Developing PC-Based Driving Simulator System for Driver Behavior Analysis Research

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Abstract. Driving simulator is one of important system for driving behavior studies. It offers a replicable virtual driving environment and it has possibility to create a various scenarios to carry out in real environment. The problem in development of this simulator is how to reduce a prices in certain point areas have made it possible to create low-cost driving simulators, but with the features that are usually found only in expensive driving simulators. This article is presented a low cost PC-based driving simulator. The aim is to use the simulator as a platform for studies of the driver’s behavior. The complete simulator is using three 27” LED screen, handle by a standard PC, typically used for computer games. As Input we using steering, pedal and shifter G29, with force feedback. For software we using city car home edition as tools to measure validity user and developing simulator to driver’s behavior study.

Keywords: Low-cost, PC-based driving simulator, fix-based rigs, driver’s behavior study.

1. Introduction
The use of driving simulators as tool to support the evaluation of safety behavior and emergency systems in the transportation study is the one of accepted method for more three decades. It is clear can be used in situations where driving in real environments is difficult, became high cost or high dangerous potential. Although that simulator can’t represent the real world with all circumstances, however, it still can be configured using multiple characteristics (i.e., various car type, visual system, motion system, sound, among others) that allow to best represent the real world.

Driving simulators have a variety of applications regarding driving safety studies, ranging from studies of driver behaviour to studies of vehicle devices and technology. It’s including behavioural studies, driver education and training, transportation infrastructure analysis, ergonomics, psychology, and intelligent transportation systems. The results of that study will lead to a reduction in the number of traffic-related deaths and injuries on a country’s highway.

Some research found in Indonesia about driving simulators can be seen in this illustration. Godham Eko Saputro (2013) [6], has made a simulation of a safe driving game with visualization of traffic signs, motorbikes, cars, traffic jams and irregular roads with the aim of reducing the number of traffic accidents on public roads. Nazaruddin Sinaga (2013) [7], held smart driving training and socialization for vehicle drivers with the aim of reducing greenhouse gas emissions and reducing the cost of land transportation. Atika Zahra Surya and Sunu Bagaskara (2016) [8], measure risk perception
by calculating how quickly responses occur when hazards are seen, with the aim of reducing risky driving behaviour for motorcycle driver. Novie Susanto et al. (2017) [9], testing the driver without using gadgets and using gadgets in driving with the aim of knowing decreased performance and driving behavior related to speed and lateral position changes resulting when driving while using a gadget. Ayu Widyowati Arya et al. (2014) [10], testing the driver while listening to music with different tempo and genre with the aim of knowing the effect of the driver’s alertness while driving while listening to music. Prisca Dwi Ariana and Thomas Dicky Hastjarjo (2018) [11], tested the driver by driving a car simulator and which was divided into two groups, music groups, and cell phone groups with the aim of testing the effect of divided attention on the awareness of the situation of the car simulator drivers. Novie Susanto et al. (2017) in the paper Analysis of the Effect of Manual and Automatic Car Transmissions on the Level of Difficulties Faced by Beginner Drivers [12]. They all measure the calculation of errors, driving time, and the occurrence of driving failure with predetermined conditions with the aim of providing recommendations for novice drivers regarding the transmission which is easier in the learning phase so as to minimize the risk of traffic accidents.

In general, driving Simulators are consist of a display, motion, audio system and to improve the impression usually they made a vehicle mock-up. Driving activity is a visual task because the driver receives most of the information through his eyes, so the best configuration of the display is most influential for accurate perception of surroundings. Most of driving simulator technology was conducted in real traffic environment, for transportation study even more it can enables an extreme situations in traffic environments. This paper discusses the construction of a simulator with a flexibility and realism similar to that of mid-level driving simulators for research, but still in lower cost and still enough to measured a practical case transportation study, in hopes that our methods and experiences can be valuable as other institutions to expand their options.

In the following sections, the simulator’s hardware and software components will be discussed, some supporting tools will be mentioned, and then we will briefly discuss the current limitations of the setup and our plans for addressing these limitations in the future.

2. Driving Simulator Hardware

The hardware used in this study is consist of medium-end Personal Computer, Driving simulator rigs and input/output devices, and display system.

2.1. Personal Computer

A single high-end desktop PC is assembled for our simulator. The CPU is a 3.0 GHz Intel I-5 6400 1150, with 32 GB of 2000MHz ADATA DDR4 XPG GAMING PC19200 RAM. A NVidia Colorful GeForce GTX 1650 4 GB DDR 5 graphics cards are used for three video output for multiple monitor system (1 DisplayPort 1.4a and 2 HDMI port). A Windows 10 was choosen as the operating system because of driver support and its compatibility with a wide system of gaming and simulation software. The total cost of all computer components was under $1600.

2.2. Driving simulator rigs and Input/output devices

The Flexi Game Seat system [15] was use as fixed-based cockpit-style seat (see Figure 1). This is considering a low-cost rigs, and still in enough for our research now. A Logitech G29 force-feedback wheel bolted to the Flexi Game Seat affords primary steering input. This is one of the largest and most solidly built game controllers on the market, and comes with a weighted throttle, brake, and clutch pedal assembly as well as a shifter knob. Engine noise and sounds generated and played through a Headset Rexus ThunderFox HX2 7.1 USB speaker system. The Flexi Game Set chair includes the Logitech G29 and the speaker system, and retailed for $1000 in 2019.
2.3. Display System

Three display configurations using LG LED 27” IPS 27 MK600, each monitor measuring 76 cm diagonally and offering 2560 x 1600 native resolution (SLI-mode video was necessary for smooth rendering at this resolution). This display was placed on a shelf approximately 100 cm off the floor (as shown in Figure 2). This configuration offered two horizontal viewing in the left and in the right monitor angle of $\pm 120^\circ$ to the center monitor, and a vertical viewing angle of 85° for every monitor in the worst case (the seat can adjustable to sliding as far back as it will move to back, resulting in a viewing distance of approximately 80 cm). We purchased three LG display for $1245. While it could be compared that using $1,500 commercial-grade curve displays the positioning of our simulator still as a low-cost alternative.

The display system is arranged in 3x1 layout and combined their inputs from NVidia Colorful GeForce GTX 1650 device. This allows them to appear to the Windows display driver as one large, combined 5760 x 1060 display from three individual displays. In order to bring the subject’s eye level in line with the vertical center of the displays (approximation 100 cm off the floor), we placed the Flexi Gaming Seat custom mounts for three displays. At a viewing distance of 108 - 128 cm, again in the worst case, the driving experience more realistic in this configuration because of the larger screen size. The illustration in the “hood view” for this physical layout shown in Figure 3.
3. Driving Simulator Software
After evaluating several open-source and commercial alternatives, the commercial driving game City Cars [13] was chosen as the software platform to measure validity user. City cars offers a realistic driving experience with rich detailed of graphics, convincing environment, accurate vehicle physics, and full support of force feedback steering wheels.

4. Data Analysis and Supporting Tools
According many research in the driver behavior research, the researches was collected a set of multi modal and time stamped synchronized data. These data is consist of 1) data from user experience (subjective reports) [4], 2) data from observe user's behavior [3], 3) data from electrophysiological recordings (heart rate, EEG, EMG), 4) data from eye movement recordings using eye tracker, 5) mechanical data from the vehicle, including the use of different control parts (steering wheel, brake, accelerator), and more continuous events at vehicles, and 6) data from environmental situation such as video recording other vehicles, the road and driving environment, weather conditions, pedestrians, traffic signs). [1][5]

This system setup offers a wider possibility for the integrated analysis the important factors in driving. This knowledge can be applied to make a planning of the traffic environment or to teaching of safety driving.

Many researcher using a test to collect data from user experience by measuring a driving simulator validity. In this test, some development tasks transferred from the real road into driving simulator using City Car simulation engine. A subject study is 20 participants to investigate the subjective experiences of the participants using our driving simulator setup. Before the driving test have been started, we introduce to participant how to control the vehicle using the steering system, shifters and pedals at our simulator and we give the participants drive along virtual urban city roads for around 5 minutes to get familiar with the environment and familiarize them using manual transmission vehicle. After that, we were instructed the the participants to pass the track as safety as possible, and with as little traffic violations as possible. The participants sit in front of three flat screens with a combined resolution of 5760 x 1080 pixels and with a approximately FOV 135° depending on the height of the participants. We displayed in-cockpit perspective (see Figure 4 left) since it is common in simulator studies due to the hardware steering wheel in front of the participants. As a compromise we displayed a speedometer on the higher left edge of the left screen, shifter indicators in the lower right edge and GPS task in the higher right edge of the right screen. as shown in Figure 4 right.
To keep participants focused on the driving task and foster the simulation character, Graphic settings were the same and geared to provide maximum frame rates.

![Figure 4. in- cockpit view set from City Cars Software.](image)

The simulator validity analysis is based on self-reported data. The participants were asked to complete a questionnaire during the test. We recorded participant feelings of comfort while driving in the simulator. Each question was a 1-9 Likert type item, and the questionnaire is consist of 7 subjective questions: 1) Comfort feeling in simulator, 2) Nervous feeling, 3) the degree of visual realism of simulator content, 4) the degree of physical realism, 5) Ease of use of the simulator, 6) adaptation levels in the use of simulators, and 7) Experience and expectation to the simulator.

The lowest response recorded at question 4 (the degree of physical realism) at 3.81 and the highest response recorded at question 2 (nervous feeling) at 6.32. Responses from participant recorded with no high negative or high positive scores. The score for question 1 is 5.70, question 3 is 5.80, question 5 is 5.54, question 6 is 6.02 and question 7 is 5.99.

The comfort feeling of participants generally found in the slighly above the middle area of Likert. These comfort and nervousness levels still scored fairly low, but its already above a psychological level. Visual realism scored better because City Car Software can give a realistic driving experience. Physical realism scored slightly below the middle area because our physical system simulator has a minimal feedback; only at steering wheel, with no motion system installed. In the question related to ease of use and adaptation to simulator, also scored on the positive side of the middle area of Likert. Generally, participant comments that their driving performance in simulator improved after the first trial. The question related to experience and expectation also scored positive; they were generally impressed by the overall driving simulator experience.

5. Advantages And Limitations
The advantages of this approach are cost and time. Typical high end simulation software for research, is very high cost. Our choice of City Cars as the simulation engine also meant significant time savings to measure validity user when using this simulator, but still need customizing function to meet our research purpose. In the next step of our research, development custom simulator platform to measure a driving behavior and create a realistic 3D environment is needed. We plan to use a full-scale software modeling suite Unity as engine [14]. Many asset of unity make an easier a difficulty to model the complex street layouts and intersections found in urban areas. The game engine furthermore just need a very little programmatic control over the computer-controlled “AI” drivers; one can merely tweak relatively opaque “strength” and “aggressiveness” settings in the configuration files. Another limitation in our hardware systems is the using a fix-based rigs as support. According Slob (2008) research, the using of fix-based rigs can generates a new problem known as simulator sickness, and also can reduce a realism of driving feel.
6. Future Plans
In the further to enhance the realism and immersion of the driving experience we can use a design of vehicle mock-up, such as dashboard, with motion platform. Finally, we also have plan to evaluate our driving simulator collecting data using supporting tools such as eye tracker and to determine the validity of HCI studies.

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