Pillion Simulation System (PISIS): An Exclusive System for Simulating Pillion's Motorcycling Experience

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ABSTRACT

In the recent years, studies in the motorcycle niche area have been an overwhelming area of research interest. Researchers utilized motorcycle simulator as an alternative assessment to conduct studies in the motorcycle niche area. However, it is noticeable that studies on motorcycle and pillion are very limited. This might be due to most of the motorcycle simulators were built exclusively for the rider, thus lack of capability to conduct experiments and assessments toward pillion. This paper deal with the development of a new simulation system for pillion motorcyclist named Pillion Simulation System (PISIS), in a controlled laboratory setting using an established motorcycle simulator, Postura Motergo^{TM}. Integration of several elements and development of PLC programming architecture written in CX-Programmer were done. As a result, the PISIS consists of 6 compositions: i) an audiovisual element that generates the visual and environmental sound; ii) a windblast element that generates the wind from an industrial blower; iii) motion system that generates movement of the motorcycle simulator in roll axis; iv) pillion features that enable the subject to perform riding posture as pillion; v) a vibration element that generates vibration from the sound system; and vi) programming architecture that simulates the dynamic of the PISIS system. Having such system integrated into the Postura Motergo^{TM} provides a new, safer medium and workstation for researchers to conduct

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continuous studies in the motorcycle niche area involving the pillion motorcyclist and hope to expand in the coming years.

Keywords: *Motorcycle, Simulator, Pillion, Motorcyclist*

Introduction

The increasing use of motorcycle nowadays is motivated by a great number of automobile users worldwide [1]. The increased number of automobiles critically changed the traffic into a congested area. Fewer parking areas, the economic downturn and the increased of fuel costs have recently created a bunch of problems to the road users [1, 2]. Therefore, motorcycles have become a popular transportation solution to these problems.

However, motorcycles have become a global transportation safety issues where motorcyclists suffer mortality and non-fatal injury crashes [3, 4]. It is undeniable the road safety of motorcycle has been marginalized compared with the four-wheeled vehicles such as cars, vans and trucks. It is reported that motorcycle has a higher risk of death compared to the four-wheeled vehicles [5]. In Malaysia, motorcycles have contributed to road accident statistics of 100,000 motorcycles annually since 2005, yet the number is increasing each year [6]. The statistics of motorcycle road accidents in Malaysia are considerably high, hence continuous researches related to the motorcycle niche area are needed.

In the recent years, researcher have attempted to conduct studies in the motorcycle niche area. However, most of the study focused on the rider, without the consideration of the pillion motorcyclist. Pillion motorcyclist, also known as pillion, can be referred as a passenger who sits at the back of the main rider on the same motorcycle, as illustrated in Figure 1. As a rider, carrying the pillion on the motorcycle means accepting a lot of responsibility. Riding as a pillion means the pillion may have a profound effect on the controllability of the motorcycle.

Figure 1: Pillion on the motorcycle [7]

In Iran, 30,901 motorcyclists suffer mortality in traffic accidents between the year 2006 to 2010 involving 25.7% of the total crash fatalities. Over 20% of motorcyclists killed from the total crash fatality were pillions, with an average of 3.4 pillions died per day [8]. A study in Singapore reported that, the fatality rate of pillion was higher compared to the riders [9]. It is found that riders sustained more severe chest and abdominal injuries compared to pillions, a higher incidence of fatalities involving run-over injuries for riders compared to pillions, and that the proportion of fatal injuries related to tumbling was higher for pillions than riders [9]. In addition, a literature reported that pillions sustain more crash injuries to the lower extremity (the limb of the human body involving thigh, foot, hip, gluteal region, ankle and knee) as compared to riders [10]. Recently, there was a case report highlighted that a pillion was burnt to death, where he was stuck under a motorcycle, however, the rider surprisingly escaped unhurt [5]. Both rider and pillion have been classified as vulnerable road users with a higher risk compared to other road users. Based on the studies made on motorcycle road involving pillion, the causes of the accidents and information on the pillion were mostly not indicated. Therefore, it is crucial to conduct research towards pillion as much as study performed for rider and passenger of other vehicles.

In conducting research towards the motorcyclist, as an alternative to real world assessment, researchers tend to utilize a motorcycle simulator. A motorcycle simulator was invented to give near-to-real experience while handling motorcycle in a controlled laboratory environment with the capability to compute the dynamic behaviour of the motorcyclist [11]. Suggestively, it is the safest way of handling the motorcycle due to the absence of real hazardous conditions from the real road.

There are a few numbers of motorcycle simulators being developed all around the world, such as Honda SMARTrainer Motorcyle Simulator [12], NIHON Motorcycle Simulator [13] and UNIPD Motorcycle Simulator [14]. However, most of the motorcycle simulators are purposely developed for the rider as the main subject, in other words, the motorcycle simulator is controlled by the subject. Till now, a motorcycle simulator specifically built for pillion as the main subject is not yet developed. Normal motorcycle simulator still can be used for conducting research towards pillion. This can be done by having 2 subjects on the motorcycle simulator acting as a rider and a pillion. However, it is more convenient if only a single subject is needed, acting as the pillion. By mean, the motorcycle simulator is controlled by a special system, instead of controlled by the rider, which makes the motorcycle simulator to be fully automated. The movement and behaviour of the motorcycle simulator are fully automated, integrated with elements such as vibration, windblast, noise and visual. During the simulation process, only a single subject is required, acting as the pillion. Having a motorcycle simulator for pillion passenger will provide a new medium and workstation for researchers to conduct study towards the pillion, within a controlled laboratory, without having to include the rider during the simulation.

For this study, a special interest is made on the Postura Motergo™, a revolutionary motorcycle simulator established by a group of researchers from the Motorcycle Engineering Technology Laboratory (METAL) of the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM) [3, 15]. Figure 2 shows the setup of the Postura Motergo™.

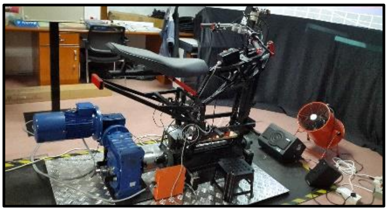
Figure 2: Postura Motergo™

This paper aimed for the development of a new simulation system for pillion named Pillion Simulation System (PISIS), which is integrated into the Postura Motergo™. It is a system that composes the rider, motorcycle and environment into a single system. It enables the Postura Motergo™ to be fully automated, providing a new medium and workstation for conducting research on the pillion. As a result, there is a vast room for explorations and innovations in research towards pillion.

The Composition of the Motorcycle Simulator

Unique from other simulators, the Postura Motergo™ is an established motorcycle simulator that provides different riding postures based on the Riding Posture Classification (RIPOC) system. Unlike other motorcycle simulator that uses real motorcycle as part of the setup, the Postura Motergo™ was completely built from scratch, without using any real motorcycle. In developing the simulation system for pillion, these compositions are privileged within the motorcycle simulator, Postura Motergo™.

The mock motorcycle integrated with pillion features

The mock motorcycle is shown in Figure 2 previously. The chassis of the motorcycle simulator was designed and fabricated, mainly using mild steel. The motorcycle simulator consists of important features for the rider, and also integrated with pillion features. Pillion features can be defined as the parts of the motorcycle that are in contact with the pillion during motorcycling activity. In simulating the pillion on the motorcycle simulator via the PISIS, pillion features are significant. These features include the pillion seat, foot-pegs, handrails and removable back supporter, as shown in Figure 3. Standard parts available in the market were bought and integrated into the simulator.

(a) (b)

Figure 3: (a) Handrail, (b) Foot-pegs

Audio visual element

A curved projection screen is placed 1.5m in front of the motorcycle simulator. The curved projection screen was fabricated by using plywood and formica as the main material. The front view images are generated by a computer and then projected onto the curved screen by using multiple EPSON EB-X18 projectors, placed behind the motorcycle simulator. The images generated by the 3 projectors were mapped and warped using Immersive Calibration PRO to fit the curved screen. Immersive Calibration PRO is an image mapping software that offers the most advanced tools and algorithms for automatic alignment and soft-edge blending of multi-channel projection systems. Figure 4 shows the audiovisual element of the setup.

Figure 4: Simulator point of view

Windblast element

A set of industrial blower is placed in front of the motorcycle simulator, as shown in Figure 5. The wind generator is placed strategically after careful consideration of the generated wind strength, range, and the rider's vision range was done. The industrial blower is connected to a EMBPAPST voltage regulator as a method to control the speed of the windblast. With the inclusion of this windblast element, the subject who acts as a pillion feels a more realistic riding experience.

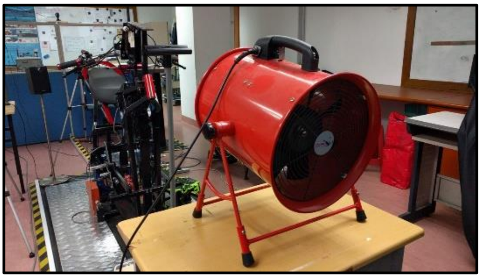

Figure 5: Industrial blower for generating windblast

Vibration element

In order to generate the vibration element within the simulator, a device named ButtKicker Gamer 2 is installed. The ButtKicker is a mechanical device that provides vibration and action from the games, via audio input. The device is widely used in most simulators, and also 4D cinemas around the world. For the motorcycle simulator, it could deliver the feel and vibration of the engine sound, throttling, gear shifts, bumpy road and much more. The ButtKicker Gamer 2 produces the vibration element from the audio input of the games. High amplitude of sound produced by the game will increase the vibration intensity. Figure 6 shows the ButtKicker Gamer 2 integrated into the motorcycle simulator.

Figure 6: ButtKicker Gamer 2 integrated to the Postura Motergo™

Motion system

Motion system is the most critical system in the development of PISIS. The motion of this motorcycle simulator has 2 degrees of freedom, roll-axis and steering axis. However, steering axis is not part of the PISIS as the subject act as the pillion, not the rider. At the roll-axis, a DC servo motor is placed to operate and control the movement of the motorcycle simulator, as shown in Figure 7. The angles which are controlled by the servo motor is set to have a movable range of ±20° in the roll axis. An emergency stop button is also included in the system as a precaution to prevent accidents. An encoder is integrated within the servo motor, and connected to a Programmable Logic Controller (PLC).

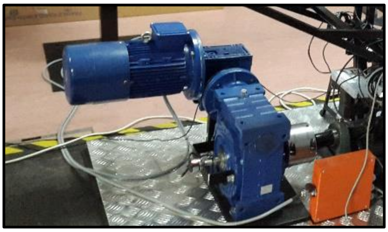

Figure 7: Motion system of Postura Motergo™

Pillion Simulation System

The new simulation system exclusively for pillion is named as the Pillion Simulation System (PISIS). The PILLION refers to the subjects who act as the pillion on the motorcycle simulator. The SIMULATION refers to the imitation or the act of simulating the near-to-real motorcycling activity by using a motorcycle simulator in a controlled laboratory. Meanwhile, the SYSTEM refers to the set of integrated component which forms the new simulation system for the pillion. The PISIS is an acronym for the Pillion Simulation System.

The composition of the motorcycle simulator described previously is part of the development of the Pillion Simulation System (PISIS). It is a system that ables to transform a motorcycle simulator, Postura Motergo™ from manually controlled by a subject to be fully automated by the system. The system is able to simulate pillion motorcycling conditions in a controlled laboratory setting, as well as provides a new medium and workstation for researchers to conduct research and experiment towards the pillion. Data and information of the subject as a pillion can be captured by various ergonomics tools such as surface Electromyography (sEMG) for the muscle activity measurement, via the use of the Postura Motergo™ and the Pillion Simulation System (PISIS). The users and researcher, especially ergonomics experts, can apply the outcomes of the analysis to perform modification of the workstation design to conduct various researchers as an effort to minimize the motorcycle road accident involving pillion.

Modules of the PISIS

There are 4 modules developed for PISIS as shown in Figure 8. Each module simulates the different pillion motorcycling condition on a different road. Instead of gaming software, a video clip of motorcycling activity is projected on the screen. The intention is for the subject to acquire the psychological impression of performing motorcycling activity. 4 video clips of motorcycling activity are used in the development of the PISIS's visual counterpart. They are video clips of motorcycling activity in motorcycle highway route, highway route, urban route and rural route. The duration of each video is set to 5 minutes. Hence, there are 4 modules of PISIS which are Module 1: Motorcycle Highway Route, Module 2: Highway Route, Module 3: Urban Route and Module 4: Rural Route.

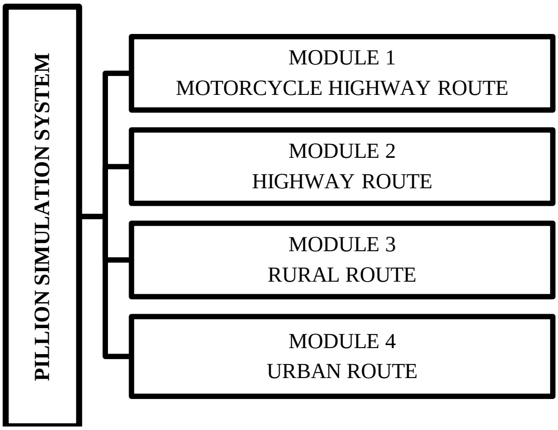

Figure 8: Modules in PISIS

The clips were recorded by using Mobius Action Camera. Table 1 describes the information of each video clip recorded and used for the PISIS's visual. For each route, a cruising speed of 60 – 100 km/hr was maintained. The generation of the environmental sounds from the clips is provided by multiple sets of speakers surrounding the motorcycle simulator. The sound is limited to 90db noise level, as a precaution to the ear of the subject. Figure 9 shows the action camera used to record the clips of the motorcycling activity.

Figure 9: Mobius action camera attached to the a motorcycle

Table 1: Clips information

Clip	Route	Information
1	Highway Route	Exit Sunway – Federal Highway - Bulatan Bekerly Klang Distance Travelled – 12.3 km Length of Video Recording – 5 minutes
2	Motorcycle Highway Route	Seksyen 7 – Federal Highway (Motorcycle Lane) - Jalan SS 7/2 Sungai Way Distance Travelled – 13.7 km Length of Video Recording – 5 minutes
3	Urban Route	Jalan SS 7/2 Sungai Way – Bandar Sunway Distance Travelled – 6.5 km Length of Video Recording – 5 minutes
4	Rural Route	Jalan Batu 3 Lama – Jalan Dato Mohd Sidin – Jalan Sungai Rasau Distance Travelled – 4.5 km Length of Video Recording – 5 minutes

Programming architecture

The programming architecture of the PISIS is developed using CX-Programmer, a programming software for PLC. It is a programming language that represents a program by a graphical ladder diagram. It is commonly used in industrial control applications. In developing the programs for PISIS, a combination of arithmetic comparison and shifting sequence were used. The advantages of using CX-Programmer are that, it is fully programmable and available for on-line editing.

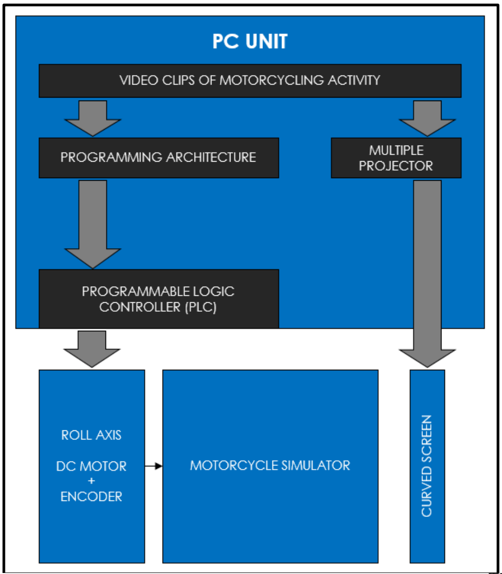

Figure 10: Architecture of the Postura Motergo™

Figure 10 shows the architecture of Postura Motergo™ in the development of PISIS. The motorcycle simulator is connected to a DC servo motor and an encoder, which enables the movement of the motorcycle simulator in the roll axis. Meanwhile, a video clip of motorcycling activity is projected on the screen. The DC servo motor and encoder are connected to an OMRON PLC. The PLC is programmed by using a software CX-Programmer. Basically, the PLC is programmed so that the motorcycle simulator follows the motorcycling activities in the video clip. For example, when the motorcycle in the video clip leans to the left, the motorcycle simulator also leans to the left, and vice versa.

Several data were recorded from each of the videos recorded. The data were utilized in programming the PISIS, as follows:

i. Time frame for each video
ii. Number of right turns
iii. Number of left turns
iv. Number of normal position
v. Duration of each right turn
vi. Duration of each left turn
vii. Duration of each normal position
viii. Angle of leaning for right turn
ix. Angle of leaning for left turn

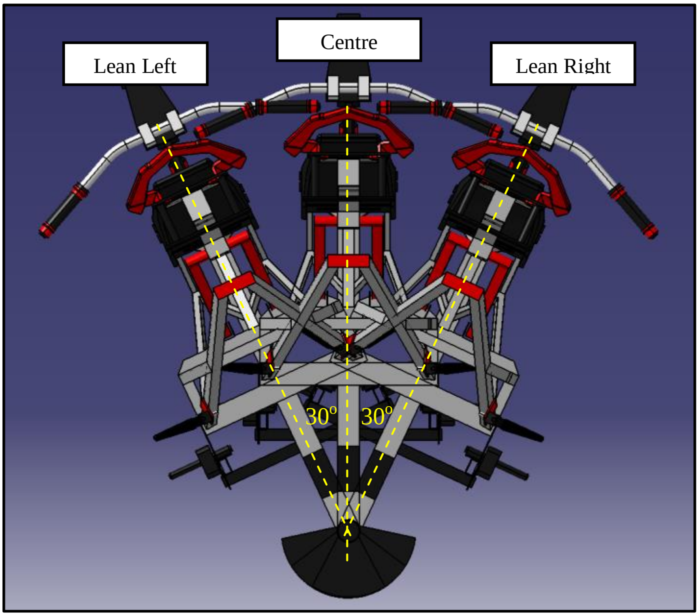

Figure 11: Motion of the simulator

In the programs developed, the rotation of the motor encoder is very critical as it indicates the angle of the rotation for the motorcycle simulator in the roll axis. The value of negative (-) indicates the motor turns to the left while positive (+) to the right. The range of the value is set to be from 20 to 100, either (+) or (-). The value of 100 represents the maximum rotation of the motor, which is 30^{o}. Even though in real motorcycling activity, the highest angle of leaning is 65^{o} done by a MotorGP racer, Marc Marquez, 30^{o} is chosen as the maximum angle of leaning due to the motorcycle simulator is in static condition, hence to avoid the subject from falling down. Figure 11 shows part of the motion of the simulator in roll axis with 30^{o} maximum leaning angle.

Figure 12 shows the flow chart of the programming architecture. A timer, or countdown is used as a reference to map with the time frame of the video. This is to ensure that the video's time frame and program's time frame is parallel and synchronized.

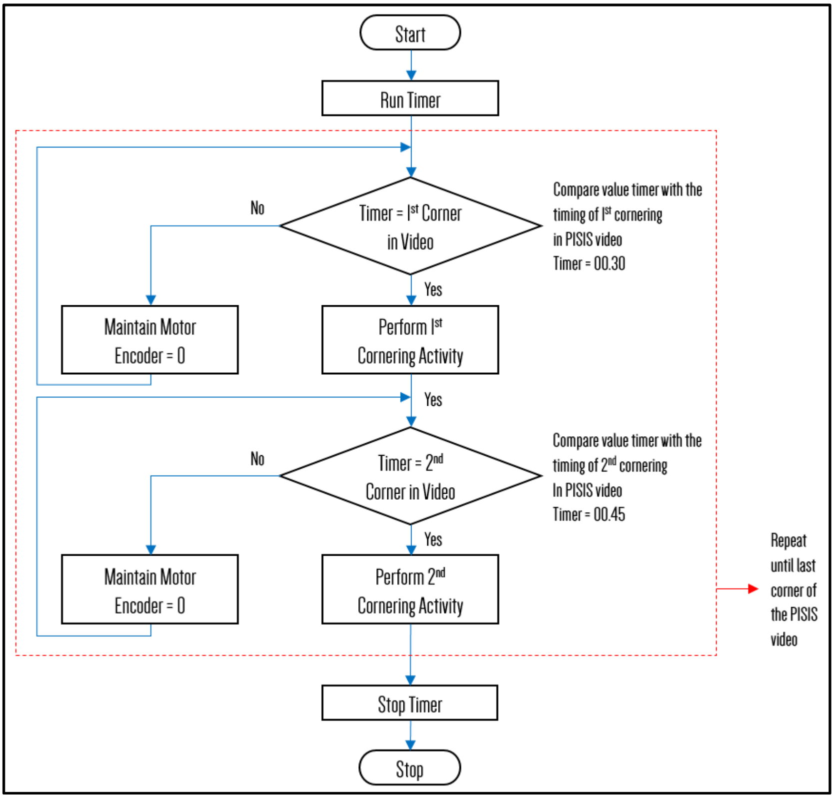

Figure 12: Flow chart of PISIS programming architecture

Table 2 shows some of the data and value recorded in the programming architecture. The H. Value represents the variable for the action of the cornering and normal position in the video. Meanwhile, Time Value represents the variable of each timing for each action. Jump Value is a special value added in order to ensure the program and the time frame of the video is synchronized. Figure 13 shows some part of the program in the CX-Programmer.

Table 2: Some of the data and value used in the CX-Programmer

NO	H. VALUE	ACTION	DURATION	TIME VALUE	JUMP VALUE
1	H0.01	Delay CENTRE	260	T011	260
2	H0.02 – H0.04	Turn LEFT – CENTRE	60	T012	-

3	H0.05	Delay CENTRE	80	5.01 JUMP 1	42
4	H0.06 – H0.08	Turn LEFT – CENTRE	30	T013	-
5	H0.09	Delay CENTRE	50	5.02 JUMP 2	50
6	H0.10 – H0.14	Turn LEFT – RIGHT – CENTRE	0 + 0	T014 + T015	-
7	H0.15	Delay CENTRE	333	5.03 JUMP 3	87
8	H1.00 – H1.06	Turn LEFT – CENTRE – RIGHT – CENTRE	0 + 10 + 15	T016 + T017 + T018	-
9	H1.07	Delay CENTRE	40	5.04 JUMP 4	99
10	H1.08 – H1.14	Turn LEFT – CENTRE – RIGHT – CENTRE	10 + 45 + 10	T019 + T020 + T021	-
11	H1.15	Delay CENTRE	30	5.05 JUMP 5	110
12	H2.00 – H2.06	Turn RIGHT – CENTRE – LEFT – CENTRE	10 + 10 + 65	T022 + T023 + T024	-
13	H2.07	Delay CENTRE	210	5.06 JUMP 6	143
14	H2.08 – H2.12	Turn RIGHT – LEFT – CENTRE	0 + 0	T025 + T026	-
15	H2.13	Delay CENTRE	280	5.07 JUMP 7	175
16	H2.14 – H3.00	Turn LEFT – CENTRE	20	T027	-
17	H3.01	Delay CENTRE	120	5.08 JUMP 8	190
18	H3.02 – H3.14	Turn LEFT – RIGHT – CENTRE – LEFT – CENTRE – RIGHT –	0 + 0 + 20 0 + 10 + 5	T028 + T029 + T030 T031 + T032 + T033	-

		CENTRE			
19	H3.15	Delay CENTRE	45	5.09 JUMP 9	205
20	H4.00 – H5.00	Turn RIGHT – CENTRE – RIGHT – CENTRE – LEFT – CENTRE – RIGHT – LEFT – CENTRE	5 + 20 + 10 25 + 13 + 13 0 + 0	T034 + T035 + T036 T037 + T038 + T039 T040 + T041	-
21	H5.01	Delay CENTRE	110	5.10 JUMP 10	235
22	H5.02 – H5.10	Turn LEFT – RIGHT – CENTRE – LEFT – CENTRE	0 + 0 + 30 35	T042 + T043 + T044 T045	-
23	H5.11	Delay CENTRE	440	5.11 JUMP 10	240
24	H5.12 – H5.14	Turn LEFT – CENTRE	40	T046	-
25	H5.15	Delay CENTRE	0	T047	0

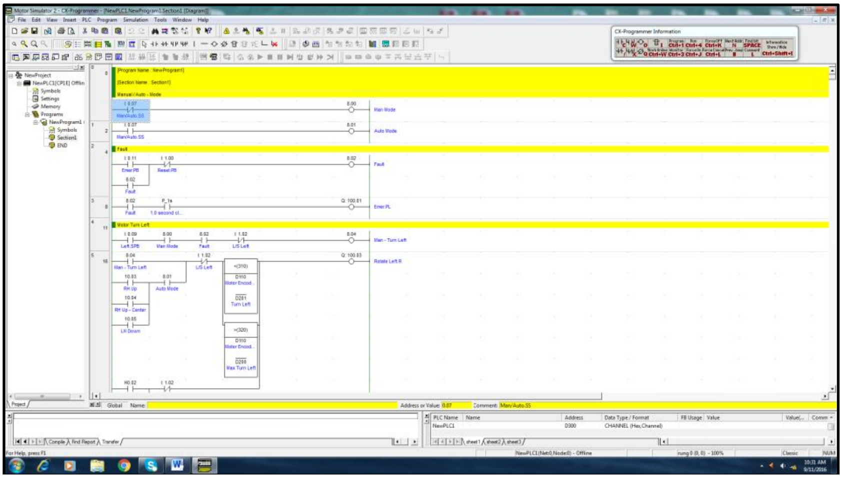

Figure 13: CX-Programmer

Application and Experimentation Tests

The purpose of PISIS is to provide a new simulation system for the researcher to conduct studies on the pillion. As a summary for this type of simulation, the respondent will act as a pillion. Instead of using gaming software, a video clip of motorcycling activity is used in order for the respondent to acquire the psychological impression of performing motorcycling activity as a pillion. There are 4 types of video clips with different routes for the visual counterparts which are highway route, motorcycle highway route, urban route and rural route. The respondent can choose which video clip to be used during the simulation. The respondent only sits on the Postura MotergoTM, while maintaining the pillion riding posture. The Postura Motergo^{TM} will be fully automated, moving and leaning according to the video clips. The windblast produced is linked to the motorcycle speed in the video.

The PISIS was validated via questionnaire survey among 100 respondents and has been used for a pilot study muscle activity measurement using surface electromyography (sEMG) among 31 respondents. Results obtained from the questionnaire and the sEMG show that PISIS is able to simulate motions realistic enough such that experiments which involve the human factor and traffic condition, can be safely and realistically simulated. Therefore, PISIS is a suitable system for conducting research on the relation between pillion and motorcycle. Figure 14 shows some of the simulation of pillion using PISIS and the Postura Motergo^{TM}.

Figure 14: Constructed riding the motorcycle simulator as pillion

The PISIS managed to give reliable and valid results for the muscle activity measurement using sEMG. For example, the posterior deltoid, one of the most significant muscle for pillion during motorcycling shows almost symmetrical pattern between the sEMG data via real motorcycle and via Postura Motergo^{TM}. Figure 15 and Figure 16 shows the comparison of the sEMG data for posterior deltoid and erector spinae respectively.

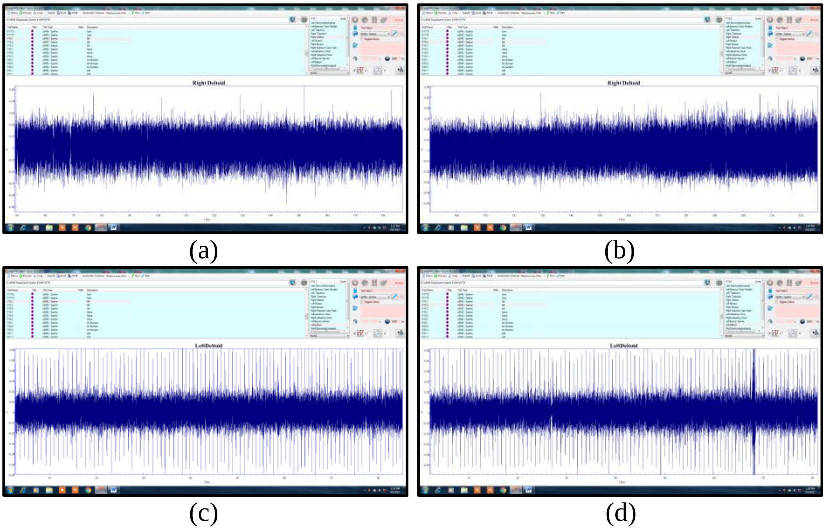

Figure 15: (a) Right posterior deltoid on real motorcycle, (b) Right posterior deltoid on Postura Motergo^{TM}, (c) Left posterior deltoid on real motorcycle, (d) Left posterior deltoid on Postura Motergo^{TM}

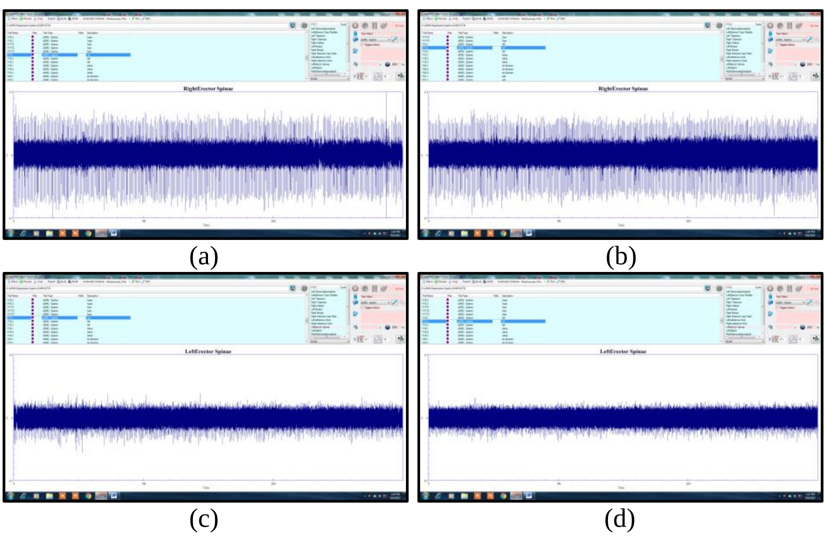

Figure 16: (a) Right erector spinae on real motorcycle, (b) Right erector spinae on Postura Motergo^{TM}, (c) Left erector spinae on real motorcycle, (d) Left erector spinae on Postura Motergo^{TM}

Same goes to the erector spinae, where the pattern of the sEMG data is almost similar between the real motorcycle and Postura Motergo^{TM}. Having these setup and result help to bridge the gap between the researcher and studies concerning the pillion in motorcycle niche area.

Achievements

Upon the completion of integrating Pillion Simulation System into the Postura Motergo^{TM}, the author participated in the 1st ACED (Asian Council on Ergonomics and Design) Ergonomic Design Award in conjunction with the 2nd Asian Conference on Ergonomic and Design 2017 which was held at Nihon University, Japan. The "Postura Motergo^{TM} – A Full Scale Ergonomic Motorcycle Simulator" managed to secure the Best of Best Award, as shown in Figure 17.

Figure 17: ACED Design Award 2017 – Best of Best

Conclusion

This paper managed to achieve its main goal in the development of a new simulation system for pillion motorcyclist named Pillion Simulation System (PISIS). The system also was validated via questionnaire survey and some experiments on the muscle activity measurement using sEMG. As for further development of the system, a longer duration of the simulation and consideration on the pitch axis of the Postua Motergo^{TM} for the inertia effect could be included. Conclusively, PISIS can help to bridge the gap between the researcher and studies concerning the pillion in motorcycle niche area. Such development presents a vast room and exploration for further research on pillion in the motorcycle niche area.

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