PREDICTING THE USE OF A HYBRID ELECTRIC VEHICLE

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Abstract: This paper outlines the initial stages of a project to analyze the requirements and then design an intelligent controller for hybrid electric vehicles. Such a controller would be required to manage energy flow through the hybrid drive train and for optimum control would require a number of parameters normally available only upon journey completion. This paper presents work to attempt to predict these parameters at the start of the journey using intelligent classification techniques and a knowledge base of previous journey histories.

Keywords: Hybrid Vehicles, Prediction Methods, Automotive Control, Intelligent Control, Navigation Systems.

1. INTRODUCTION

Much of the research into new forms of vehicle propulsion is motivated by legislation intended to limit the polluting effects of vehicle exhaust emissions. Future legislation in both the USA and European Community will introduce progressively more stringent limits on vehicle exhaust emissions over the next 15 to 20 years. Ultimately, there will be a requirement for vehicle manufacturers to supply Zero Emission Vehicles (ZEVs) and Low Emission Vehicles (LEVs) for use as a form of private transport within large urban conurbations. At present electric vehicles are the only practical candidates as ZEVs, whilst hybrid electric vehicles currently form the most serious contenders as LEVs.

Hybrid electric vehicles have a propulsion system which includes a heat engine, and one or more electric motors and/or generators with an associated traction battery. The propulsion system in a hybrid electric vehicle can be assembled in a variety of configurations. One possible arrangement is a parallel hybrid vehicle consisting of a single electric motor (E) and heat engine (HE) mechanically coupled to a single drive shaft. A typical parallel hybrid vehicle configuration is described in figure 1. Power from the electric motor and/or heat engine is transmitted to the road wheels by drive shafts and gear mechanisms. Power for the electric motor is supplied by the traction battery (B). If the motor is driven either directly from the heat engine or during braking, it will generate current to charge the traction battery.

In its simplest form, the power from the two drives can be provided in one of three modes:-

1) Electric motor only.
2) Heat engine only.
3) Electric motor and heat engine combination.

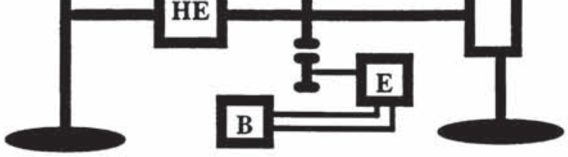

figure 1. Structure of a typical parallel hybrid vehicle.

Using the electric motor or heat engine exclusively (modes 1 and 2) present a manageable control problem for the driver of the vehicle, but their combined use (mode 3) makes it very difficult for the driver to control optimally. Previous work at the University of Warwick (Farrall and Jones, 1993; Farrall, 1993) has investigated the use of fuzzy decision making for the management of energy flow within a hybrid electric vehicle in this third mode. It was concluded that fuzzy control could provide benefits over a limited range of operation, but in order to obtain better performance over the complete range of operation, a method of adapting the fuzzy rules would be required.

To enable a hybrid electric power train controller to adapt to a wide variety of vehicle operation many parameters not normally used in vehicle control systems would be required , e.g. Journey duration, journey distance, time of departure, journey destination. Unfortunately most of these parameters are only known upon completion of a given journey. Therefore a means of intelligently estimating these parameters, based on the controller's past experience is needed.

A programme still very much in its infancy is the design of an intelligent controller. The proposed controller will allow journey parameters to be reliably estimated upon journey departure, and therefore allow for optimal operation with respect to exhaust emissions and fuel consumption.

The successful implementation of such a controller relies on the idea that many cars will have habitual usage characteristics for a high percentage of their journeys, and hence the ability to predict the occurrence of a journey and its associated characteristics will be quite high. A commuter journey is a particularly good example of a journey that exhibits habitual characteristics, and in the UK accounts for around 20% of all journeys taken by car (National Travel Survey, 1993). Other journey types (Business, Education, Shopping, Leisure) may also exhibit habitual characteristics, therefore the benefits to be gained from the use of an intelligent controller are high. The impact of such benefits will depend upon the geographical location the vehicle is used in. (National Travel Survey, 1993).

2. HYBRID POWER TRAIN CONTROL

As previously stated, the proposed controller will allow journey parameters to be reliably estimated upon journey departure. In order to do this the information available to the controller could take one of two forms:-

1st Generation Control

The essence of this type of control is that all information would only be available internally to the vehicle, from transducers belonging to the vehicle. A controller of this type, if implemented, would use signals derived from technology already present in modern day vehicles (e.g. electronic tachometer, engine management system).

Such information would include:-

a) Drivers Operational Inputs:-	Throttle Brake etc.
b) Time of day/year.	
c) Engine Management Data:-	Engine speed etc.
d) Road speed.	

2nd Generation Control

This type of control would employ the use of 1st generation control information, but also would have the additional advantage of vehicle location information relayed into the vehicle from external sources. Such external sources could take the form of a GPS (Global Positioning System) navigation system, or a road transport telematic infrastructure of the future, perhaps employing the use of road side beacons. Much research is currently underway into the use of such systems for road transport. GPS systems have been suggested for use in vehicles for a variety of applications; for example rapid vehicle location in the event of a road accident (Voger and Harrer, 1994). Road side beacons have been a suggested tool not only for automatic debiting in road tolling schemes, but also for interactive route guidance systems (Bueno and Ongaro, 1991). A 2nd generation controller would explicitly know its location by receiving vehicle location information via such systems.

Information available:-

a)All 1st generation control information.

b)Vehicle location information i.e. latitude and longitude.

Control Decisions.

An intelligent hybrid electric powertrain controller would have to make a decision of control strategy in

Am I Going? decision. Where Am I Now? is a means by which an intelligent controller would continually reassess its original prediction.

Where Am I Going? is the initial estimation on the type of journey at the time of departure. The initial decision here is based on the Expectation of a journey type. Information available at the time of this decision differs between 1st and 2nd generation control.

1st Generation Control:- This can only use the present system time (time of day, day of week), the only information that is available at this instant. A journey is expected only if it frequently occurs at the same time of day, e.g. a morning commuting type journey.

2nd Generation Control:- This has the additional information of the vehicle's ground position at the time of departure. Expectation here is based on time of day, day of week and the vehicle's present global position.

If the controller decides a journey is expected it can make an estimation of the expected journey parameters, and an appropriate optimized control strategy can be referenced from the controller's memory. If a journey is not expected, the controller will choose the use of a general purpose control strategy, thus providing reasonably efficient operation only. Figure 2. shows the decision process.

Previous studies (Smeed and Jeffcoate, 1971; Herman and Lam, 1974) have examined commuter journeys in different geographical locations. They have found that they can describe the travel time variability on these routes mathematically with variables such as departure time and journey distance.

3. VEHICLE EXPERIMENTS

Data is required throughout the project for investigation into methods of vehicle use prediction. This is achieved by the use of a data logger based around a GPS navigation system. Data recorded by the logger can be considered in terms of 1st or 2nd generation control data as follows:-

1st Generation Control Parameters
Time of departure,
Journey time elapsed,
Speed over ground, derived from latitude and longitude.

Additional Parameters for 2nd Generation Control
Explicit vehicle location (i.e. Latitude, Longitude)
Bearing relative to north, derived from latitude and longitude.

The GPS data logger is described in Figure 4. The GPS system requires signals from 3 satellites in order to obtain a 2-D position fix, and at least 4 satellites to obtain a 3-D position fix.

Careful consideration has gone into the selection of subjects. They are being chosen so that the main vehicle user represents a subset of the UK driving population, and their selection is based on age and sex statistics from UK driving licence registrations (National Travel Survey, 1993) and occupational statistics (Labour Force Survey Quarterly Bulletin, 1994). The subjects are being selected to give a spread of different occupations, different geographical location and different hours of work (shift, fixed hours, flexible time, part-time etc.). As a result, twenty subjects will have the GPS data logger installed in their car for a period of one month each.

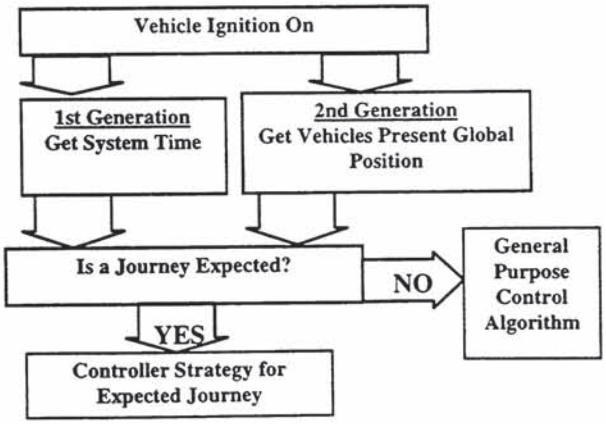

Figure 2. Decision Process of Where Am I Going?

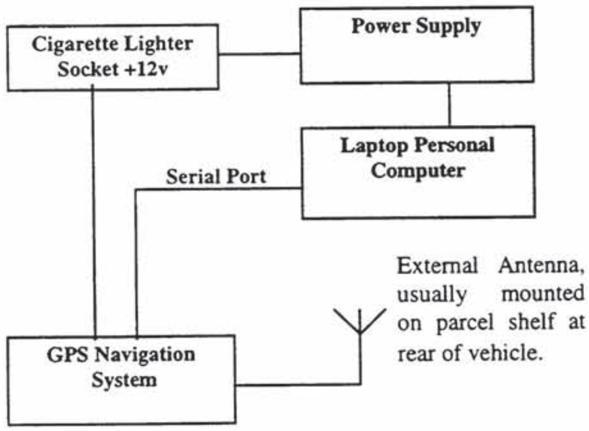

Figure 4. GPS Data Logger set-up

vehicle were available. All of the journeys taken in this vehicle have been logged over a one month period; a total of 125 journeys. Figure 5 shows an example of the form of the raw data for latitude and longitude obtained on a single journey. Speed over ground and bearing are derived from this data.

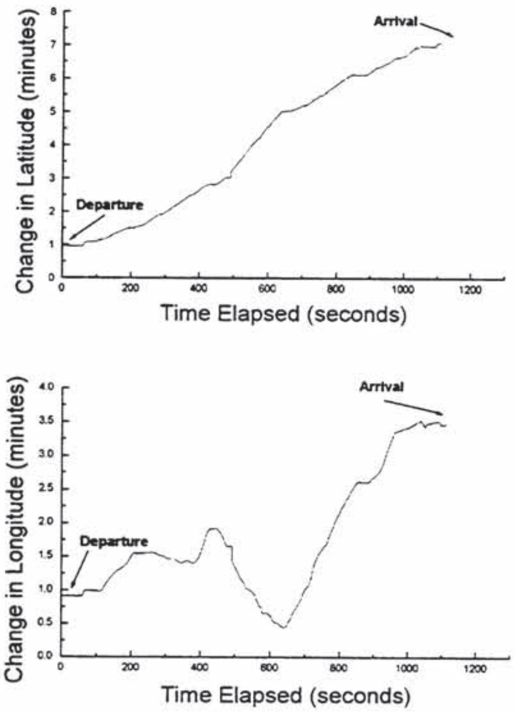

Figure. 5 Raw Data Obtained from GPS Data Logger.

A summary of initial data analysis is presented (i.e. journey duration, journey distance, and ground locations visited). The data is considered to develop rules to assist in journey prediction. 1st generation control data is considered first. This is followed by considering any additional advantages gained by using 2nd generation control.

1st Generation Control Data

As it is the case that many people work a five day week Monday to Friday, the data has been split into two distinct subsets for consideration; weekdays and weekend. Figure 6 shows the duration of our subjects journeys over the month period.

The weekend distribution shows a no obvious pattern, whereas the week day plot shows a number of journeys occurring between the hours 07.00 - 08.00, with a duration between 1000 - 1300 seconds. This actually corresponds with the subjects morning journey to work.

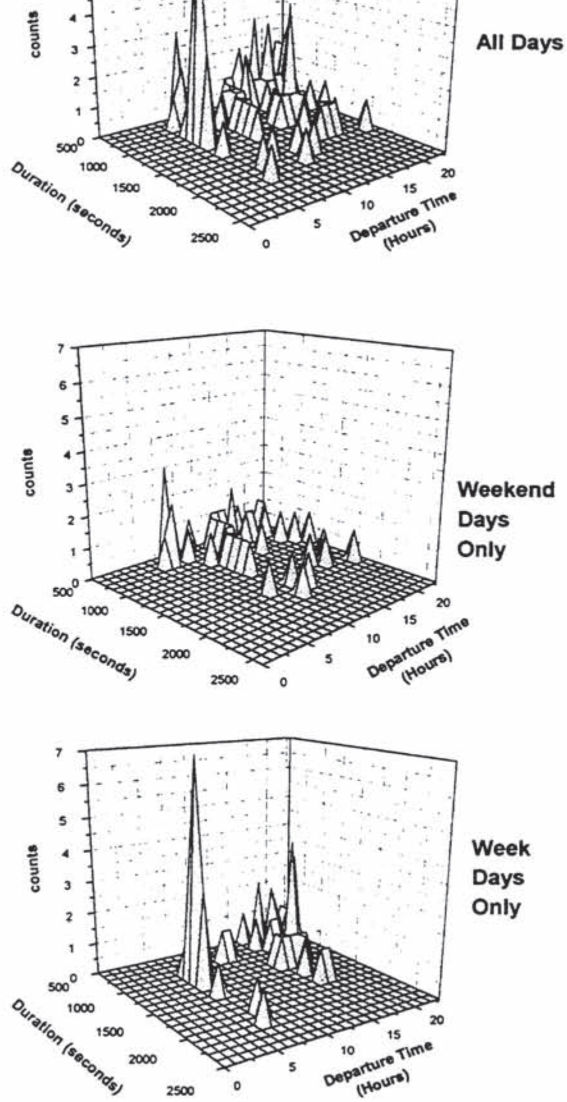

Figure 6. Variability of Journey Duration

Figure 7 shows the distribution of the distance covered on the vehicle's journeys. Again the weekend distribution shows no obvious pattern. The week day plot shows a number of journeys occurring between the hours 07.00 - 08.00, with a distance around 14km. This correlates well with the data obtained for journey duration. The journeys occurring between 07.00 - 08.00 hours in fact account for only 13.6% of the journeys in one month.

From this data we can deduce the following rule on journey expectation:-

there is a high expectation of a journey of 1000 to 1300 seconds duration, with a distance around 14km.

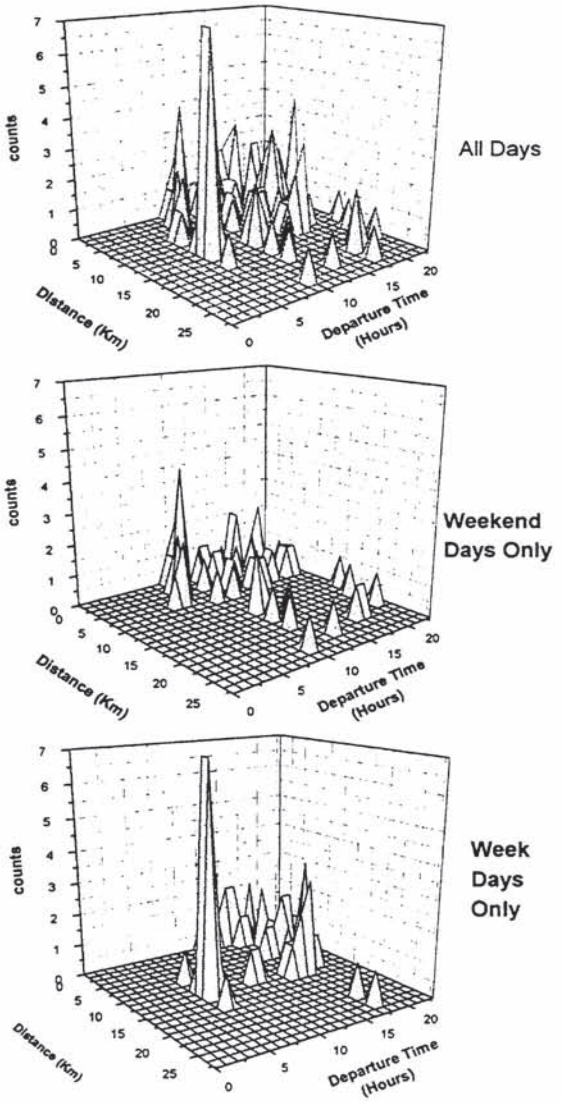

Figure 7. Variability of Journey Distance

<u>2nd Generation Control Data</u>

Plotting the cumulative distribution of vehicle global position (expressed in latitude and longitude) both at journey departure and arrival, gives an indication of the locations regularly visited. Figure 8 shows the distributions for all days, weekend days only, and week days only.

The weekend distribution shows a number of locations visited covering a large geographical area. Only two of these locations are regularly visited (Positions A and B). The week day plot shows only three visited locations (Positions A, B and C).

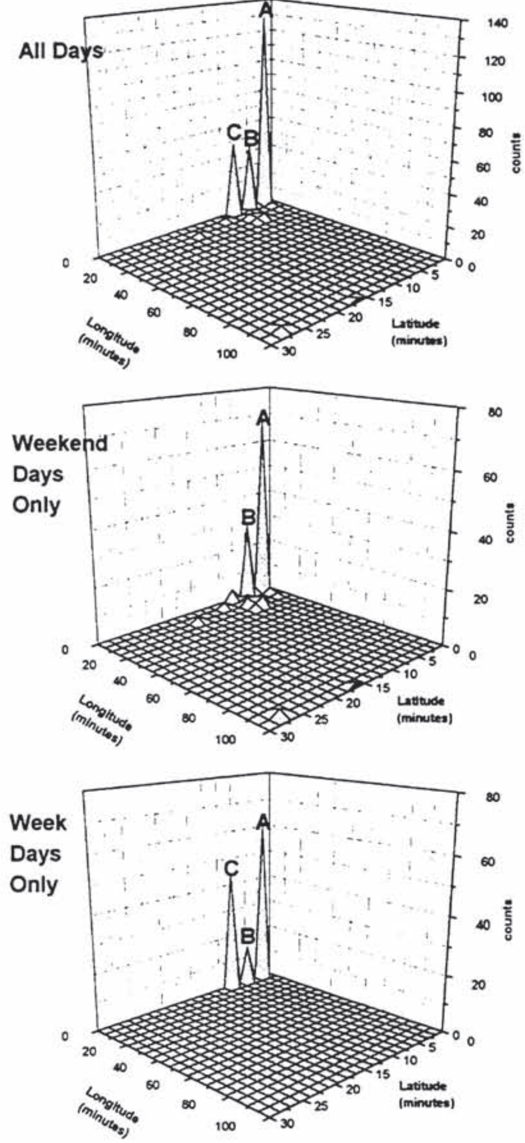

Figure. 8 Area Covered by Vehicle During Logging Period

Nodal Analysis (Figure 9) gives a better view of how each location is inter-related. In the example shown, locations A, B and C account for about 62% of the journey destinations for this subject. Optimization from journey prediction could provide quite high benefits if the interconnecting journeys to these locations could be predicted. Each node has latitude and longitude as its properties (not shown on the diagram), each arc of the nodal diagram has the following properties associated with it:-

Length of journey.
Duration of journey.
Usual times of departure, e.g.
Day of week
Time of day

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