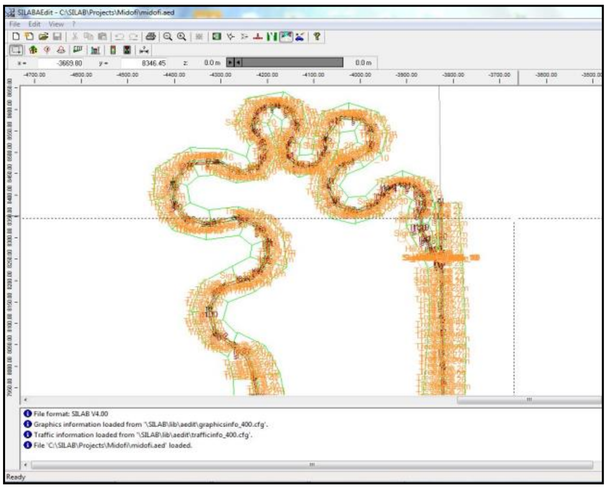

Figure 3: Interface of the simulation software

Figure 4: Illustration of the scenario

2.5 Motion Platform

Two DOF motion platform was developed in this project to produce more realistic driving feeling as compared to older version (non-motion simulator). It consists of two axis movement, which are roll and pitch as shown in Figure 5. Roll defined as rotation around the longitudinal axis, while pitch is rotation around lateral axis.

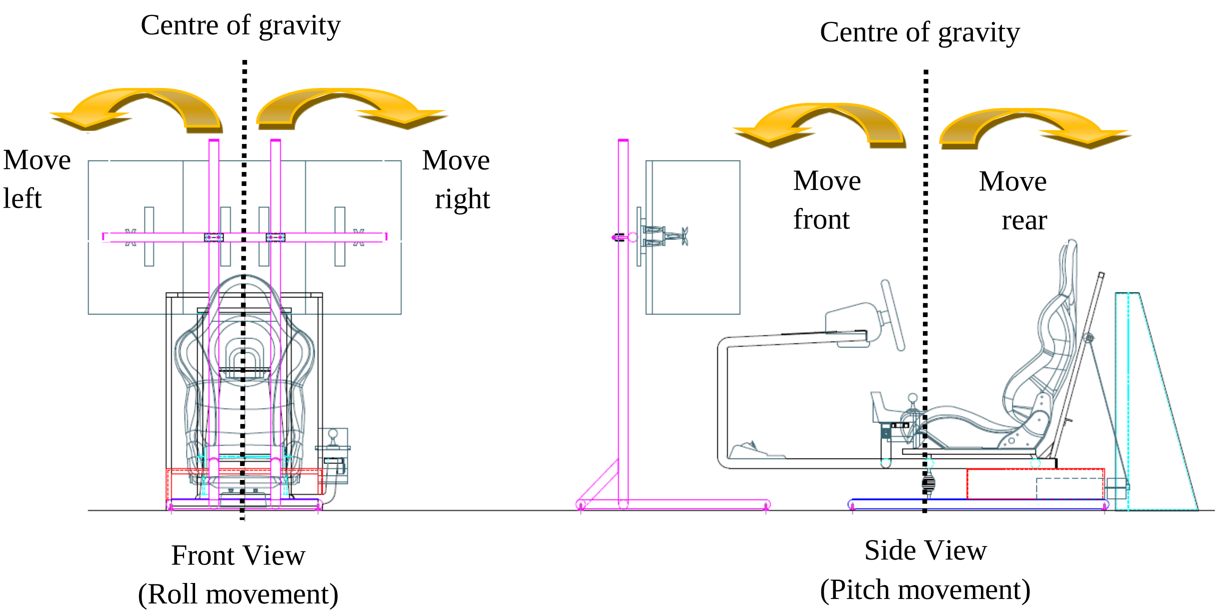

Figure 5: Overview of the two degree of freedom motion platform movement

The motion platform will be interfaced with control system in order to perform the two DOF motion cues. Arduino was used as a main controller of the two DOF motion platform. Arduino is a physical computing platform based on a simple controller board, and a development environment for writing software for the board (Arroyo, 2016). It offers some advantages that are: 1) Arduino boards are relatively inexpensive compared to other microcontroller platforms; 2) Arduino software able to run on Windows, Macintosh OSX and Linux operating systems, and most microcontroller systems are limited to Windows; 3)

Arduino programming environment is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well; and 4) Arduino software is published as open source tools, available for extension by experienced programmers (Arroyo, 2016).

3.0 BENEFITS

This section will discuss the benefits of the MiDOF driving simulator usage as compared to the other methods and tools.

3.1 Alternative Approach

Utilising driving simulator is an empirical alternative approach to traditional methods such as self-reports, questionnaires and observation which were widely argued to have limitations in studying driving behaviours. Among the limitations were the reliability of self-reports, truthfulness of respondents, variation in levels of subjectivity, researcher bias and infrequency of specific driving events.

3.2 Simulation Environment

There are some advantages of using driving simulator as compared to on road driving research which are the controlled and repeatable environment, safety purposes and cost reduction (Nilsson, 1993). Driving simulator enables researchers to isolate experimental variables from other factor that might influence driving performance, therefore improving the accuracy of the recorded measures. Furthermore, simulator can study the hazardous driving situation that could not be replicated by on road study without exposing subject to unacceptable risks (Eskandarian et al., 2008). Simulator study could reduce the research operation cost since the simulation environment and other factors can be controlled. Hence, there are no costs for fuel, toll fare, on road vehicle maintenance, etc.

3.3 Simulator Sickness Reduction

The main reason why a motion platform is important in simulator development, outlined by Piatkiewitz (2004), is to reduce simulator sickness. Simulator sickness is a type of cyber sickness, which occurs as a result of exposure to a virtual environment (VE). VE is an environment simulated by a computer as a real environment or an imaginary environment which is displayed on a computer screen which is often placed in special equipment like driving simulators. Simulator sickness could contaminate the data collected through the driving simulator as what it will be capturing is unlikely to be participant's actual behavior (Ariffin et al., 2012). Out of 30 respondents, only 3.3% (n=1) of them reported that they experienced simulator sickness by using MiDOF. On the other hand, 30% (n=9) of them reported that they experienced simulator sickness by using fixed-based MIROS mini simulator. Barrett and Thornton suggested that fixed-base simulators are likely to induce sickness because a cue conflict arises when the operator visually senses the appearance of incident vehicular motion but never receives corresponding physical acceleration or positional cues (Barrett and Thornton, 1968). In addition, Sinacori stated that the addition and proper tuning of motion cueing systems to some simulators has greatly reduced the sickness problem (Sinacori, 1967).

4.0 LIMITATION AND LESSON LEARNT

The simulation interface and video camera systems used in MiDOF required individual switches for data recording. This design was found to be subjected to human error during data collection. An operator had to manually turn the switches on at the beginning of each data collection session to ensure the video and data were recorded synchronously. This process requires additional manpower to operate both recording systems. The time synchronisation error was perhaps due to the use of two separate recording systems. Possible modification in the future will be to use a single recording system for both video and simulation output to solve this issue.

5.0 CONCLUSION

The paper has highlighted an overview of the design and systems architecture of MIROS 2 Degree of Freedom Driving Simulator (MiDOF). Data containing information such as participants' response time, vehicle speed, acceleration, braking, turn signals use and vehicle positioning were collected from the simulator which will enable numerous analyses on driver behaviour study. The development has led to a better understanding of a simulator instrumentation setup to cater for the needs of specific research on driver behaviour. This paper also discuss the benefits and lesson learnt of the simulator driver behaviour study. The lesson learned was vital in planning the upgrades in terms of the choice of instruments and data collection process.

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