Towards Egocentric Fuel Efficiency Feedback

Tiago Camacho **Filipe Quintal** **Michelle Scott** **Vassilis Kostakos**
Ian Oakley
Madeira Interactive Technologies Institute (M-ITI)
Funchal, 9000-390, Portugal
{tiago, filipe, mscott, vassilis, ian}@m-iti.org

ABSTRACT

Motivated by anecdotal evidence, we hypothesize that an egocentric approach is more appropriate and relevant to providing fuel efficiency feedback than a systemic approach. In this paper we describe a proposed study to test this hypothesis, and present the design of a fuel efficiency feedback system for public transit bus drivers.

Author Keywords

Feedback systems, fuel efficiency, public transit bus drivers

ACM Classification Keywords

H5.m. Information Interfaces and Presentation (e.g., HCI): Miscellaneous

Introduction

In 2010 the public transport authority in Madeira, Portugal, installed onboard electronic equipment that gauged driving fuel efficiency by presenting the driver with very simple feedback: 3 green lights progressively suggested that efficiency was increasingly optimum, while 3 red lights progressively suggested that driving efficiency was increasingly sub-optimal. The system was intended to give drivers feedback on their driving and to help them achieve optimal driving efficiency. The result was negative: drivers complained to human resources that the system constantly showed 3 red lights, suggesting that their driving was bad. Human resources complained to operations that the system was bad for morale.

In response, operations attempted to "calibrate" the system by tweaking its thresholds. The result was that the feedback became useless and largely inaccurate, ultimately resulting in the abolishment of the system. In our discussions with the transport authority, it became clear that in addition to the misinterpretation of the feedback by the professional drivers as a rating of their driving, the mountainous terrain of Madeira caused genuinely inefficient driving. There was simply no way to avoid steep hills that took a significant toll on fuel consumption, thereby skewing the feedback towards inefficient driving. The attempts at calibrating the system failed because, effectively, the on-board equipment measured pure fuel consumption which in turn was intricately related to the steep terrain of the environment. On the other hand, drivers perceived the feedback as a reflection of their skills.

Our anecdotal experience with the public transport authority's feedback system caused us to hypothesize that providing feedback on specific driver behaviour, as opposed to overall fuel efficiency, may be a more appropriate way for motivating driver behaviour change. Adopting a systemic approach to this issue, we argue that existing feedback mechanisms relating to efficiency provide a view of the complete system, parts of which the driver has simply no way of effecting (such as the steep terrain). Hence we argue that efficiency feedback focusing on parts of the system that the driver can effect (such as acceleration) may result in more efficient driving behaviour. We term this approach to feedback egocentric.

In this paper we describe a fuel efficiency reporting and advisory system that takes advantage of the multi-sensor and interactive nature of modern smart-phones to present feedback to drivers. More specifically, we are interested in deploying the system in public transit buses to measure its effectiveness on positively influencing drivers' behavior. By continuously capturing real-time sensor data, we can calculate the Vehicle Specific Power (VSP), a surrogate variable that strongly correlates with both fuel consumption and pollutant emission levels, providing a systemic view of efficiency [11]. Crucially, we are able to manipulate the calculation of VSP to ignore environment variables and provide egocentric feedback. Taking advantage of this manipulation, we propose a study where we intend to test our hypothesis about the benefits of egocentric over systemic feedback. We believe that through the use of our system we can promote not only short-term but also medium/long-term positive changes in public transit bus drivers' behaviours.

Related Work

Research suggests that it is possible to achieve up to 15% of fuel consumption decrease when appropriate driving behavior is used [2, 6–8, 12]. Independent of contextual settings, appropriate driving behavior is characterized by a combination of two main factors: speed and acceleration. Specifically, it is believed that smoothness of driving (i.e. slow acceleration levels) has a considerable effect on fuel consumption. Therefore, fuel efficiency systems should be dedicated to promoting adequate driver feedback in relation to these two essential factors, i.e., reasonable speeds and low acceleration/deceleration levels. Accurately accounting for all factors that influence fuel consumption and consequent pollutant emissions can be a complex exercise. Nevertheless, And & Fwa present a possible vehicular fuel consumption explanatory framework [1]: Physical characteristics of the vehicle; vehicle usage and route characteristics; road characteristics; and driver's behavior.

Of these factors, engine efficiency (physical characteristics of the vehicle) is considered the most important [4]. Still, the driver's attitude and behavior towards the maneuvering of the vehicle can considerably impact fuel consumption levels. Therefore, it is commonly argued that smoothness of driving leads to higher efficiency of fuel consumption.

Raw fuel consumption levels and pollutant emissions can be calculated through the use of Portable Emissions Measurement Systems (PEMS). These are connected to vehicles through their On-Board Diagnostic (OBD) interface, letting the PEMS system access the vehicle's on-board computer and calculate multiple parameters [13]. Still, PEMS systems work primarily as a diagnostic/analysis tool, not as a feedback support mechanism. Furthermore, PEMS systems fail to reflect contextual characteristics such as road gradient values. It is common to augment PEMS with GPS for analysis purposes [13].

The Vehicle Specific Power (VSP) approach is used to approximate and predict actual emissions levels and fuel consumptions [10, 11]. VSP is a model that tries to explain consumption and emission levels from a physical perspective; it corresponds to the Power Demand or Vehicle Engine Load values, therefore correlating strongly with fuel consumption and pollutant emission levels [13]. The VSP model depends on three variable factors: speed, acceleration, and road grade. Through the combination of these factors, along with vehicle specific air and roll resistance coefficients, VSP values are calculated as follows [11]:

$$VSP = v * (a + g * sin(\varphi) + rcoef) + acoef * v^3 \quad (1)$$

where v is speed in m/s, a is acceleration in m/s^2, g is 9.807 m/s^2, φ is the road gradient value, $rcoef$ is the rolling resistance term coefficient, and $acoef$ is the air drag term coefficient. Another characteristic of VSP is its ability to support payload modeling, especially important in situations where this value has noticeable impact, such as is the case with public transit buses [11]. Still, VSP does require that we calibrate the model for each type of vehicle, as it is necessary to obtain the ground truth for fuel consumption and pollutant emission levels for the model to be effective.

Devices such as smart-phones possess a wide variety of sensors, like GPS and accelerometers, that enable calculation of vehicle dynamics and consequently VSP values. It is then possible to approximate fuel consumption using solely internal smart-phone sensors. These devices can be easily incorporated into vehicles, and their ability to provide a rich and extensible interaction platform make them a feasible alternative mechanism to provide drivers with fuel efficiency feedback. Furthermore, and comparing with usual commercial systems such as Scania Fuel-Saving Driver Support System[1], smart-phones are not restricted to specific vehicles, and can even be device independent, which is the case when using development platforms such as Google's Android.

Receiving timely feedback is key to motivating behaviour change, people need to be aware of their behaviour in order to change it. Fischer found the most successful feedback was given frequently, clearly presented, used computerised tools and allowed historic or normative comparisons [9]. Our mobile interface reflects these types of feedback. Utilising a mobile display allows frequent opportunities for self-reflection and should increase driver awareness of their behaviour.

Consolvo, McDonald, and Landay [3] suggest a number of design strategies for persuasive technologies that wish to motivate behaviour change. These strategies are based on psychological theories and recent persuasive technology research and we have chosen to follow some of their guidelines.

First, we make use of abstractions rather than counting solely on raw data to display to drivers. Secondly, the data shown should be unobtrusive. This is of paramount importance for safety reasons, as we need the mobile display to support ignorability and not distract the driver unnecessarily. Thirdly, since the data is to be presented in public, we need to present it in a way that the driver will not feel uncomfortable if others are aware of it. Fourthly, we decided to ensure that only positive feedback is given, not punishing any "bad" behavior. Concretely, we aim at rewarding possible low consumption levels, but not use punishment for poor performance. This decision is supported by the notion that positive feedback can indeed increase intrisic motivation by affirming competence [5]. The anecdotal evidence from the use of a commercial system by the public transit company also supports this notion. Finally, we have chosen to provide historical feedback. Doing so allows the driver to reflect on past behaviours in order to make more informed decisions on current behaviour.

Research Methodology

We propose an experimental approach to study to what extent we can, through the use of egocentric feedback,

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[1] http://www.scania.com/media/feature-stories/sustainability/every-drop-of-fuel-counts.aspx

	Real-time	Historical
VSP	Real-time& VSP	Historical &VSP
egoVSP	Real-time &egoVSP	Historical &egoVSP

Table 1. 2x2 design of combination factors

influence public transit bus drivers driving behavior. In our study we are interested in the following research questions:

- Can we accurately establish driving behavior profiles for bus drivers through the use of VSP calculations?
- To which extent can we positively influence driving behavior through the use of egocentric feedback techniques?
- Is the use of real-time more effective than the use of historic feedback, or is a combination of the two approaches most effective?

Consequently, and based on the previous mentioned research questions, we raised the following hypotheses:

- H1. The use of the VSP surrogate variable (and its derivatives) allows for accurate driving profile characterisation
- H2. The use of egocentric driver feedback improves average fuel consumption levels
- H3. The use of real-time feedback does not significantly influence driving behavior

To test these hypotheses we propose to develop an Android based software to continuously collect sensor information so that trip instantaneous parameters, such as speed and acceleration, can be calculated. We will also consider the use of additional variable(s) to model the influence of passenger payload on the overall vehicle weight. Then, we intend to install equipment on-board public transit buses and calibrate the VSP model. The ground truth establishment of instantaneous fuel consumption levels is a necessary condition for the success of the VSP model. This may be achieved through the use of a PEMS system or a similar mechanism. Subsequently, we will develop a derivative of VSP called egoVSP, which ignores road gradient and is defined as follows

$$egoVSP = v * (a + rcoef) + acoef * v^3 \qquad (2)$$

Terms of the equation are defined equally as in eq. 1. These two fuel efficiency models, VSP and egoVSP, are one of the two variables we intend to manipulate in our study. The other variable is the type of feedback to provide: real-time versus historical. Table 1 shows the possible combinations of these two variables.

Ongoing Work

As it stands, the system is a working prototype. Targeted mainly at public transit bus drivers, the system is flexible and extensible enough to provide support for any kind of vehicle.

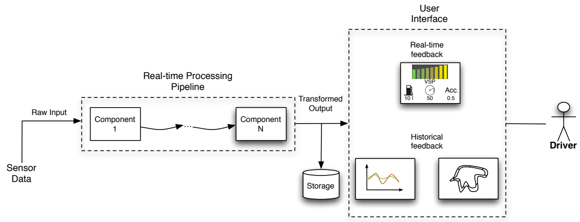

Figure 1. Overall view of system functionality

An overview of the architectural design is seen in Fig. 1, where the mechanism that is used to produce the final output to the driver is visible. Raw sensor data is sampled at several times per second, before it is passed to a real-time processing pipeline. This allows us to execute tasks in parallel that may require some computational complexity, therefore increasing system overall speed and responsiveness. The advantage of such a scheme becomes more evident when, for example, the system is required to perform continuous sensor data integration by means of a Kalman Filter.

The calculation of the vehicle dynamics and the VSP modeling is also included in the processing pipeline. After exiting the pipeline, the transformed output is then fed to the feedback mechanism, which transmits specific information to the driver, according to the type of feedback used. All data is continuously stored in a local database, so that further off-line analysis may be performed. Repeated sampling from sensors will undoubtedly drain the battery in its full in a matter of hours, so there is the need of ensuring that the device is fed continuous power by connecting it to the vehicle's internal electric circuit.

Drivers initiate interaction through the system's main menu (see Fig. 2). In order to use the system, drivers must register themselves before receiving a 3 digit PIN code that uniquely identifies them. Vehicles registration and VSP model calibration is also required to be performed, but this may be done by the developers before the system is made available to the drivers. This will be the case when doing the experimental study with the public transit bus drivers. Besides the VSP model calibration, it is also possible to calibrate both the device accelerometer, as well set up the desired orientation of the phone inside the vehicle. This last step has some limitations, as currently we are working with a phone with only one accelerometer and no gyroscope, which limits the phone's orientation recognition. Just before starting a trip, the driver introduces his PIN code and indicates the vehicle that he is currently using. After this the trip is marked as initiated.

In order to test the effectiveness of the feedback system, we propose using two different types of feedback: real-

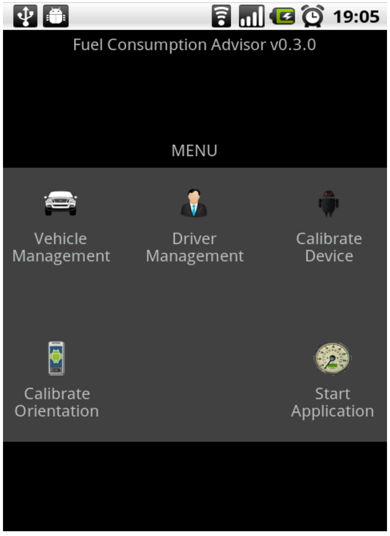

Figure 2. System main menu

time and historical. In the first, we will show a real-time VSP graph that represents an approximation to the actual VSP value. The graph is an abstract representation, where it goes from green (low VSP values) to red (high values) with an approximate quadratic function increase. Additionally, actual fuel consumption, speed, and acceleration values are to be represented.

In regard to the historical feedback, our system will make available two modes to the driver. The first will show the distribution of time in the pre-defined VSP bins, and the second will show a heat map of the route, indicating VSP "hot zones". The use of historical feedback gives the driver a more broad perspective of his driving behavior, as it recalls and identifies potential patterns that may be improved. Furthermore, historical feedback will only take place when the driver is not actively driving.

Conclusion

In this paper we have argued that egocentric feedback on fuel efficiency can be more effective than systemic feedback on motivating driving behaviour change. Motivated by anecdotal evidence, we hypothesise that an egocentric approach is more appropriate and relevant. By re-defining the VSP surrogate metric, we are able to switch between systemic and egocentric feedback while maintaining minimal changes between our experimental conditions. Orthogonal to the manipulation of the efficiency model, we describe our interest in testing the effect of instantaneous versus historic data in the feedback system.

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