Development of Decision Support System via Ergonomics Approach for Driving Fatigue Detection

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Abstract

Driving operation has become more important nowadays as this method becomes practical, faster, and cheaper to move humans from one location to another. However, driving activity can cause a human being to suffer tragedy or death in everyday life as they get exhausted while driving. Driver fatigue is a major contributing factor in road crashes. This paper's primary aim was to develop a decision support system (DSS) for the monitoring of driving fatigue. The decision support system seeks to provide systematic analysis and approaches to minimize the risk associated with driving exhaustion and the number of accidents involved. Four major stages involved as the cornerstone in the development of decision support system; knowledge acquisition, knowledge integration, development of driving fatigue strain index using fuzzy logic membership function, development of the fatigue driving decision support system (DSSfDF) model using the graphical user interface. The decision support system is an essential program for evaluating the risk factors which would significantly contribute to driving fatigue associated with driving activity. Furthermore, the decision support system offers users solutions and recommendations to minimize the number of road accidents in Malaysia.

Keywords: Decision support system, driving fatigue, road accidents, fuzzy logic, graphical user interface

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INTRODUCTION

Malaysia, along with other countries are now in the exciting rate of urbanization level. The report by Transformasi Nasional 2050, also known as TN50, estimated that almost 60% of the world population will be staying in urban areas during 2025 (Land of Public Transport Commission, 2017). As the urbanization level increases, the human population around the world has become more dependent on the transportation system. Indirectly, the growth of many vehicles on roads has made the current transportation system face several challenges and problems. One of the challenges and problems is road safety and accidents. Speeding and risky driving are the major cause of accidents in road transportation. Many efforts have been made by the governments, researchers, road safety practitioners, and road safety society and organizations regarding these two causes. However, the number of road accidents is still on the dangerous level. Hence, this study will focus on other causes of road accidents that are driving fatigue.

In 2018, 6,740 road deaths and 548,598 road accidents is reported on the basis of a report by the Royal Malaysian Police (RMP) and the Department of Statistics Malaysia (DOS), as shown in Table 1{ MIROS, 2019; Department of Statistical Malaysia, 2019; Ministry of Transport Malaysia, 2019; Department of Traffic Investigation and Enforcement, 2018). The data shows that since 2008, the number of road accidents in Malaysia has been rising year by year. In addition, from 2008 to 2018 the total average number of vehicles involved in accidents is around 467,566. Some of the crashes were triggered by exhaustion element from that number of accidents (MIROS, 2019). Driving fatigue causes the driver to be tired while driving, which reduces the motor control and strength capacity, leading to decreased performance and increased risk of accidents and human error (Yung, 2016).

Table 1. Total casualties and damages caused by road accidents in Malaysia from 2008-2019

Year	Total Number of Accidents	Casualties			
		Death	Serious	Minor	Total
2008	373,071	6,527	8,868	16,879	32,274
2009	397,330	6,745	8,849	15,823	31,417
2010	414,421	6,872	7,781	13,616	28,269
2011	449,040	6,877	6,328	12,365	25,570
2012	462,423	6,917	5,868	11,654	24,439
2013	477,204	6,915	4,597	8,388	19,900
2014	476,196	6,674	4,432	8,598	19,704
2015	489,606	6,706	4,120	7,432	18,258
2016	521,466	7,152	4,506	7,415	19,073
2017	533,875	6,740	3,310	6,539	16,589
2018	548,598	6,284	Undisclosed	Undisclosed	Undisclosed
2019	133,912	1,483 (Jan-Mac)	Undisclosed	Undisclosed	Undisclosed

Figure 1 shows contributors to the accident according to MIROS (MIROS, 2019). According to the MIROS report, 80.6% of road accidents are caused by human error, 13.2% by road conditions and 6.2% by a vehicle. MIROS (2019) conducted in - depth collision studies on some accident cases, finding that reckless driving, speed and fatigue are major categories of human error.

Figure 1. Accident's contributors (MIROS, 2019)

LITERATURE REVIEW

Driver fatigue is one of the driver's major causes of road road accidents during transport (San et. al., 2016; Desmond et. al., 2012). Driver fatigue can be described as one of the main areas of driver behavior that needs to be addressed to reduce the number of people killed in road accidents and seriously injured. Based on previous research, fatigue like other road safety issues, such as drunk driving, can be risky and there are no laws regulating driver fatigue. As a driver, fatigue will trigger and carry several problems and consequences like slowing down driver reactions and decisions, reducing car awareness for other road users, poor lane control and maintaining speed and reduce driver alert.

Driving fatigue has been described as a feeling of drowsiness due to extended traveling time, monotonous road conditions, adverse weather conditions, or driver's characteristics are leading or contributing factors to road accidents. It can also be described as feeling tired and decreased alertness while driving combined with drowsiness and impairing the driving task's ability and willingness (San et. al., 2016). According to Meletis and Baker (2004), a subjective feeling of fatigue combined with negative effects on performance due to time spent on cognitively challenging tasks can somehow affect driving performance due to sleepiness, monotonous driving environment and driving length, as previous studies have shown (Otmani et. al., 2005; Papadelis et. al., 2007; Seen et. al., 2010). A Mohammed et. al., (2008) pointed out that 37.7% of commercial bus drivers in Malaysia had reported exhaustion while driving, where long travel times and intense working hours had a synergistic effect on the onset of fatigue.

Several risk factors play a significant role of fatigued-traffic accidents happening. Dobbie's earlier work (2009) concluded that continuous driving without rest would increase the level of fatigue and deteriorate driving performance. The long driving time, inadequate sleep and other combined factors led the sleep - deprived drivers to make a greater amount of right edge-line crosses and other mistakes (Otmani et. al., 2005; Philip et. al., 2003). However, tests have also shown that working time and sleep deprivation, as a result with disturbing the normal sleep cycle of an adult (Tippayanate, 2006; Philip et. al., 2005; Philip et. al., 2003), clearly contributed to a decline in driving performance. Previous studies conducted had limited driving fatigue awareness and focused only on commercial bus drivers by questionnaires and salivary cortisol (Mohamed et. al., 2008). There was a lack of study on the development of regression models of psychophysical and biomechanical factors, and more focus on one or other issues or problems.

Many recent studies have been performed on the application of the decision support system (DSS) for transportation. However, there is no study on the development of a decision support system that focuses solely on the causes of road accidents which drive fatigue in particular. DSS was conceived in the early stages as simple databases for the storage and retrieval of information deemed useful to decision - makers. This tool was then enhanced and became real support in complex human decision - making processes that help decision - makers identify a possible solution that can optimize choice (French, 2014; Dell'Acqua et. al., 2011).

Fancello's et. al., (2015) in their recent study designed a policy support framework for the study of road safety to assist the national sector in planning road safety measures. Furthermore, the Dell'Acqua et. al., (2011) developed the knowledge - based decision support system in the field of road safety. These DSS identify and rank dangerous roadside sites to reduce the number of road accidents. Another recent study is the implementation of DSS to examine the safety issues facing vulnerable road users, called SAFEBRAIN (Tripodi et al., 2012). The DSS has been built to emphasize safety strategies to reduce the risk of new road users ' accidents.

METHODOLOGY

This section discussed the four stages for the development of a decision support system for driving fatigue (DSSfDF).

STAGE 1: KNOWLEDGE ACQUISITION

Knowledge is a brain for processing system-received input data and information, which can be by gathering, structuring, and organizing knowledge from one source to more. In this study, the risk factors that significantly contribute to driver fatigue are described by the knowledge acquisition. In addition, the methods for measuring ergonomics are also being determined at this point. This knowledge acquisition is achieved by collecting information from reliable sources such as pre-surveying, carrying out the actual road test, evaluating previous research and papers, referencing recommendations and international standards from approved organisations or bodies, and seeking advice from the ergonomics specialist to establish the Driving Fatigue Strain Index (DFSI).

The pre-survey and the actual road test experiment is conducted and performed among road users in Malaysia to analyze and collect information and data on each risk factor; muscle activity (MA), heart rate (HR), handgrip force (HGF), whole body vibration (WBV), seat pressure distribution (SPD), and driving duration (DD). In addition, previous studies, papers or journals, magazines and online databases on the risk factors affecting driving exhaustion are reviewed (Lu et. al., 2017; Halim and Rahmah, 2012; Zak, 2010; Lee et. al., 2008; Karwowski et. al., 2006). In addition, the author has referred guidelines and standards from the authorized organization, society or institutions such as the International Standard Organization (ISO), the Royal Malaysian Police (RMP), the Perusahaan Otomobil Nasional (PROTON), and the Malaysian Institute of Road Safety Research (MIROS) to obtain information and data on the number of road accidents and driving fatigue. The subjects in this study consist of drivers with at least two years of driving experience, and the subject's age is between 20 - 25 years.

STAGE 2: KNOWLEDGE INTEGRATION

At this point, the strategies for integrating the risk factors and the ergonomics evaluation are analyzed. The risk factors of driving fatigue and the evaluation tools are integrated to measure the levels of risk, and the DFSI was developed directly. Risk factors are selected based on the actual road test experiment (as shown in Figure 2) and an earlier study that has demonstrated that all these factors have a significant impact on driving fatigue (Ani et. al., 2018; Ani et. al., 2017; Firdaus et. al., 2017; Ani, 2016; Rahayu et. al., 2016; Rahayu & Firdaus, 2015). In addition, some of the preceding studies were used as guidance for quantifying the risk levels of each risk factor.

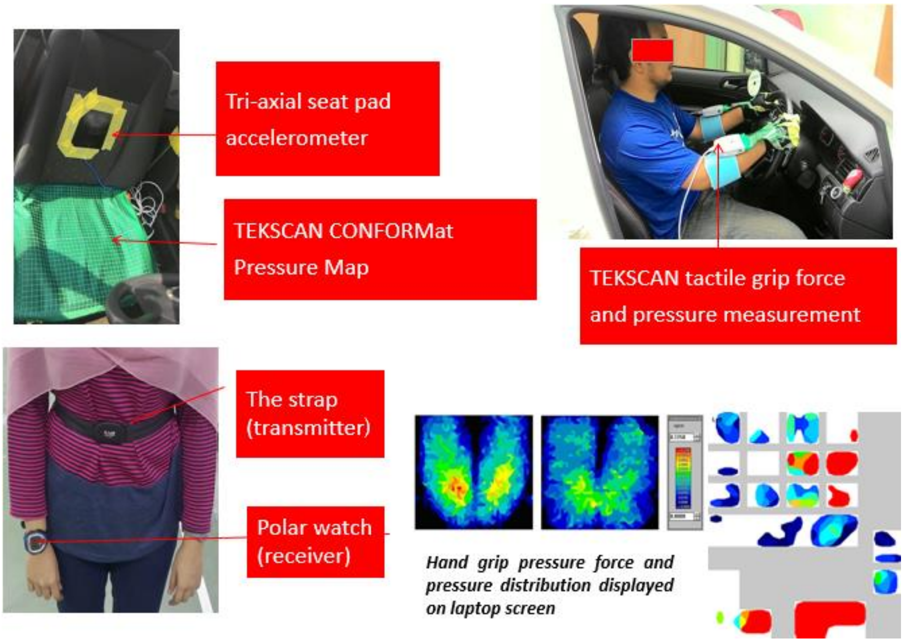

Figure 2. The experimental apparatus and setup.

Evaluation of each risk factor produces a level of risk that reflects the impact on the driver of evaluated risk factors. The risk criteria for each factor to suggest risk levels due to driving fatigue are summarized in Table 2. These requirements for classification and risk levels are based on prior tests and guidelines. In stage 3 of development for DSSfDF, the risk criteria and risk level will be used.

Table 2. The risk criteria and risk level for the driving condition

Risk Factor					
MA (μV)	**HR (bpm)**	**HGF (N)**	**WBV (m/s^2)**	**SPD (kPa)**	**DD (min)**
Little fatigue: 52 ≥ 129	Very fit: <84	Non-fatigue: ≥ 189.60	Comfort: < 0.315	Comfort: ≤ 5.80	Non-fatigue: < 40
Moderate fatigue: 130 ≥ 300	Fit: 84 – 105	Mild Fatigue: 57.80 > 189.60	Little comfort: 0.315 > 0.63	Discomfort: > 5.80	Fatigue: ≥ 40
Fatigue: 301 ≥ 600	Average: 106 – 122	Fatigue: < 57.80	Fairly comfort: 0.50 > 1.0		
Very fatigue: 601 ≥ 1100	Unfit: >122		Discomfort: 0.8 > 1.6		
			Very discomfort: 1.25- 2.5		

STAGE 3: DEVELOPMENT OF DRIVING FATIGUE STRAIN INDEX (DFSI) USING FUZZY LOGIC

Fuzzy logic is based on the concept of partial membership function (MF) in a set described by the MF(μA), a curve defining how each point in the input space is mapped to a membership value described by real values 0[μA(x)] ≤1. The Fuzzy Inference System (FIS) was built during this stage. FIS is the practice of using fuzzy logic to formulate the mapping from a given input to a product. The MATLAB software used the fuzzy logic toolbox graphical user interface (GUI) to develop the FIS. The toolbox contains five key GUI tools to build, update, and monitor the FIS; FIS editor, MF reader, rule editor, rule editor, and surface viewer. The FIS editor shows FIS information such as input and output, and type of FIS as shown in Figure 3.

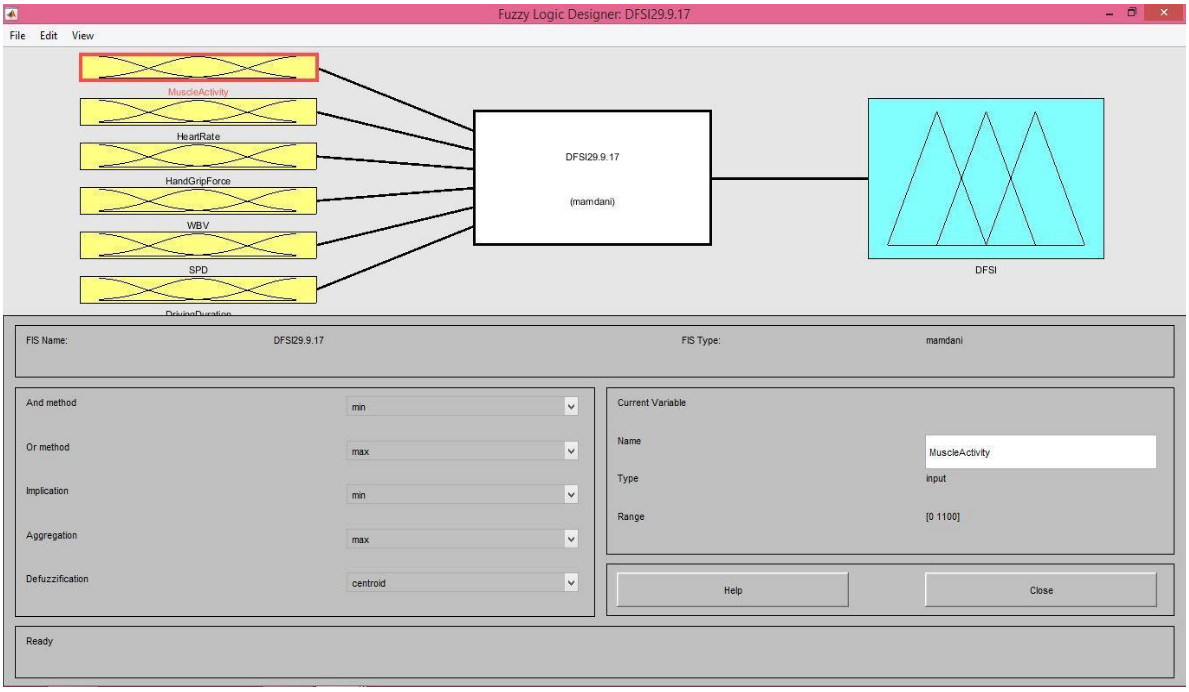

Figure 3. Fuzzy Inference System (FIS) editor

The inputs or also known as this study's linguistic variable are consisted of six risk factors; MA, HR, WBV, HGF, SPD, and DD. While that study's output variable is the linguistic variable DFSI. The linguistic variables and their discourse universe (i.e. range) are categorized into fuzzy sets identified by the MF, implying the degree of membership within that group. The fuzzy sets for a single input value x represent the linguistic value of the linguistic variables. The variable' WBV,' for example, is divided into five fuzzy sets;' low acceleration,'' slightly acceleration,'' moderate acceleration,'' high acceleration,' and' very high acceleration.' Each fuzzy set's input value is based on the risk criteria and risk levels as discussed in the previous chapter and expressed in Table 2. For example, the x= < 0.315 m / s^2 WBV input partially belongs to the' low acceleration ' fuzzy set. The fuzzy sets input value is real numbers.

For fuzzy reasoning, the rules of inferences are needed at the FIS. The structure of the IF-RULE statements is used to explain the rule of inference. The inference method was used with the Mamdani-type, which is based on a simple structure of max and min operations. The GUI's rule editor was used to update the list of inference rules describing system behaviour. In this analysis, there are 20 statements of rules that the author has constructed. Upon building the rule statement, a road map of the whole fuzzy inference system was shown on the rule viewer for a system consisting of six linguistic variables,' MA,'' HR,'' HGF,'' WBV,'' SPD' and' DD.'

<u>STAGE 4: DEVELOPMENT OF DECISION SUPPORT SYSTEM FOR DRIVING FATIGUE (DSSFDF)</u>

A DSS can be defined as the ability to make the right decision and the effective advisory method using the computer - based system , which helps the decision - maker solve complex and unstructured transportation decision problems and provides the structural analysis and solution in the shortest possible time. This section is prepared to architecture the graphical user interface (GUI) for a driving fatigue driver decision support system that helps road users select driving conditions to minimize the risk of driving fatigue and directly reduce the number of road accidents in Malaysia. The Python programming language - based Django framework is used to construct the GUI for web - based decision - support systems. The Django is a Python web framework full-stack which promotes rapid development and clean, pragmatic design. Django is based on Python, which is a very popular programming language that provides powerful integration support with other languages and tools, which includes large standard libraries.

For the database, the author used the SQLite database. The system has the db.sqlite3 database file and has the extension .sqlite3. The SQLite database was chosen by the author for this system as it implements a small, fast, self-contained, high-reliability, and full-featured system. Besides, the SQLite database is a commonly used database engine. For the webserver, Django has its web server. The Django itself is equipped with a lightweight web server for developing and testing applications. The advantage of using the web server is the server can be restarted whenever there is a modification on the code. In this study, five main GUI's were designed to perform different functions; the admin interface, superuser GUI, the user profile and driving information GUI, regression model GUI, and risk factor analysis GUI. The more detailed discussion on these five GUIs was explained in the result.

RESULTS AND DISCUSSION

The system starts by running the server using the command prompt (cmd.exe). The command will be called the system to search the python programming file from the saving folder. The command python manage.py run server will start the server and perform the system checks. This system check is required for validating the Django projects as it detects common problems or errors regarding the programming. Serious errors will prevent Django commands from running the server. Figure 4 shows the command prompt for performing the system checks.

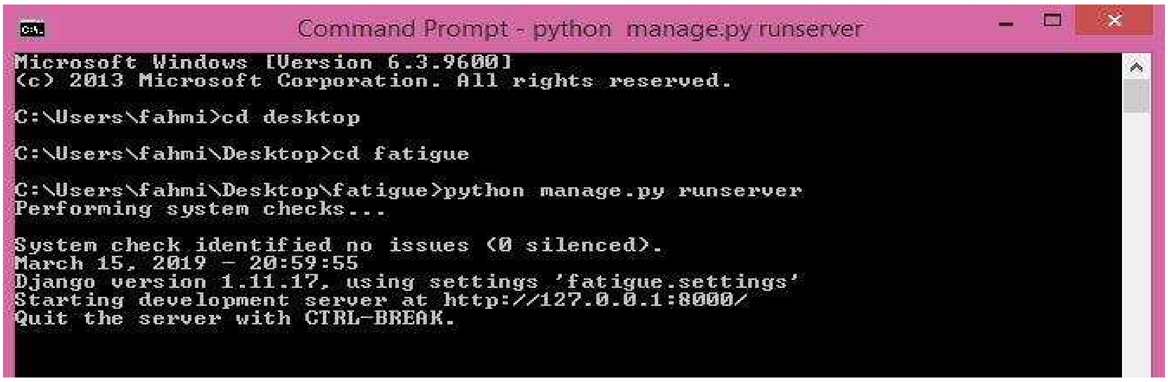

Figure 4. Performing system checks for the server.

ADMIN INTERFACE

The first GUI for the DSS is an admin interface that can perform CRUD (Create, Read, Update, and Delete) operations on the system. The admin interface is a ready-to-use user interface for administrative activities provided by Django. Figure 5 shows the Django admin interface for administrative activities.

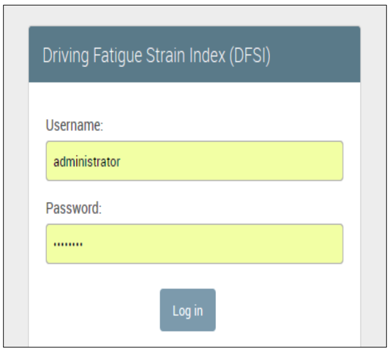

Figure 5. Django admin interface

This interface depends on the django.countrib module. To enable it, ensure that some modules are imported in the INSTALLED_APPS and MIDDLEWARE_CLASSES tuples of the myproject/settings.py file. Then, search this interface by typing the localhost:8000/admin at the search toolbar of the web browser to access this interface as shown in Figure 5.

SUPERUSER GUI

Once the admin has logged in into the system, the superuser GUI was displayed as shown in Figure 6. This superuser GUI enables the admin to perform the CRUD operations. The admin can monitor any activities in the system such as create, read, update, and delete the information and input entered by the user. Only the admin can access this interface.

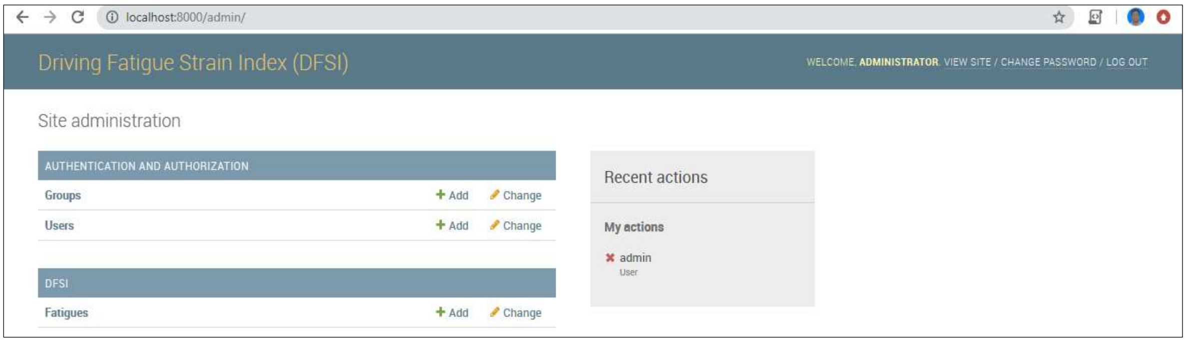

Figure 6. Superuser GUI of DSS

USER PROFILE AND DRIVING INFORMATION GUI

The main GUI for users consists of two classes; user's profile, and driving information. The user profile and driving information GUI is designed and used to enable the user to record the details of the user and driving as shown in Figure 7. After the information and data required in the interface have been entered and selected, the user should click the "Next" button in GUI for saving the information into the database of the DSS and continue for the next GUI. All the information entered and given by the user will be saved in the SQLite database as has been explained earlier.

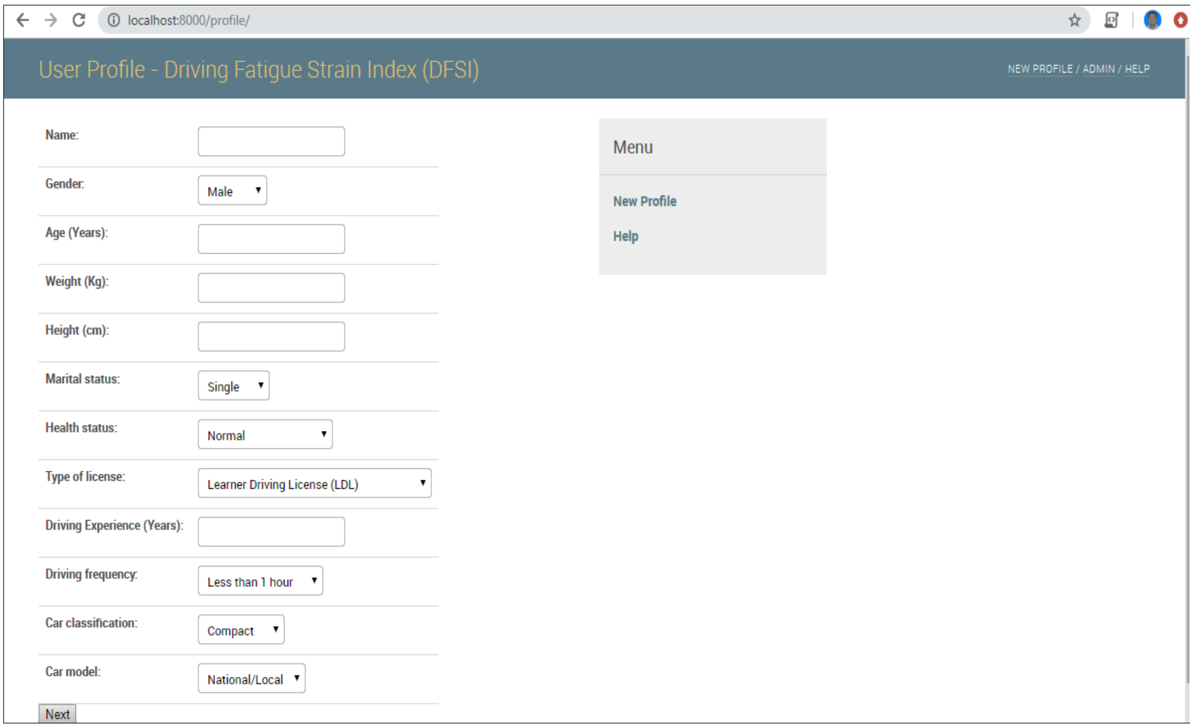

Figure 7. User profile and driving information GUI of DSS

REGRESSION MODEL GUI

The next interfaces, as shown in Figure 8, are for regression model. The purpose of this GUI is to obtain the user's outcome and risk factors data without having to do the actual road test trial. This is achieved by substituting the regression model for the true experiment. The six regression model groups representing six driving fatigue risk factors; muscle fatigue, heart rate, handgrip force whole-body vibration, seat pressure distribution, and duration were established in previous studies by the author (Ani et. al., 2018; Ani et. al., 2018; Ani et. al., 2017; Firdaus et. al., 2017; Firdaus et. al., 2017; Ani et al., 2017; Ani, 2016).

Figure 8. Regression model GUI of DSS

For this interface, the user is required to select and enter the gender, type of road, and time exposure of driving. The system will calculate the results based on the appropriate regression models. Figure 9 shows the interface for the result from the regression model. The interface will display the results for each risk factor; muscle fatigue, heart rate, handgrip force, whole-body vibration, and seat pressure distribution. These results will then be saved and submitted to a fuzzy inference system (FIS).

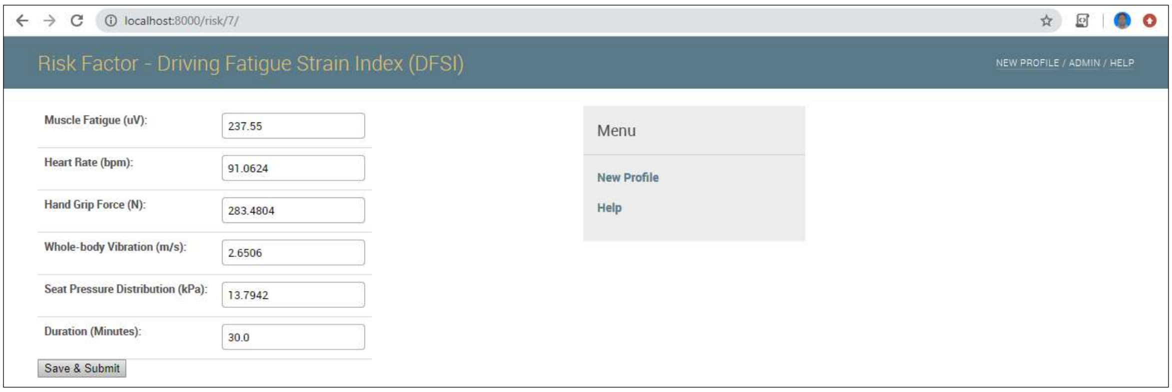

Figure 9. Result's interface from the regression model GUI of DSS.

RISK FACTOR GUI

The final GUI for the DSS is risk factor analysis GUI. This interface consists of driving fatigue strain index (DFSI), which has been developed using the fuzzy inference system by MATLAB software and SciKit-Fuzzy by Python. SciKit-Fuzzy is a fuzzy logic toolbox for python that implements many useful tools and functions for computation and projects involving fuzzy logic. The development of DFSI has been discussed in a previous study (Ani et. al., 2018; Ani et. al., 2019). From the result of the regression model, the system will analyze the result through SciKit-Fuzzy. The system will calculate the value of DFSI. The driving condition of the user is identified based on the DFSI's value, which has three fuzzy sets; safe, slightly unsafe, and unsafe. Figure 10 shows the risk factor analysis GUI.

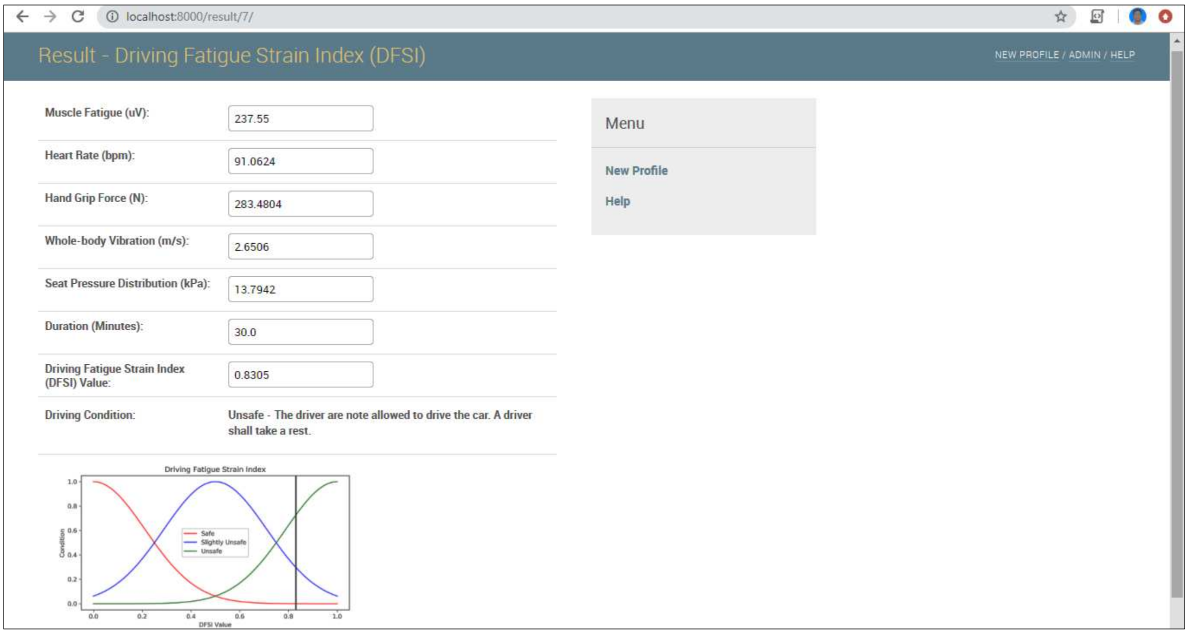

Figure 10. Risk factor analysis GUI shows the DFSI's value and driving condition of the user

VALIDATION OF THE SYSTEM

In order to validate this system, the author developed a driving fatigue strain index (DFSI) using the MATLAB software by building the fuzzy inference system (FIS) (Ani et. al., 2019). The author compared the results obtained from the system with the results from FIS, and the results from both systems are similar driving conditions. The details about the study are not discussed in this paper, however the reader can refer to the author's previous study (Ani et. al., 2019).

CONCLUSION

This research successfully developed the decision support system for driving fatigue, also known as DSSfDF, which is a very important system for providing systematic and fast analyzes of the risk factors that significantly lead to driving fatigue. Furthermore, this device can successfully deliver the risk level of the driving condition, offer initial warning and fatigue detection, and give users a better approach and advice when driving. Indirectly, it is becoming one of the efforts to reduce road accidents and fatalities, particularly in Malaysia.

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