DEVELOPMENT OF LOW COST VEHICLE DYNAMIC DATA ACQUISITION DEVICE USING GPS, IMU AND OBD INTEGRATED SYSTEM

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ABSTRACT

Malaysian automotive industry was develop to the level of improvement of the comfort of riding to the users. The researched for the comfort of riding is needed the data to improve the development of the vehicle component design. However, the technique to acquire data used by one of Malaysian's automotive company is only by subjective testing. This is because the investment needed to access the proper DAQs for testing is very costly. The solution for this problem is the development of low cost vehicle dynamics DAQ system. The development of this device is the purpose of this thesis. The device is developed with the UAV evaluation board which is available in the market. The developed device was developed with low cost and capable of acquire 6 DoF data with 500 Hz sampling time, GPS data, altitude data, 3-axis magnetometer and engine parameter.

ABSTRAK

Industri automotif Malaysia telah dibangunkan ke tahap peningkatan keselesaan memandu kepada pengguna. Pengajian untuk keselesaan penunggang memerlukan data untuk meningkatkan pembangunan reka bentuk komponen kenderaan. Walau bagaimanapun, teknik untuk memperoleh data yang digunakan oleh salah satu syarikat automotif Malaysia ialah ujian subjektif. Ini kerana pelaburan yang diperlukan untuk mengakses DAQs untuk ujian adalah sangat mahal. Penyelesaian bagi masalah ini ialah pembangunan peranti DAQ untuk mengukur dinamik kenderaan yang kos rendah. Pembangunan peranti ini adalah tujuan tesis ini. peranti ini dibangunkan dengan papan penilaian UAV yang boleh didapati di pasaran. Peranti ini telah dibangunkan dengan kos yang rendah dan mampu memperoleh 6 data DoF dengan 500 Hz masa persampelan, data GPS, data ketinggian, 3-axis magnetometer dan parameter enjin.

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LIST OF ABBREVIATIONS

ABC	Ant Based Control
ADA	Automated data acquisition
AFR	Air/Fuel Rate
AHRS	Attitude and heading reference system
API	Application program interface
ASCII	American Standard Code for Information Interchange
CDM	Clean development mechanism
DAQ	Data acquisition
DLL	Dynamic link library
DoF	Degree of freedom
ECU	Electronic control unit
ESM	Experience Sampling Method
GIS	Geographic information system
GPS	Global Positioning System
GUI	Graphical user interface
HCI	Human–computer interaction
ICT	Information and communications technology
IMU	Inertial measurement unit
MEMs	Microelectromechanical systems
OBD	On-board diagnostics
PCI	Peripheral Component Interconnect
PIDs	Parameter IDs
SoC	System on a chip
UAV	Unmanned aerial vehicle
UX	User experience
VBA	Visual Basic for Applications

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF PROJECT

The automotive industry, the quality of the parts need to be evaluate. There are a lot of testing were done by parts such as the fatigue and durability testing but the overall assembly testing is not easy to measure. Although there are a testing in the lab for the collision. Some of car's manufacture in Malaysia test their cars by the subjective methods. This was done by the car professional driver. Although the testing was done by the professional tester, the actual measurement is crucial in adjusting, design and recalculating the car system. The main factors for designing cars is the efficiency and the comfortability of the ride. The good designing need a good feedback data. The data need from the objective testing rather than subjective testing. The subjective testing is based on the tester and have a large range with no specific value of measurement and very large bias and errors. Meanwhile the objective testing have the specific value of measurement with low bias and errors. The objective testing also give the good feedback for estimating the car system condition and errors. In order to bring the testing to the objective method, the car dynamic data need to be acquire. The vehicle dynamic measurement during the actual road drive need to be taken to ensure the performance, safety and the comfortability to the user and the passenger for all class not specified to professional tester only. The objective testing method is more consistent than the subjective method which is based on the tester. The vibration exposure also need to be monitored and the effectiveness of the overall vehicle dynamic system need to be monitored. In order to get the measurement data the data acquisition system need to be developed for the vehicle. There are already an advanced

DAQ hardware such as in Figure 1.1 for measured the car dynamic but the cost is very high and need a professional to install it to the car. This will needs the cars manufactures to invest more money on the testing and car evaluating department. Some car manufactures or cars component manufactures may have a difficulty to invest. The cars user, whose make modification or tuning to their car also may find difficulty to evaluate their cars.

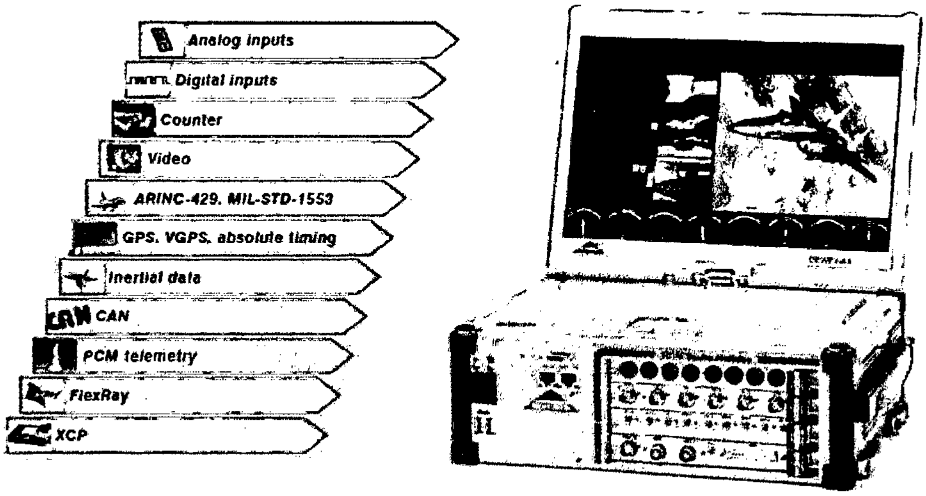

Figure 1.1: The inputs of one of DEWETRON Device

Source: dewetron_technical-reference-guide_2014e

1.2 PROBLEM STATEMENT

The availability data acquisition system for the cars dynamics is the market is quite rare. It is existed but in higher price and focussed on the advanced customer, which usually global markets cars manufactures. For the locals or small cars components or cars manufactures, it is not very profitable to invest in high cost testing device. Nowadays, there are lot of the system on a chip (SoC) and Microelectromechanical systems (MEMs) sensors available and very cheap with small in size compare to 20 years before. This technology may have a potential to develop into the low cost vehicle dynamics data acquisition system. The problem in the acquisition system is the accuracy and the precision of the reading. The availability of the inertial measurement unit, global positioning system and the on board diagnostic may can solve this problem by compensate each other sensor's weakness. The available car data acquisition system on the market not only expensive but also not easy to install. This problem may cause the difficulty in testing the car if there are parameter change for example if there are some component is change or the tune. The data acquisition may need to uninstall and reinstall. This process consume more time and money.

1.3 OBJECTIVES

The main objective of this research is to develop the data acquisition system for the car dynamics system. The detailed objectives of this research are:

i. To develop the low cost car dynamic data acquisition system based on market availability of the sensors component.
ii. To develop the data acquisition device which is easier to install and uninstall than the car data acquisition device on the market.
iii. To develop DAQ system to help design engineer to have better information before finalizing their specification

1.4 SCOPE OF PROJECT

The scope of this project is to develop the device in three part. The mechanical part, the electrical part and the software part. In the mechanical part, the housing of the device need to be design and place at the most suitable place at the car with the easiest way to attached and detached process. In the electrical part, the microcontroller and the sensors only used the market available device such as Unmanned Aerial Vehicle (UAV) development board which come out with complete 9 degree of freedom of MEMs IMU. For software part, the needed to design the user interface and data logging. It may also include the data processing part which is may do by the post-processing rather than online processing to increase the sampling frequency.

1.5 SUMMARY

This thesis consist of five main chapters which is introduction, literature review, methodology, result and discussion and the conclusion and future work. The first chapter which is introduction will state the introduction of the project, the problem which drive the project, the objectives of the project and the scope of the project.

The second chapter which is the literature review will state the related work which is done before this project to evaluate the significant of this project before proceed. It also discussion the data which significantly needed to be sampled based on the previous work discusses.

The third chapter will state about the methodology of this project to achieve the goal of this project. The methodology of this project consist of four phases which is information gathering, software development, the mechanical development and the testing process of the project.

The fourth chapter is the result and the discussion of the project. In this chapter, the result of the design and the sampling capability is stated. The assumption and the limitation of this design is also discuss in this chapter.

The fifth chapter is the conclusion and the future work. The conclusion will review the objective of this project and compared to the project achievement. The future work will discuss the possibility of the usage and the improvement of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discusses the related work in the field of data acquisition system or the data sampling in automotive including data sampling in the control system for automotive. The work of the previous project about the data acquisition system is reviewed to consider the best method to sampling the data. The consideration of the data which need to be sampling and the sensor need to be used is determine by reviewing the related work.

2.2 THE CAR DATA TOOLKIT: SMARTPHONE SUPPORTED AUTOMOTIVE HCI RESEARCH

The Car Data Toolkit (CarDaT) (Wilfinger, Murer et al. 2013) was develop so it is easier for the researcher to collect data from the car because of some previous difficulties in accessing car data. The data in the car have a high potential for further development. The processing and the core component of the car data toolkit is the smartphone. It utilize the sensors of the smartphone and the car engine. The car data architecture was design to acquire the data from various sensors. The sensors included was the 9 degree of freedom sensors from the smartphone which is 3-axis accelerometer, 3-axis magnetometer and 3-axis gyroscopes. It also included the data from GPS system of the smartphone and the environmental factors from data provider from the internet such as weather data. To connect to the internet, CarDaT need to use the network infrastructure. The data from the network provider which is called remote data can be used to estimate the driver behaviour. Smartphone also make it possible to access the OBD-II dongle. This tools will give the data from the car's sensors. The access of the smartphone's sensors, the android hardware sensor package was used. This package was included the low level data filtering and fusing. This package will give the orientation of the car by relatively using the orientation of the smartphone.

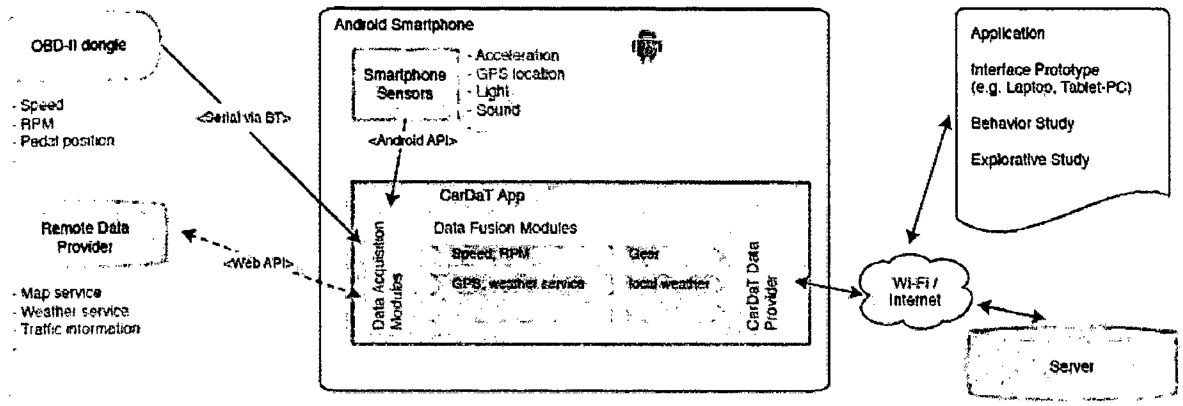

Figure 2.1: Car Data Toolkit architecture

Source: Wilfinger, Murer et al. 2013

The smartphone is a good device but prone to some problems. The smartphone device is prone to the disturbances (Foss and Goodwin 2014). These disturbance may cause an inappropriate danger to the car driver. These due to the mass media apps and call incoming. The usage of the internet also limit the device usage. For certain country the facility to obtain the coverage is limited. The application on the smartphone may have due to the dynamic programming (Zhauniarovich, Ahmad et al. 2015). This may affect the performance of the system.

2.3 COMPUTERIZED EXPERIENCE SAMPLING IN THE CAR

The computerized experience sampling in the car (Meschtscherjakov, Trösterer et al. 2013) was develop to measure the user experience (UX) which is happen in-situ. This system use the ESM tool based on the OBD-II interface. The ESM tools is psychological method to measure the user experience and was develop by Larson and Csikszentmihalyi in 1970s (Kubey, Larson et al. 1996). The system utilized the smartphone as the based for the programming based. The developed ESM tools was operate by using OBD-II dongle and sense and store relevant context parameter. This parameter will trigger the right question at the right moment for the user on the smartphone. An external acoustic sensor were used to determine if the situation is in parking process or not. It use sound fingerprint to decide the parking situation. This was develop due to the lack of information can be obtain by OBD-II dongle. After the question was triggered, visualize ESM question will appear and the system will capture and stored user responses. These system has external interruption, so the interruption to the driver may occur at triggered condition (Wheeler and Reis 1991) rather at random. The ESM tools have disadvantage of disrupts user activity and the user may need to stop their current activity and answer question (Hektner, Schmidt et al. 2007).

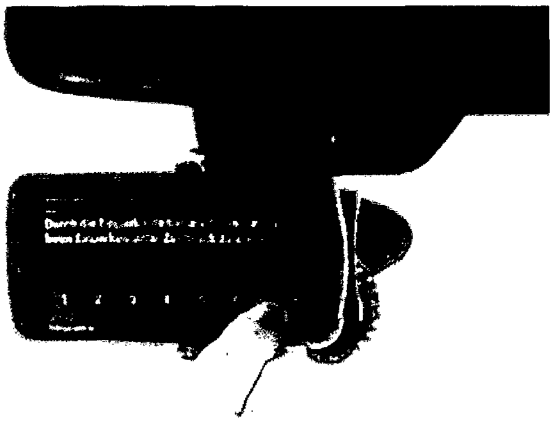

Figure 2.2: Example of typical ESM question

Source: Meschtscherjakov, Trösterer et al. 2013

2.4 ADA FOR A LARGE SCALE CAPACITATED VEHICLE ROUTING PROBLEM

The automated data acquisition (ADA) for a large scale capacitated vehicle routing problem (CVRP) (Garzón-Garnica, Cruz-Benítez et al. 2015) was developed to find the optimize route for the Personnel Transport in manufacturing enterprise from Mexican automotive cluster. The problem is in every CVRP, the data grows exponentially. This will make the data collection is more difficult. For a full scale model, the nodes is 728 which is produced a matrix of 529,256 pairs. This data acquisition will need to collect the data for each of the pair travelling time. For each pair, the travel will be recorded and used for routing system. The ADA software was connected to Geographical Information System (GIS) with every possible path between each pair location. This system will acquire the data matrix for the medium and large scale model. Linear routing algorithm was used for the software. This routing algorithm need the high processing power. Fòr ADA paper demonstration, the small scale of only 27 nodes with the solution to get the minimal travelling time for 3 routes of personnel transport. For only 27 nodes, it is quite limited. The Travelling Salesman Problem (Gutin, Yeo et al. 2002) algorithm was developed and it can solved several thousand nodes in an instances on a regular basis.

2.5 DATA ACQUISITION AND REAL-TIME CONTROL USING SPREADSHEETS

Data acquisition and real-time control using spreadsheets (Aliane 2010) is a system which utilized the usage of the spreadsheet as a software for data acquisition system. Spreadsheet is a powerful tools in engineering to perform various engineering processing and analysis. The usage of spreadsheet id engineering including transient response of linear systems (Alak and Abdulkarem 1990), inverse Laplace transform (Ramadurai 1991) and feedback controller design (Rives and Lacks 2002). The spreadsheet also has been used since 1989 (Bissell and Chapman 1989) for engineering. The spreadsheet need to be run on the host computer. The system is programmed with visual basic for application (VBA) language which is synonym with Microsoft software. The VBA programming used the hardware driver application programming interface (API) which is specifies the communication protocol between the spreadsheet with the hardware. This API provide a set of high-level function for input-output of the software without the knowing of the detail operation of the hardware. The excel Daq-Board which is used (Aliane 2010) is Advantech PCI data acquisition which can be load up to 8 analog sensors up to 200Hz sampling rate.

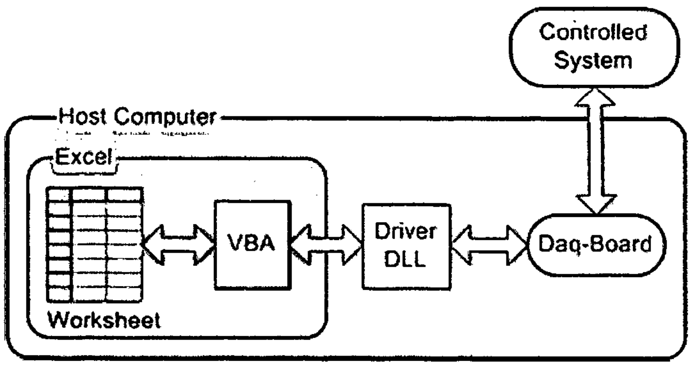

Figure 2.3: spreadsheet data acquisition architecture

Source: Aliane 2010

2.6 DYNAMIC ROUTING USING THE NETWORK OF CAR DRIVERS

Dynamic routing using the network of car drivers (Rothkrantz 2009) is design to an ICT solutions for traffic control and warning system. This system will used the car's driver to communicate with each other via intelligent system implemented on the network of lamppost. The system will acquire the real time information of traffic speed along the roads by tracking individual car drivers. This data will used as an input for dynamic routing system. The currently available route planners may not take the dynamic traffics information thus it was called 'static planner' (Rothkrantz 2009). This 'static planner' has its own serious demerit in the very high traffic density. The dynamic routing will used the algorithm call the Ant Based Control (ABC) routing algorithm which is based on the ideas from artificial life and computes the shortest travelling time from start to destination.

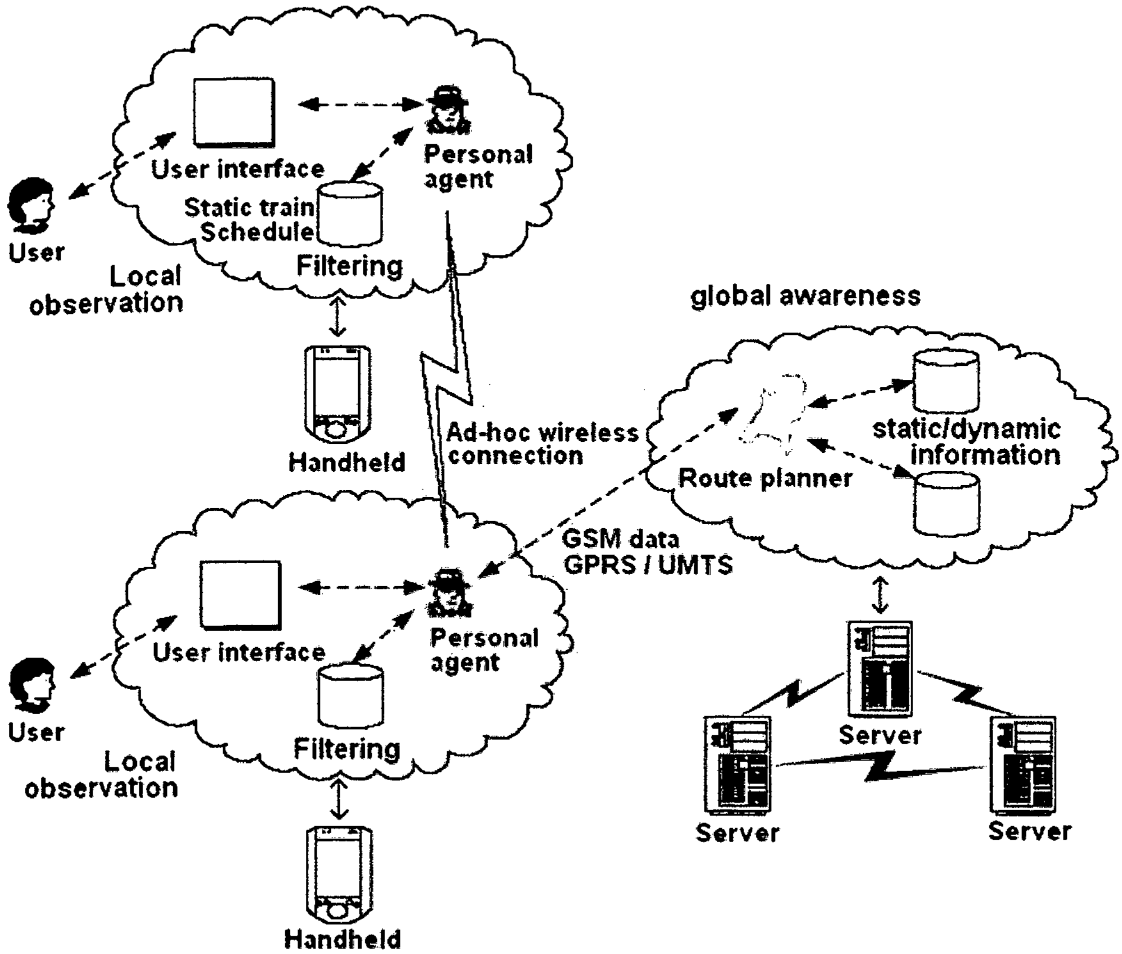

Figure 2.4: The system components interconnections

Source: Rothkrantz 2009

2.7 NOISE SOURCE IDENTIFICATION WITH BEAMFORMING IN THE PASS-BY OF A CAR

The noise pollution by the vehicle or car is a measurable and a concern to produce the noise pollution. The noise source identification with beamforming in the pass-by of a car (Ballesteros, Sarradj et al. 2015) is develop to measure the noise produce by the vehicle vibration. The European Community established the regulation for a homologated car (Directive 1970) in the respond of car's noise consideration. The consideration for the noise testing is the speed of the vehicle. It is in fact the strongly related between the noise source and the speed of the vehicle. Thus the static test are not suitable because some noise is produce during the movement of the vehicle (Michel and Barsikow 2003).

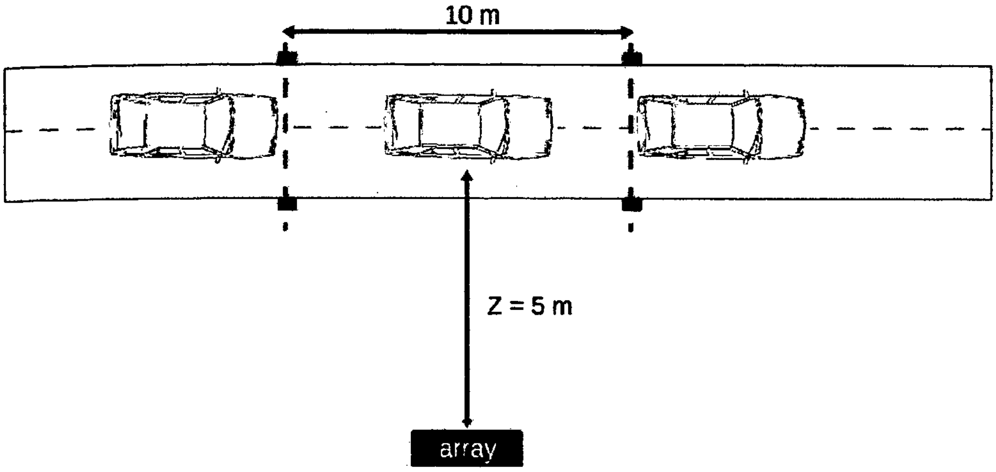

Figure 2.5: Measurement setup

Source: Ballesteros, Sarradj et al. 2015

The data acquisition system for measuring the dynamic vehicle noise is setup as in Figure 2.5. The instrument used is a planar 56-microphone array with 28 additional microphone which is located on 8 external arms attached to the centre array. This array is placed 5 m from the car linearly trajectory of 10 m. The sensor is start and stop measure the noise when the vehicle triggered the light barrier. The measurement only occur when the vehicle is into the measurement area. The first light barrier is to star the measurement and the second light barrier is to stop the measurement (Ballesteros, Sarradj et al. 2015). This test is tested by using two medium sized commercials car with diesel engine and gasoline engine. The test is done by measuring the vehicle during travelling at constant speed as proposed in the revision of the ISO 362 standard (Braun, Walsh et al. 2013).

2.8 ECODRIVE: A MOBILE SENSING AND CONTROL SYSTEM FOR FUEL EFFICIENT DRIVING

EcoDrive (Kang, Qi et al. 2015) system was develop to improve fuel efficiency and reduce carbon emission. This system is implemented in an embedded platform. The operation of this system is by sensing the fuel consumption via the standard vehicle On-Board diagnostics (OBD) ports and controlling the system of the vehicle. This system can be implemented due the fact which is the modern vehicles is the ultimate mobile computing. Modern vehicles equipped with significant embedded computing system that control and manage different functions (Urmson, Anhalt et al. 2009). The instant fuel efficiency due to different driving behaviour can be estimate by using OBD-port. The instant fuel consumption as the function of the vehicle dynamics modelling produce the fuel consumption profile called Air/Fuel Rate (AFR) profile. This AFR will be utilized by the control system to calculate the fuel efficiency driving strategies according to speed limit and vehicle condition.

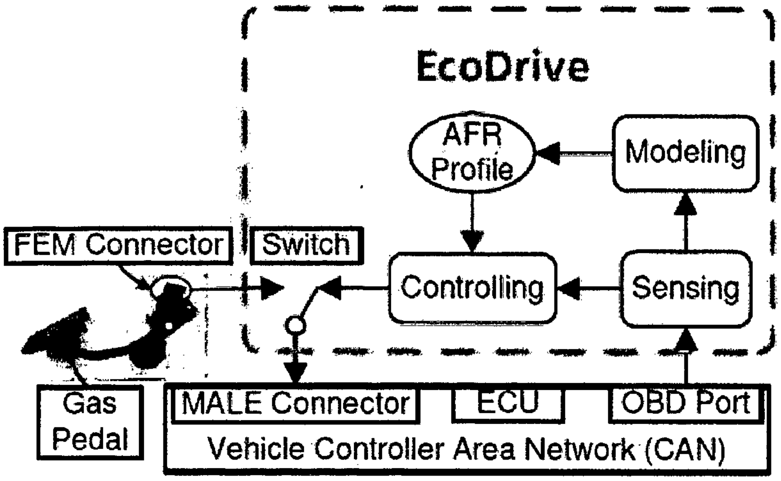

Figure 2.6: EcoDrive Architecture

Source: Kang, Qi et al. 2015

2.9 FUEL ECONOMY VALIDATION OF THE SMART MICROHYBRID SYSTEM FOR USED CARS

The smart micro hybrid system (Son, Park et al. 2012) was develop for used car to improve fuel efficiency via OBD-II interface. This system will accurately measure the amount of fuel that is saved by stopping engine idling and estimate the amount of fuel that is consumed when the engine begin to start. The development is for the clean development mechanism project (CDM). This system offers a simple installation than legacy micro hybrid system and can analysed and measure the fuel consumption from OBD-II. This system control engine-off after a given period of engine idling and engine-on when there are interruption to car's driver panel.

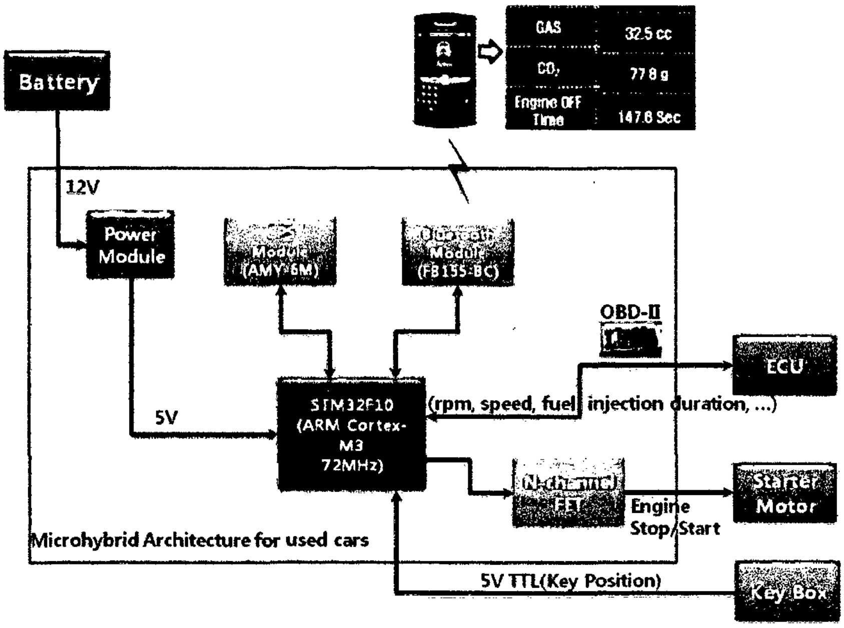

Figure 2.7: Micro hybrid Architecture for used cars

Source: Son, Park et al. 2012

2.10 GREENGPS: A PARTICIPATORY SENSING FUEL-EFFICIENT MAPS APPLICATION

The GreenGPS (Ganti, Pham et al. 2010) was develop to allowing drivers to find the most fuel-efficient routes for their vehicles between arbitrary end-points. This system work as a navigation services system which uses participatory sensing data to map fuel consumption on city streets. The participatory sensing (Burke, Estrin et al. 2006) has very vast application and this system is one of the example. The participatory sensing relies on data collected by individuals which is voluntarily shared their data from their vehicles and a generalization framework that predicts the fuel consumption of an arbitrary car on an arbitrary street. This participatory sensing for this system is using PoolView (Ganti, Pham et al. 2008). The car status data is obtained via the OBD port and the position of the car is obtained via the GPS. This data will used to calculate the most fuel-efficient routes.

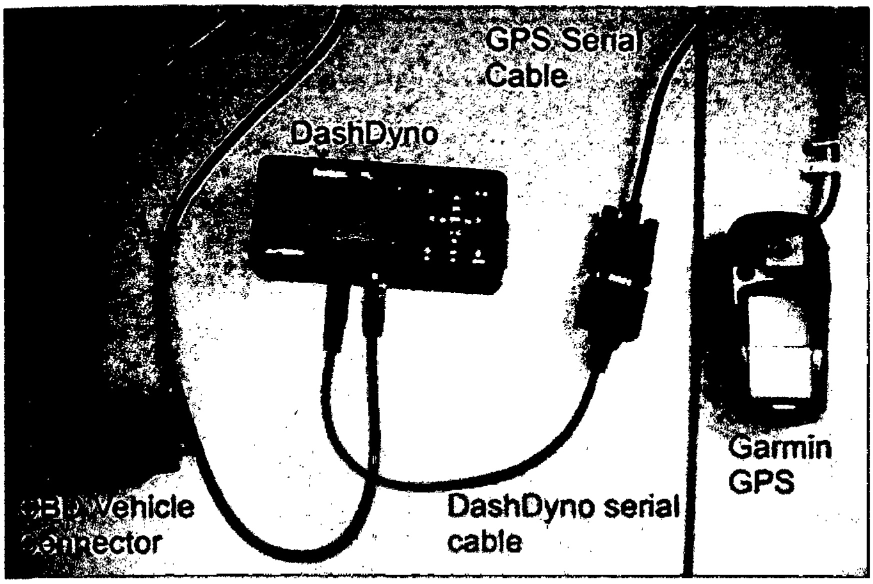

Figure 2.8: Hardware used for data collection for GreenGPS

Source: Ganti, Pham et al. 2010

2.11 SUMMARY

Table 2.1: Related Works

Num	Title	Objective	Data Acquire	Hardware
1	Car Data Toolkit	Low cost DAQ for HCI research	• Status data • contextual data • event data	• Smartphone • OBD-II Dongle
2	Computerized Experience Sampling in the Car	To express the challenge to measure the user experience	• User Experience data	• Smartphone • OBD-II Dongle
3	Automated Data Acquisition for a Large Scale Capacitated Vehicle Routing Problem	Optimized the travelling time	• Time travel for each node	• GIS
4	Data acquisition and real-time control using spreadsheets: Interfacing Excel with external hardware	Utilized the usage of spreadsheet in data acquisition	• Voltage in time domain	• Advantech pci-1710 • Computer
5	Dynamic routing using the network of car drivers	ICT solutions for traffic control and warning system	• Travel time between nodes	• Integrated GIS system (Quintiq)