DETECTION OF DR [illegible] UNDER SECONDARY
[illegible]

HENG POH CHAI

A report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Electrical Engineering (Electronics)

Faculty of Electrical & Electronics Engineering
University Malaysia Pahang

20 JUNE 2012

## ABSTRACT

Driver distraction is an important and growing safety problem. Nowadays, in this modern era or know as technology era, as the use of in-vehicle infotainment systems (IVISs) which include satellite radios, navigation systems or known as GPS, mobile phones and MP3 players has increase and thus resulted traffic crashes increasing. One of the major types of distraction that interfere with driving is none other than cognitive distractions. The way to overcome this problem is to detect driver distraction and adapt IVISs accordingly to reduce those distractions. The purpose of this project is to develop a new method to detect the driver distraction under secondary task. In this project, real driving data will be use in order to develop a real-time approach for detecting cognitive distraction via driving performance data which will be collect in the experiment in the situation of driving with secondary task or inattentive driving and without secondary task or normal driving. The driving performance data including the degree errors of steering. At the end, by using Matlab, this experiment will come out a result that can be used to detect driver distraction in real data.

# ABSTRAK

Gangguan pemandu merupakan masalah atau isu yang sangat penting bagi keselamatan jalan raya. Pada masa yang moden kini atau dikenali sebagai zaman teknologi, kegunaan sistem teknologi dalam kenderaan seperti radio satelit, sistem navigasi atau dikenali sebagai GPS, telefon bimbit serta pemain MP3 semakin meningkat dan ini menyebabkan peratus kemalangan jalan raya turut meningkat. Salah satu faktor adalah gangguan kognitif. Bagi menangani atau mengatasi masalah ini, pengesanan gangguan pada pemandu adalah diperlukan. Tujuan bagi projek ini dilaksanakan adalah mewujudkan satu cara atau kaedah bagi mengesan gangguan pemandu yang menjalani tugas yang melibatkan penggunaan sistem teknologi semasa memandu. Dalam projek ini, data memandu sebenar akan digunakan untuk menwujudkan pendekatan masa sebenar bagi mengesan gangguan kognitif melalui data prestasi memandu yang akan dikutipkan melalui eksperimen dalam situasi memandu dengan menjalani tugas berlebihan dan memandu secara biasa tanpa menjalani tugas berlebihan. Data-data prestasi memandu adalah merangkumi perubahan dalam sudut stereng. Daripada kajian ini, hasil akan didapati dan boleh digunakan untuk mengesan alih perhatian atau gangguan pemandu.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF APPENDICES

# CHAPTER1

# INTRODUCTION

## 1.1 Background

Driving is a complex task which required the simultaneous execution of various cognitive, physical, sensory and psychomotor skills. Instead of these complexities, it is not unusual to observe drivers engaging in various non driving-related activities while driving. Nowadays, driving is a very common activity for mankind. Safely driving is a very important case in life, thus distraction of driver is also a very important safety problem that needs to be highlighted. It was reported that from 13% to 50% of crashes are cause by driver distraction. According to the research of National Highway Traffic Safety Administration (NHTSA), average of 1200 deaths and $12.4 billion in damage occur each year in the United States [1]-[3]. In this modern era, the use of in-vehicle infotainment systems (IVISs) such as GPS navigation systems, mobile phone satellite radio and MP3 player is increasing and thus the safety problem which cause by distraction also greatly increasing [4]-[8]. Any activity that competes for the driver's attention while driving has the potential to degrade driving performance and have serious consequences for road safety. The definitions of driver distraction is the driver distraction occurs when a driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object or person within or outside the vehicle compelled or tended to induce the driver's shifting attention away from the driving task [15].

There are several types of technology products that can be used for detecting the drowsiness or fatigue of a driver, however there are less effective methods that can be used to predicting or detecting driver cognitive distraction under secondary task or define as driver's inattention due to the use of in-vehicle infotainment systems (IVISs) compared with a normal driving task that without use of IVISs. Due to the costly and computationally of the methods or techniques such as image processing, we concentrate on the interfaces between vehicle and driver which can be concluding the pedal of accelerator or brake and the steering wheel. In order to overcome this problem, one of the solutions is to undergo the detection and estimation in term of driver's condition in real time and follow by the compensation of the effects of inattention or the redirection of the driver's attention or focus to the main driving tasks by using the real driving data or information together with advanced driver support systems.

## 1.2 Problem Statement

The problem statement of this project is:

i. Physiological measures utilize biological signals such as EOG, EEG, ECG, etc., which are need to be contacting the human body and it is intrusive to driver operation.
ii. Computer vision approach is more practical as it is non-intrusive to driver operation however it is required high cost of hardware.
iii. Propose a driver operation signal and signal processing method to detect the driver inattention or driver distraction under secondary task.

## 1.3 Objective

The objective of this project is to:

i. Find the characteristics or features of information that can be differentiate between neutral or normal driving and inattentive driving.
ii. Study an evaluation method that can be used to detect the driver cognitive distraction.

## 1.4 Scope of Project

The scope of this project is to:

i. Use the pedal of brake or accelerator or the steering wheel signal.
ii. The conditions of the driving data are on the highway and during daytime.
iii. The types of secondary task used are repeating alphanumerical word and music searching.

## 1.5 Organization of Thesis

This thesis consists of five chapters. In the first chapter, it discuss about the introduction, problem statement, objectives and scope of the project. In the chapter two, it will discuss more on theory and literature reviews that have been done. In the chapter three, it will discuss about methodology that have been done to complete this project. It will explain details such as the flow of the project, calculation and formula for the evaluation method.

Result and discussion will be presented in the chapter four. Last but not least, the chapter five will discuss the conclusion and recommendation that can be done for the future work.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Previous Project Work

The purpose of this review is to study the previous literature on detection of driver cognitive distraction under secondary task. Cognitive distraction gives the definition of the distraction that occurs when drivers were thinking about stuffs that are not directly related to the current vehicle control task or in another meaning which driver attention is affected due to distraction. For example, having a conversation with someone on a hands-free mobile phone or interaction with the technology devices while driving.

According to some studies, driving performance is affect when cognitive distraction occurs by interrupting the visual attention while driving and the processing of attended information. Cognitive distraction gives bad influences to the ability of drivers to detect objects through the visual scene.[9] Due to the conversations on a hand-free mobile phone and thus greatly affected both implicit perceptual memory and explicit recognition memory for objects that drivers looked at while driving.[7] As there is a hard way to observe the mental state of drivers, so there is also no simple way to accurately measure the cognitive distraction.[10] Eye movements appear to be one of the most relevant physiological symptoms for detecting the cognitive distraction of driver. Currently, many researchers have used the eye movements to detect driver distraction. There are three fundamental types of eye movements (primary and/or secondary task performance measures, subjective measures and physiological measures) which are fixation, saccade and smooth pursuit that used to define the parameters of eye movements which might reflect the allocation of visual attention and combination of fixated information. Fixations are the eye movement that occur when driver's eyes are nearly stationary. There may be a connection between the duration and position of fixation with the quantity of information perceived and the attention of the observer from the fixated location. Saccades are very fast eye movement which occur when the attention of driver vision moves from one point to another point. On the other hand, smooth pursuit is the eye movement that occur when the visual attention of driver on a moving object such as driver tracks a passing car. Smooth pursuit is used to stabilize those objects that observe on the retina of eye so that the information of visual perceived when the objects are moving. Smooth pursuit is an important function in the context of driving which is captures information in the moving scene compared to the fixations which capture information in the static scene. Thus, both of the smooth pursuit and fixations movement are needed in order to explain for both of the ways in which drivers obtain the information of visual. Some studies have shown that there is a relationship between eye movement, cognitive workload and distraction.[11] The distances of saccades are decreases due to the increasing of the complexity of the tasks and thus shows that saccades movements is relate to the mental workload.[12] E.M. Rantanen and J.H. Goldberg found that the field of visual decrease 7.8% during a moderate workload counting task and decrease 13.6% during a cognitively demanding counting task.[13] In the same way, the spatial gaze variability decreased accordingly to the increasing of the cognitive demand during driving.[9],[14] The facial features are the individual's mental or psychological state indication. There are several groups have tried to seek out the detection of drowsiness in an individual by face image processing and its features. These images are then compared with a person without drowsiness and the alertness of the individual is estimated. In Carnegie Melon, there is a group that developed the detection schemes based on PERCLOS which is a scientifically supported the measurement of drowsiness which related to slow eye closure. FaceLAB is a commercially available software that uses a combination of real time eye and head tracking with comprehensive blink analysis for driver drowsiness detection [16]-[17].

Besides that, there are approaches which call monitoring. The steering wheel movements have been monitored for the detection of drowsiness. This method is based on the hypothesis that the frequency of the movement of the steering wheel in keeping the vehicle on road is dependent on the rate of drowsiness of the driver. There are several research groups have developed the algorithms and models in order to estimate the drowsiness by using the above method [18]. There is a new system from United States that used to monitors driver's drowsiness based on a lane tracking system. This new system is known as SafeTRAC. There is also a system from Spain which known as Anti-Drowsiness System (ADS) and it is used for the driver's drowsiness detection by monitoring the pressure of steering grip on the steering wheel [19]. There is a another popular approach in operator vigilance monitoring which measures utilize biological signals which collected through electrodes contacting the human body such as electroculography (EOC), electroencephalography (EEG), electrocardiogram (ECG) and skin resistance [20]-[25]. The combination of the above mentioned techniques can be used to make more reliable and effective vigilance monitoring systems. Daimler Chrysler has developed a detection algorithm that uses the lateral position, steering wheel angle and longitudinal speed data together with analyzed in order to detect driver's drowsiness [26].

However, there are limitations with the existing technology. The image processing technique which tracking the movements of eyes require high cost of hardware. Besides that, these methods are affected by the illumination, facial futures of driver, mental state of driver such as happiness, anxiety and others and the position of the sensors to the position of head. Furthermore, these methods are hard to detect the movements of eyes especially during night. Although the physiological measures approach which use the physiological and biological signals such as EOG, EEG and ECG are the most accurate technique, they are intrusive to the driver operation and can cause annoyance to the driver as these methods always require an attachment of devices to the driver. The lane tracking methods which require white or a particular colour of lane markers and it is not effectively working at night, in misty and rainy conditions, and also on dirty roads. Although the measurement of the frequency of steering wheel angle technique minimize the above mentioned problems, but it cannot adequately represent the responsiveness of the driver as it is affected or influenced by the road conditions and patterns and the type of vehicle.

## 2.2 Software Review

In this project, software MATLAB is used to detect the driver distraction under secondary task. Generally, MATLAB is a high-level or high-performance language for technical computing. It enables the performance of computationally intensive tasks faster than with traditional programming languages such as C, C++, and FORTRAN. There are five main parts for the MATLAB system which are MATLAB language, MATLAB mathematical function library, handle graphics, MATLAB Application Program Interface (API) and MATLAB working environment [28].

MATLAB acknowledge in solving the technical computing problems, visualization, and programming in an easy-to-use interactive environment where problems and solutions are expressed in familiar mathematical notation and vector formulation. It also has toolbox which acknowledge user to learn and apply specialized technology. Those toolboxes available such as signal processing control systems, neural networks, fuzzy logic, wavelets, simulation, and so on. It is a collection of MATLAB functions or known as M-files that extend the MATLAB environment to solve particular classes of problems [28].

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This section will discuss about the methodology for the feature extraction, evaluation method and the driver condition classification. Previously, there are several method that used to measures utilize biological signals which collected through electrodes contacting the human body such as electroculography (EOC), electroencephalography (EEG), electrocardiogram (ECG) and skin resistance. However, they are intrusive to the driver operation and can cause annoyance to the driver as these methods always require an attachment of devices to the driver.

## 3.2 Description of Experiment and Data Collection

In this project, we use the real driving data or information which was collected through the experiments which a real vehicle equipped with various sensors was used for synchronous recording of real driving data. The aim of these experiments were to record the modal of real driving data on different types of secondary tasks in order to collect normal or neutral and inattentive driving data. The two different secondary tasks are: 1) a music searching task and 2) an alphanumeric verbalization or repeating alphanumerical words task. Table 1 shows all the portions of the experiments.

Table 3.1: Description of experiments and driving conditions

| Experiments | Type of road | Type of task | Description |
|---|---|---|---|
| 1 | Highway | Neutral driving | Driving without extra task |
| 2 | Highway | Song searching | Searching for the music that required |
| 3 | Highway | Repeating alphanumerical words | Repeating ten alphanumerical words |

In this project, the operation signals of experiments 1 which is driving without secondary task or normal driving and the operation signals of experiments 2 and 3 which is driving with secondary task. These experiments involve 100 licensed drivers that can be categorized into two groups which are 50 male drivers and 50 female drivers. However, only 6 driving data which are from 3 males and 3 females were selected as example, in order to investigate the influence of the secondary task upon the driver performance and confirm or differentiate the difference between the inattentive driving or driving under secondary task and normal driving or neutral driving or driving without any extra task. Figure 1 shows the example of driver's operation signals.

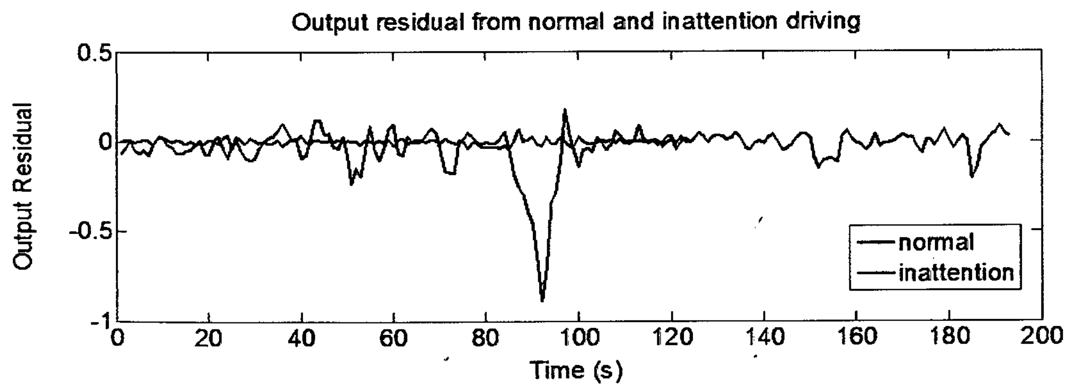


Figure 3.1: Driver's operation signals

## 3.2 Data Pre-processing

In this section, we will discuss about the data pre-processing. The raw data we get from the previous section is considered as an incomplete data or noisy data or inconsistent data and this kind of data having no quality. In order to solve this problem, pre-processing which includes data cleaning, data integration, data transformation, data reduction and data discretization is needed. In this section, we first use the sampling to choose a delegate subset from the raw data. After that, we manipulate the raw data by using data transformation. Then, we undergo the normalization such as Discrete Fourier Transform in order to organize the simplify data for more efficient access.

## 3.3 Feature Extraction

In this section, we will discuss on how we choose the feature and why we choose the feature. We will determine the feature according to the graph between the neutral or normal driving and the inattentive driving. First, we will calculate the mean and the standard deviation in order to progress to the feature extraction. Then, we will define either the spikiness suitable to be the feature to detect the difference between neutral or normal driving and inattentive driving or not.

## 3.4 Evaluation Method

In this section, we will discuss the method we use to evaluate the previous section. First and foremost, after define the spikiness as the feature use to detect the difference between neutral or normal driving and inattentive driving, we will calculate the values of the mean and the standard deviation. In order to calculate these two parameter, we need generate the formula of the mean and standard deviation in the software MATLAB that we use. The standard deviation was computed by taking the root mean square of the square of the difference between the actual data (xi) and the mean ($\mu$) for n number of the data or size of the data.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(xi - \mu)^2}{n}}$$

In order to calculate the spikiness, we need to generate a general trend. To compute this, we calculate the deviation from the moving average by using the value of standard deviation. Then, we take the actual data and the deviation from the moving average according from time 30second till 120second. Figure 2 shows the definition of spikiness where the driver profile is plotted versus time. Thus the spikiness ($\varphi$) is given by

$$\varphi = \frac{\sum_{i=1}^{n}(xj - \sigma j)^2}{nj}$$

where xj= actual data from 30second till 120second
$\sigma j$= deviation from the moving average from 30second till 120second
nj= number of the data or size of the data from 30second till 120second

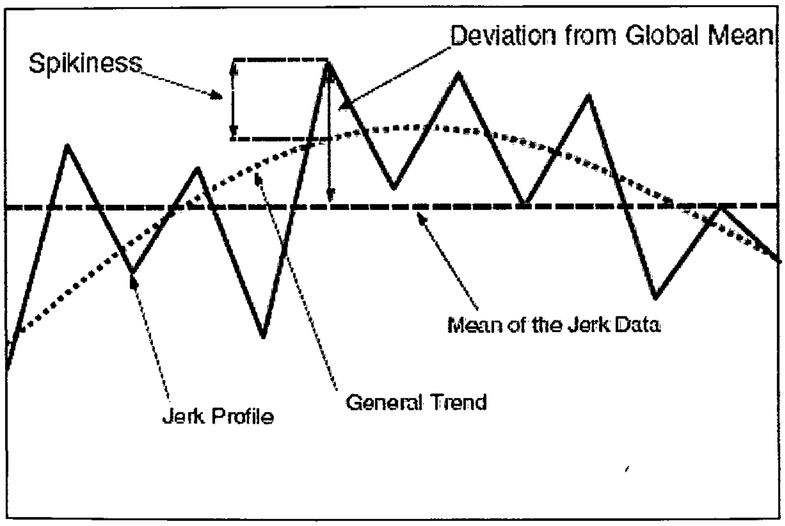


Figure 3.2: Definition of spikiness

### 3.5 Driver Condition Classification

There are several methods that we can use in classification. In this section, after getting the value of spikiness, we will determine or define the driver either under secondary task or without secondary task according to the range of the value of spikiness of each driver. Every value of spikiness we get, the classification part will differentiate to the group of inattentive driving and normal driving.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Introduction

This chapter presents the result and discussions for the project. Experiments have been conducted for this project. The experiment is conducted to determine the relationship between the secondary task and the performance of drivers. In this experiment, there will be include 3 male drivers and 3 female drivers. However, the main purpose of this project is differentiating between the inattentive driving and neutral driving. This experiment will divide into two groups which are male drivers and female drivers. At the end of this experiment, we will combine both male and female drivers into a group with respect with the feature that we choose.

## 4.2 Female Driver

For female drivers, the values of the mean and standard deviation are shown in Table 2. These two parameters can be calculated by using MATLAB which coding is shown as below.

```
>> M1=mean(Stade);
>> M2=mean(Stms);
>> M3=mean(Stnc);
>> STDV1=std(Stade,1);
>> STDV2=std(Stms,1);
```

```
>> STDV3=std(Stnc,1);
```

Table 4.1: The values of mean and standard deviation for female drivers

| | Repeating Alphanumerical Words | | | Music Searching | | | No Task / Normal Driving | | |
|---|---|---|---|---|---|---|---|---|---|
| | Driver 1 | Driver 2 | Driver 3 | Driver 1 | Driver 2 | Driver 3 | Driver 1 | Driver 2 | Drive 3 |
| Mean ($\mu$) | 8.7851 | 9.7683 | 11.3055 | 6.3176 | 8.2674 | 8.1306 | 7.0907 | 6.7144 | 8.8019 |
| Standard Deviation ($\sigma$) | 7.9445 | 3.9305 | 8.9095 | 12.6018 | 10.9092 | 12.3786 | 6.4509 | 5.5101 | 6.7327 |

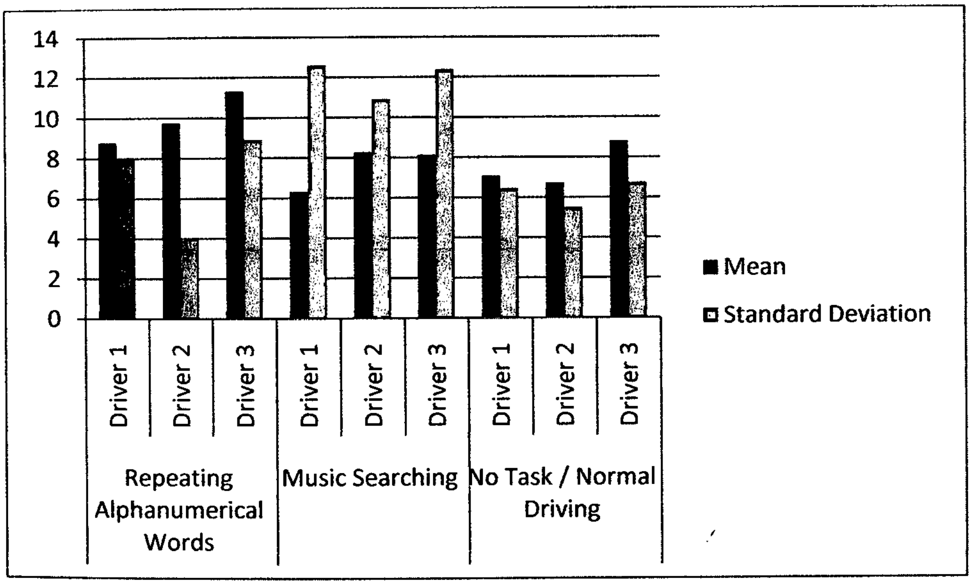


Figure 4.1: The values of the mean and standard deviation of the female drivers for repeating alphanumerical words, music searching and no task.

According to the value of mean and standard deviation that calculated, we plot the graph together with the actual data by using MATLAB. Graph plot for the mean are shown in the Figure 1, 2 and 3 in the Appendix A and the graph plot for the standard deviation are shown in the Figure 1, 2 and 3 in the Appendix B. Due to the values of mean and standard deviation, we decided to use the standard deviation as the feature to differentiate between the inattentive driving and the neutral driving. This is because according to theoretical, the inattentive driving which with secondary task will give a high frequency interaction at the interfaces between vehicle and driver while for the normal or neutral driving will give low-frequency interaction at the interfaces between vehicle and driver. The coding to compute these graphs is shown as below:

```
% for mean
>> hLine1=plot(Stade,'b');
>> xlimit1=get(gca,'XLim');
>> meanLine1=line([xlimit1(1) xlimit1(2)],...
[M1 M1],'color','k','LineStyle','-');
>> hold on
>> hLine2=plot(Stms,'r');
>> xlimit2=get(gca,'XLim');
>> meanLine2=line([xlimit2(1) xlimit2(2)],...
[M2 M2],'color','c','LineStyle','-');
>> hLine3=plot(Stnc,'g');
>> xlimit3=get(gca,'XLim');
>> meanLine3=line([xlimit3(1) xlimit3(2)],...
[M3 M3],'color','m','LineStyle','-');
>> grid minor;
>> hold off;
>>legend('Stade','M1','Stms','M2','Stnc','M3');

% for standard deviation
>> hLine1=plot(Stade,'b');
>> xlimit1=get(gca,'XLim');
>> stdvLine1=line([xlimit1(1) xlimit1(2)],...
[STDV1 STDV1],'color','k','LineStyle','-');
>> hold on
>> hLine2=plot(Stms,'r');
>> xlimit2=get(gca,'XLim');
>> stdvLine2=line([xlimit2(1) xlimit2(2)],...
[STDV2 STDV2],'color','c','LineStyle','-');
>> hLine3=plot(Stnc,'g');
>> xlimit3=get(gca,'XLim');
>> stdvLine3=line([xlimit3(1) xlimit3(2)],...
[STDV3 STDV3],'color','m','LineStyle','-');
>> grid minor;
>> hold off;
>>legend('Stade','STDV1','Stms','STDV2','Stnc','STDV3');
```

Then, we will generate the general trend together with the actual data according to the deviation from the moving average by using the values of standard deviation. The graph of the general trend with the actual data is shown in Figure 1, 2 and 3 in the Appendix C. The coding to compute these graphs is shown as below:

```
% for general trend
>> output1=tsmovavg(Stade,'s',STDV1,1);
>> output2=tsmovavg(Stms,'s',STDV2,1);
>> output3=tsmovavg(Stnc,'s',STDV3,1);
>> hold on;
>> plot(Stade,'b');
>> plot(Stms,'r');
>> plot(Stnc,'g');
>> plot(output1,'c');
>> plot(output2,'m');
>> plot(output3,'k');
>> grid minor;
>> hold off;
>>legend('Stade', 'Stms', 'Stnc', 'output1', 'output2','output3');
```

Last, we will generate the general trend with the actual data from 30 seconds till 120 seconds for female driver 1, 2 and 3 which are shown in Figure 4, 5 and 6 in the Appendix C. By using this range of data, we calculated the value of spikiness according to the repeating alphanumerical words, music searching and no task which shown in Table 3. The coding for all this is shown in below:

```
% spikiness for time 30s-120s
>> stade=Stade(30:120);
>> stms=Stms(30:120);
>> stnc=Stnc(30:120);
>> O1=output1(30:120);
>> O2=output2(30:120);
>> O3=output3(30:120);
>> hold on;
>> plot(stade,'b');
>> plot(stms,'r');
>> plot(stnc,'g');
>> plot(O1,'c');
>> plot(O2,'m');
>> plot(O3,'k');
>> grid minor;
>> hold off;
>> legend('Stade','Stms','Stnc','O1','O2','O3');
>> SP1=(sum((stade-O1).^2))/size(stade,1);
```