The Nucleus **50**, No. 1 (2013) 1-6

The Nucleus
A Quarterly Scientific Journal of Pakistan Atomic Energy Commission
NCLEAM, ISSN 0029-5698

DESIGN OF A MACHINE LEARNING BASED FRAMEWORK FOR REALISTIC WEAR AND TEAR ESTIMATION OF THE BRAKING SYSTEM OF A VEHICLE

M.A. REHMAT, M. SHAHBAZ, M. ASLAM and *A. GHAFFAR

Department of Computer Science and Engineering, University of Engineering and Technology, Lahore, Pakistan

(Received February 27, 2013 and accepted in revised form March 06, 2013)

Commuting from place to place is among one of the basic needs of human beings. Vehicles are the general mode of transportation since their commercialization. The major safety hazard in vehicles is the braking system which cannot only endanger the lives of the people travelling in it but also the others who are on the roads or in other vehicles. A realistic wear and tear analysis of the braking system can help in avoiding severe accidents. We have devised a framework which will provide the required hardware and software tools to estimate the realistic wear and tear of the braking system of a vehicle. The machine learning algorithms are used to determine different modes of the transportation of a vehicle like moving, stationary, braking, turning left or right. A high shock survivability and high resolution accelerometer is used to get the raw data and then with the help of machine learning algorithms specific criteria is set to get a threshold. When the decelerations cross that particular threshold, an indication is set to let the user know about the time for the check up of the braking system which could be the replacement of the brake pads or other component. The framework is flexible enough to be used to get the wear and tear of any part of the vehicle which has a direct impact upon change in acceleration. The framework provides a learning mode which helps to define a specific criteria and a monitoring mode which actually indicates that the specific criteria has met.

Keywords : Accelerometer based analysis, Artificial intelligence, Brake pads wear sensing, Brake testing, Data mining, Driver profiling, Machine learning and Vehicle safety

1. Introduction

Commuting from one place to another is the basic need of humans and it is increasing day by day with an exponential increase in human population. Cities are becoming populous and are expanding and people need to travel a reasonable distance to reach to their work, home or any other destination. Due to this reason the use of personal cars is increasing accordingly. Many people are also using public transport as their basic mode of commuting. Whatever is the case, the pace of life is becoming faster and faster and people want to finish their stuff in much lesser time. In this race there exists a strong possibility of missing fundamental or necessary steps to achieve safety goals and if an appropriate check and balance mechanism is not maintained, this can lead to situations where there needs to do a comparison between late and never.

The work habits of human beings are changing with the extensive use of computer aided systems and it has a positive impact in terms of efficiency and safety. God blessed humans with many senses such as sight, taste, smell, touch and sound to perceive their surroundings/environments [1]. Such perceptual capabilities are also present in many animals alongwith some additional channels [2]. Computer aided systems needs to read and understand their environment/workspace through sensors to combat the challenges of their busy daily life [3]. Any processing industry is a strong candidate for collecting the field sensory data [4]. The data is used for various purposes like monitoring, analyzing, debugging, validating etc. The data is collected either through wired or wireless links [5].

Safety in road based commuting is the number one concern in this modern world. There are many factors that need to be addressed to prevent road accidents. Many such efforts are done under European commission to increase safety factors in roads and cars reliability [6]. The basic elements that can reduce accidents are roads, car safety systems and driving habits [7]. A combination of GPS (Global Positioning System) and tilt sensor/accelerometer is extensively used to measure road conditions, prevent safety critical events and monitor/enhance driver's performance [8]. An extensive work has been done to monitor road conditions [9-11]. There are many techniques developed for car safety like anti-lock braking systems (ABS), anti-skid etc.

* Corresponding author : abidghaffar@gmail.com

Aggressive driving is also an important concern of traffic safety issues. Driving style are generally characterized as normal (typical) and aggressive [12]. Among other factors it is found that drivers drive relatively safely when their behavior is monitored and feedback of their driving observations is provided [13, 14]. Several companies [15-17] offer solutions for fleet management to monitor driving behavior using costly tools and some research work has found cheaper methods using accelerometers, GPS and smart phones through intelligent algorithms. [18-20].

Keeping in view all these issues our main work is to develop a framework in terms of hardware and software based on machine learning paradigms. This part of the research is mainly focused on proposing a solution utilizing our proposed framework to measure the wear and tear of brakes, a potential safety hazard among vehicles and a major cause of severe accidents. The design components and hardware/software implementation is discussed in this paper.

The vehicles at the manufacturing time are validated for the performance of their brakes. It is then used by the user and it becomes the responsibility of the user to make sure that brakes are well maintained or at least performing at a level that there is no risk for the users travelling in it. This is generally done through a periodically checkups of the vehicle for its brake performance. The wear and tear of braking is not just limited to the brake pads rather it is a complete system which makes sure that the brakes are performing well. The overall braking system of a car is shown below in the Figure 1 [21].

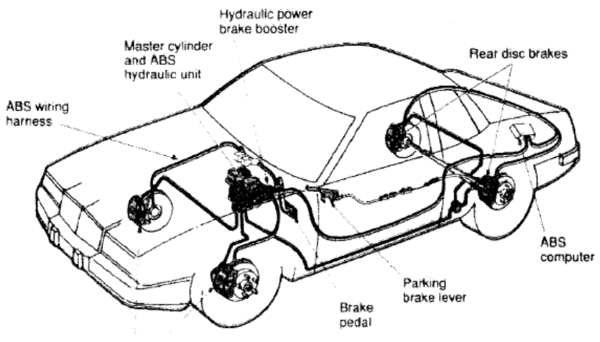

Figure 1. Braking System of a Car

There are many sensors available which are used to give the wear and tear of the brake pads and usually needs replacement with each brake pad change. These kinds of sensors are not present in most of the cars and almost all the old cars don't have any indication for even brake pads replacement. All the major car manufacturers of the high end cars like BMW, Porsche, Mercedes, Honda, G.M. and Toyota etc. are installing brake pad wear sensors.

The brake pad thickness is just one parameter for the working of overall brakes. There are many types of brake pads wear which have impact on working of the brakes even the thickness of the brake pads is of the normal size [21]. There are many types of tests that a vehicle has to pass to get a declaration for the good performance of its brakes. These tests are conducted using sophisticated instruments for the measurement of distance, speed and force at specific timings. Accelerometer is also the main tool used for many types of testing as well. These brake tests are conducted on a known appropriate surface and the force applied to the brake pedal is within the specified threshold of the respective category of vehicle. The testing start with cold tyres with a known pressure and no wheel slippage is allowed [22].

This paper describes the complete framework utilizing the software and hardware to estimate the realistic wear and tear of the braking system of a vehicle. This will be a standalone gadget that can be placed in any vehicle to estimate the wear and tear of the brakes. The basic idea is that the brake wear and tear is not related to a specific period rather it depends on the usage of the brakes and severe braking which can be measured using this framework.

2. Design Components

To detect the braking, the accelerometer board is required to be placed in the vehicle. The accelerometer is a device which detects the rate of change of acceleration. The accelerometer board can be connected to a PC via its serial/usb port. The accelerometer board can operate in two modes. In the first mode it just logs the data for training purposes. In second mode it logs as well as sends data on the serial/usb port. There is also a desktop application which can be used to receive data directly from the accelerometer board or can read the data log already stored on the accelerometer board. When the data is received by the desktop application, it draws a graph to indicate the acceleration against x, y and z axis. The system level diagram of the complete system is given below in Figure 2.

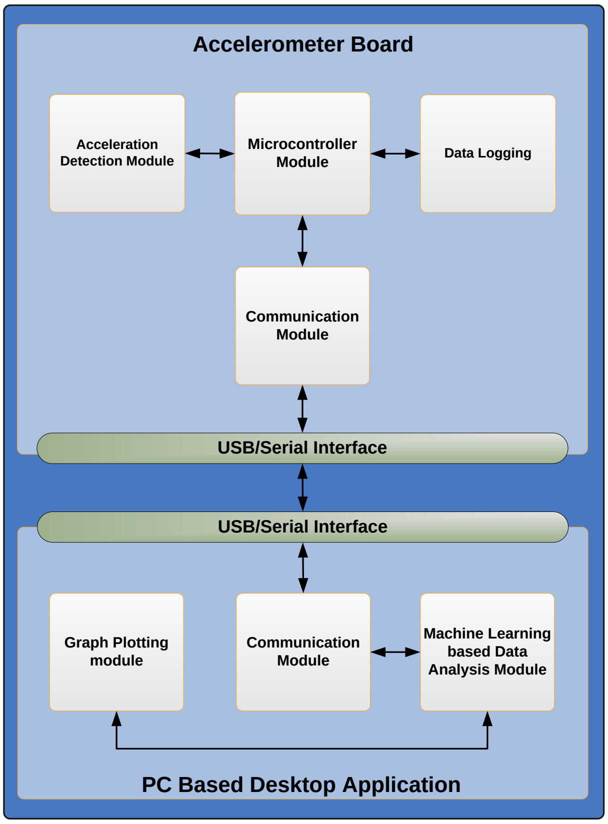

Figure 2. System Level Diagram for framework.

The accelerometer board detects acceleration against 3-axis (x, y and z). It stores the data of the 3-axis and send it to the serial/usb port when the brake is applied. The desktop application is separate application which can be used to observer the behavior of the g forces produced while braking using different machine learning algorithms. It receives data directly from the accelerometer board or can use the already saved data and plots a graph for each axis.

3. Hardware and Functionalities

The hardware consists of an accelerometer board which contains four major components as listed below:

3.1. Microcontroller Module

It consists of a microcontroller which acts as a commanding module. It periodically issues command to the acceleration detection module to read acceleration against all axis and if the values meets some criteria it stores this data in its memory which is also passed to the serial port to be sent to the PC through the serial communication module. PIC16F628 running at 5 MIPS is used which is an 8-bit RISC architecture microcontroller having internal EEPROM and has a built in support for USART that can be used for SPI/I2C/serial communication.

3.2. Acceleration Detection Module

It contains an accelerometer/tilt sensor which detects acceleration against any axis. We used LIS3LV02DQ, a three axes digital output linear accelerometer having an IC interface able to provide the measured acceleration signals via an I2C/SPI serial interface. It supports configurable full scale of ±2g and ±6g. The data rate is also user selectable for values 40Hz, 160Hz, 640Hz and 2560Hz. It has a high shock survivability of upto 10000g.

3.3. Communication Module

It is mainly a communication converter which adjusts the voltage differences for communication between PC and the microcontroller. The packet is encoded in a specific format before it is transmitted to the PC.

3.4. Date Logging Module

It is a standard 1 GB micro sd card. The data it saved in a specific format alongwith the time stamp.

When the accelerometer board is powered up all the buffers which are used to store the data are cleared and it determines that if the learning mode or monitoring mode is turned ON. Then the sensor is checked and if it is working fine then an initial packet is send to start the communication. If it receives an acknowledgement packet then it starts buffering the data from the tilt sensor in its main buffer. When the main buffer is full, a filter is applied on it and a single value is added in the secondary buffer and the same process is repeated unless the secondary buffer becomes full. Then a filter is applied on the secondary buffer and a single packet is sent on the serial port and stored in memory if it meets a certain criteria. If system is configured for monitoring mode just to make sure that a valid value is being used. In learning mode every value is saved. For monitoring mode the valid data of the accelerations and time values are accumulated and compared with a predetermined threshold which is obtained by running machine learning algorithms on captured data collected during learning mode. If the threshold is achieved the warning LED for brake is turned ON that means user needs to do a brake test. If the threshold is not achieved the accelerometer board will discard all the values in its buffer and will start to read the values again.

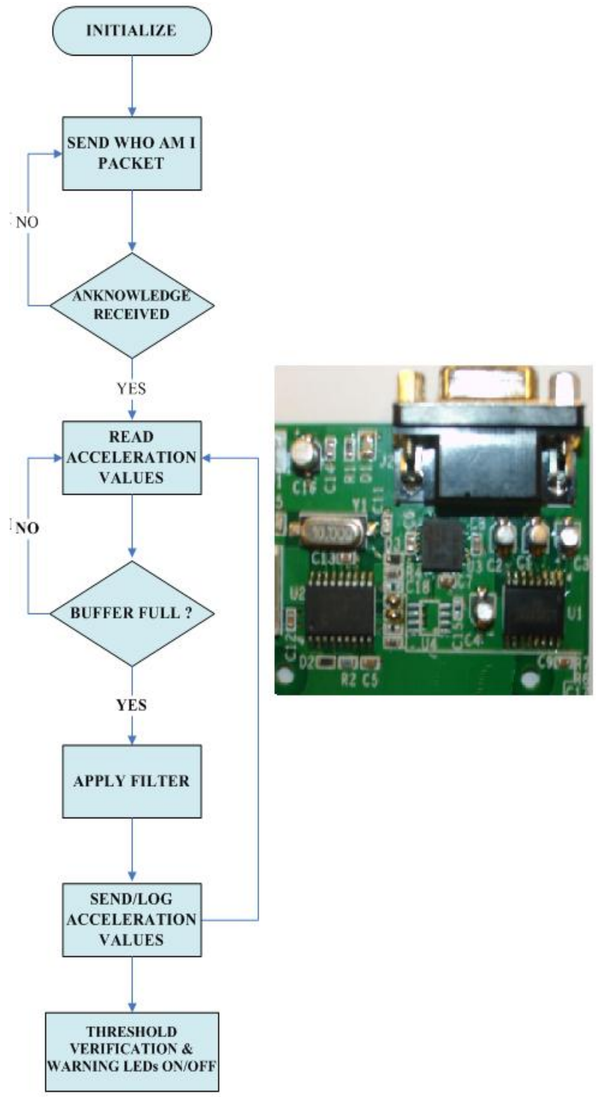

Figure 3. Activity Flow Diagram of Firmware and accelerometer board.

This data capturing activity will be performed forever. The activity flow diagram and the accelerometer board is shown below in Figure 3.

4. Software and Functionalities

The software consists of a PC based desktop application which contains three major components as listed below.

4.1. Communication Module

It is mainly handling the to and fro communication between PC and the microcontroller. The packet coming from microcontroller is decoded before it can be used.

4.2. Machine Learning Based Data Analysis Module

This is the heart of software application which contains machine learning algorithms that can be used to analyze the data coming from the accelerometer board. The data is analyzed mainly to determine specific thresholds or a specific criterion. One factor is to determine the current mode of the driving of the vehicle like turning left/right, stationary, braking and moving. This can be determined using simple decision rules like if the acceleration on any axes exceeds/decrease/ reaches a certain value for some specific period of time, then the mode of driving will be any one of the five modes. The general decision rules, which can be generated using decision tree algorithms could be of the form, as given below for X axis:

If (Acceleration in the X axis > Ax g) and (Continuous for the time > Tx Sec.) the mode is braking.

The framework allows user to make any rule based on the values of accelerations on any axes for specified period of time and with any combination. These are experimental values which are gathered by running in the training mode provided within the framework. Whatever are the rules/criteria, the user must have to find the five modes of driving. The current research work has provision to monitor the wear and tear of any component of a car but we will just discuss the braking system only and rest can be done by implementing the same generic methodology. Once we have determined the criteria for a specific car for the braking then we are good to go for the braking wear and tear threshold determination which will be used by the accelerometer board to decide whether the braking wear and tear is needed or not. The experimented data is filtered for braking events and the decelerations are accumulated like, “severe the brake the more the deceleration value”. The time for which deceleration is continued is also important and have significant role in deceleration the values of accumulation. This data is visualized on the graph in terms of g values and time. For a particular vehicle the experiment is repeated and a reasonable accumulation value for the decelerations is obtained through the learning mode. Again user can define any rule for this threshold determination or particular condition determination for which we can declare that the wear and tear point is reached but it has to be

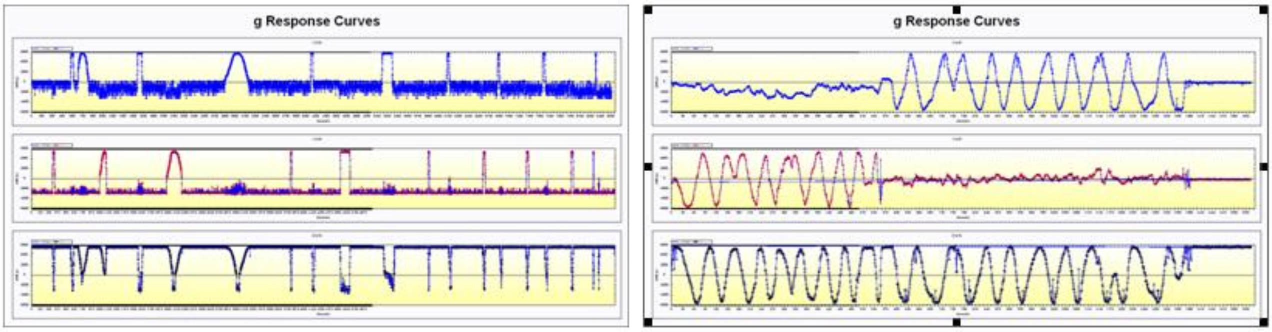

Figure 4. g curves for stored data on left and live data on right.

translated to a threshold value to be compared by the accelerometer board. Once we have achieved the specific threshold for braking system, then the board can run in monitoring mode. In monitoring mode all the decelerations are accumulated and compared with the specific threshold every time a brake is applied. Once the threshold is crossed, particular indicators are set to let the user know about the wear and tear point has arrived.

4.3. Graph Plotting Module

It is mainly used to display the g values on all axes against time. The date can be zoomed in/out to any level on any axes for analysis. The output of some sample dummy data is shown below in Figure 4.

The g curves are perpendicular to each other. The left side of Figure 4 shows the sample from a logged dataset and the right side shows the live data.

5. Conclusion

The research has been done to design a standardized framework containing all the required hardware and software tools for estimating realistic wear and tear for the brake system of a vehicle based on machine learning algorithms. The architecture provided is very flexible and adaptive to include the new techniques/algorithms as well as any other system of the vehicle which has a direct impact on the acceleration changes. A generic platform is built which can assist further in the research and development of extracting such parameters for any type of vehicle for any environment.

References

[1] M.M. Smith, Sensory History, Berg Publishers, ISBN-10:184520414X, ISBN-13: 9781845204143 (2008).

[2] P. Hickman. Illustrated by Pat Stephens, Animal Senses: How Animals See, Hear, Taste, Smell and Feel, Kids Can Press Ltd. (1999) 40 pages, ISBN: 1550744259, 9781550744255

[3] B.Z. Sandler, Robotics: Designing the Mechanisms for Automated Machinery, Academic Press 2nd Edition (July 15, 1999) ISBN: 0126185204.

[4] The Measurement and Automation Catalog, National Instruments, Data acquisition, (2000) 186 http://www.ni.com/

[5] S. Muknahallipatna, IEEE Newsletter **45**, No. 2 (June 1998) 15.

[6] European Commission, ICT - Information and Communication Technologies, Cooperation, Seventh Framework Programme (2007).

[7] G. Reveriego, C. Urdiales and F. Sandoval, Vehicle Risks Assessment using a Nokia N95, Proceedings of the 12th International IEEE Conference on Intelligent Transportation Systems, St. Louis, MO, USA, (October 3-7, 2009) MoCT1.3.

[8] S. Wang, C. Chen and J. Ma, Accelerometer Based Transportation Mode Recognition on Mobile Phones, Asia-Pacific Conference on Wearable Computing Systems (2010).

[9] J. Eriksson, L. Girod and B. Hull, The Pothole Patrol: Using a Mobile Sensor Network for Road Surface Monitoring, 6th International Conference on Mobile Systems, Applications, and Services (MobiSys 2008), Breckenridge, USA (June, 2008) pp. 29-39.

[10] R. Bishop, A Survey of Intelligent Vehicle Applications Worldwide, IEEE Intelligent Vehicles Symposium (IV 2000), Dearborn, MI, USA (May, 2000) pp. 25-30.

[11] X. Chu and Y. Wu, Design on the Low Cost System Framework of Road Condition Recognition Based on Roadside Multi-Sensors, Asia-Pacific Conference on Information Processing (APCIP 2009), Guangdong, China (July, 2009) pp. 173-176.

[12] D.A. Johnson and M.M. Trivedi, Driving Style Recognition using a Smartphone as a Sensor Platform. Intelligent Transportation Systems (ITSC), 14th International IEEE Conference (2011) pp.1609 -1615.

[13] J. S. Hickman and E. S. Geller, Journal of Organizational Behavior Management **23**, No. 4 (2005) 1.

[14] How am I Driving Bumper Stickers and Online Driver Safety Training for Employees. [Online]. Available: http://dmvreportcard.com/ How- Am - I- Driving - Safety – Bumper - Stickers.htm (2009) l.

[15] Drivecam Teen Vehicle Kit Overview. [Online]. Available: http://www.drivecam. com/our-markets/family/overview (2011).

[16] Seeing Machines [Online]. Available: http://www.seeingmachines.com/ (2011).

[17] How Snapshot Works. [Online]. Available: http://www.progressive.com/auto/snapshot-how-it-works.aspx (2011).

[18] A. Aljaafreh, N. Alshabatat and M.S. Najim Al-Din, Driving Style Recognition Using Fuzzy Logic, IEEE International Conference on Vehicular Electronics and Safety, Istanbul, Turkey (July 24-27, 2012).

[19] D.A. Johnson and M. M. Trivedi, Driving Style Recognition Using a Smartphone as a Sensor Platform, Laboratory for Intelligent and Safe Automobiles (LISA), University of California, San Diego, La Jolla, CA 92093-0434, Intelligent Transportation Systems Washington, DC, USA (October 5-7, 2011).

[20] S. Boonmee and P. Tangamchit, “Portable Reckless Driving Detection System”, Department of Control System and Instrumentation Engineering, King Mongkut's University of Technology Thonburi,126 Prachauthit Rd., Bangmod, Tungkru, Bangkok, Thailand 10140 (2009).

[21] M.N. Bin Mazlan, ‘’Brake Pads Wear and Tear Indicator’’, Faculty of Mechanical Engineering, Kolej Universiti Teknikal Kebangsaan Malaysia (November 2005).

[22] Bosch Automotive Handbook. Robert Bosch Gmbh (2004) p.1232.