Computers & Education 78 (2014) 124–139

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Blended learning system for efficient professional driving

Abel Rionda [a], Xabiel G. Pañeda [b, *], Roberto García [b], Gabriel Díaz [c], David Martínez [a], María Mitre [d], David Arbesú [a], Ignacio Marín [a]

[a] ADN Mobile Solutions, Gijón/Xixón, Spain
[b] Informatics Department, University of Oviedo, Oviedo, Spain
[c] Electrical and Computer Engineering Department, Spanish University for Distance Education (UNED), Madrid, Spain
[d] Business Administration Department, University of Oviedo, Oviedo, Spain

ARTICLE INFO

Article history:
Received 23 November 2013
Received in revised form
25 May 2014
Accepted 28 May 2014
Available online 11 June 2014

Keywords:
Blended learning
Learning by doing
Lifelong learning
Efficient driving
Combustion vehicle

ABSTRACT

One of the most important expenses in bus and truck transport companies is the cost of fuel. A small increase in the price of petrol can have a very negative effect on the companies' balance sheet. Apart from that, road transport companies are targeted due to their influence on air pollution. All of this has made the reduction in fuel consumption the most important priority for this type of companies. One of the cheapest measures to reduce fuel burning is efficient driving. According to various studies, more efficient driving could reduce fuel consumption by more than 5%. This article presents a blended learning method which makes use of an on-board tutoring system, an e-learning platform and traditional courses to guide professional drivers to more efficient driving. Through visual and acoustic recommendations, the tutoring system helps drivers achieve more efficient driving in real-time. The on-board system is complemented with a Web portal where drivers can check their driving and receive recommendations for further improvement and a set of traditional seminars imparted by experts in the area. To evaluate the performance of the whole learning system, the driving of 34 professional drivers of the Urban Bus Company (EMTUSA) in the City of Gijón (Spain) has been monitored and analyzed over a period of 12 months. The results of the study showed an improvement in driving efficiency and a reduction in fuel consumption of almost 7% compared to the previous year.

1. Introduction

Fuel is one of the most important overheads of bus and truck transport companies. This concept represents more than 25% of all the operational costs in European countries where petrol derivatives have an important taxation. With this influence in the company balance, a minimum increase in the price has a very negative impact, immediately generating an increment in fares. Another effect of being an important petrol consumer is an adverse image of pollution generator. Every day millions of tons of CO_2 are released into the atmosphere due to the road transport sector. Several studies point to combustion vehicles, especially diesel engines, as one of the principal causes of air pollution as it is stated in Kinney Aggarwal, Northridge, Janssen & Shepard (2000) and Rogula-Kozlowska, Pastuszka, and Talik (2008). In fact, some studies such as, Loh, Sugerman-Brozan, Wiggins, Noiles, and Archibald (2002) and McEntee and Ogneva-Himmelberger (2008) blame the particles emitted by these vehicles for respiratory diseases such as asthma. Other studies, such as Ramanathan and Feng (2009) point the finger at combustion vehicles as one of the principal causes of global warming through the emission of CO_2.

Motivated by the cost reduction and the corporate social responsibility, companies have established the reduction of fuel consumption as one of their maximum priorities. Thus, they have designed plans to tackle any waste or misuse of petrol. One of the measures included in the plan is in many cases the acquisition of new vehicles which are technologically designed to reduce fuel consumption (hybrids, aerodynamics, start-stop systems, etc.). However, this action is expensive and has a limited impact as it only affects the new vehicles in the fleet while the rest will go on consuming as before.

* Corresponding author.
E-mail addresses: xabielgp@gmail.com, xabiel@uniovi.es (X.G. Pañeda).

http://dx.doi.org/10.1016/j.compedu.2014.05.008
0360-1315/

Efficient driving has been put forward as an alternative to technical measures to reduce fuel consumption and is applicable to both new and old vehicles. TNO Science and Industry (Netherlands-based Organisation for Applied Scientific Research) indicates in one of its publications, Smokers et al. (2006), that education in efficient driving is very effective in terms of cost and can potentially reduce the total emissions of motorized vehicles by 3 percent. Nevertheless, the process of learning to drive efficiently is very expensive if it is based only on educative courses, as drivers would have to attend specialist driving schools. Moreover, after some time many of the learned concepts are forgotten and others not applied by the drivers due to different factors such as fatigue, leading to a decrease in efficiency in the long term as remarks Beusen et al. (2009). Furthermore, this learning strategy suffers from the lack of a training follow-up channel. As an alternative, the use of intelligent tutors capable of advising drivers during journeys could be used. An efficient driving routine could be incorporated little by little to their driving habits. In that respect the European Commission, European Union (2012), approved a 2012 regulation that cars should incorporate an optimum gear change indicator.

In this paper we present a learning methodology to make the driving of professional heavy vehicle drivers more efficient, composed of traditional courses, a distance learning platform and an on-board intelligent tutor. The combination of these three learning elements has revealed an interesting method to achieve a long-term reduction of fuel consumption. The drivers have an initial course to learn the fundamentals of efficient driving, the practical process is tutored by the on-board tutoring system which gives them real time recommendations and alarms while driving. Moreover, drivers can use a Web site to update and complement their knowledge. The learning process is permanently supervised by the drivers themselves using the Web site and by specialists in the area who give them specific recommendations as feedback using information provided by the on-board system. The most important piece of the learning process is clearly the on-board system which is connected to the CAN bus or the OBD-II port of the vehicle to analyze the driving process in real-time, conforming the core of the "learning by doing" spirit.

Due to the interest of the companies for proving their actions related with energy saving, many are becoming involved in the ISO 50001 (Energy Management System, ISO (2011a)) certification process to reach more efficiency in their energy use. For this reason, we have aligned our learning methodology with the ISO 50001, hence, the companies which apply it would be able to use it in their energy management process.

The learning system has been evaluated over a period of 12 months, using 10 buses and 34 drivers of the Urban Bus Company (EMTUSA) in the City of Gijón (Asturies/Spain). The results have shown remarkable fuel consumption reductions (improving savings over time, reaching almost 7% in the most recent records) and some learned lessons that will lead to improvements in the system and method in the future.

The rest of the paper is organized as follows. Related work is analyzed in Section 2. The learning methodology is outlined in Section 3. Section 4 describes the designed system to tutor the drivers during their time behind the wheel. The case study and its results are presented in Section 5. Section 6 focuses on discussion and Section 7 outlines the conclusions and future work.

2. Related work

Efficient driving or "eco-driving" is one of the different initiatives which have been studied with the purpose of reducing human energy consumption. In Chen, Cook, and Crandall (2013), authors use data mining techniques to find patterns and anomalies and propose a set of activities to save energy at home. However, according to the cited percentages, it appears much more important to study and improve the driving behavior of the general public and, especially, of driving professionals. Following this idea, different experiences are being developed to obtain an "eco-driving" behavior that becomes the norm rather than the exception. The term "eco-driving" means simply applying a set of rules while driving in order to save fuel. There is a general consensus, as is explained in Barkenbus (2010), about the necessity to involve education, especially using feedback to obtain a continuous learning process.

With this in mind, efficient driving training has been traditionally based on different types of face-to-face courses. For instance, the work in Beusen et al. (2009) shows the results of the long-term impact of an eco-driving training course, received by 10 drivers in real life conditions. Although the experience was limited in time and there was no continuous reinforcement, the average fuel consumption was reduced by 5.8% four months after the course. The methodology used was the classical face-to-face course and drivers were not professionals, although they introduced an on-board monitoring system (without any type of feedback). Another pilot scheme worthy of mention based on this paradigm, presented in Zarkadoula, Zoidis, and Tritopoulou (2007), was conducted by the Centre for Renewable Energy Sources of Greece in collaboration with the Organization of Urban Transportation of Athens, and the Thermo-Bus Company to assess the effects of changing urban bus drivers' driving style. In this case, participants were professional drivers that received a traditional face-to-face course. Although the scheme was very simple with few parameters included and for a much reduced number of drivers, the results were satisfactory.

In the last few years several initiatives have followed a new approach to improve driving efficiency using tutoring systems to assist the driver on-board. For instance, the paper Chou, Lin, Lin, & Chen (2012) describes an intelligent eco-driving suggestion system based on a vehicle loading model for individual drivers. It computes the "instantaneous fuel economy" using information from an on-board vehicle diagnostic system. The system then establishes, by using a fuzzy inference system, a vehicle loading model and infers eco-driving suggestions. When it was tested on real vehicles, it produced fuel savings of up to 7%. Authors in (Wada, Yoshimura, Doi, Youhata, & Tomiyama, 2011) built another eco-driving assistant that "changes a level setting adaptive to the driver's growing skill in continuous effective use of such a system". In this case, the system was only tested through driving-simulator experiments showing a certain improvement in fuel use. Other researchers, such as in Araujo, Igreja, De Castro, & Araujo (2012) and Corcoba & Muñoz (2011), focused their systems to be installed on cheap smartphones which run autonomously. Interacting with an OBD-II sensor to gather the information from the vehicle switchboard and a GPS to detect the vehicle position, the systems have a complex architecture conformed by databases, intelligent data processing and presentation modules. Both papers include different prototypes but no case studies were presented.

Away from the academia, the automobile industry has worked on different systems to provide vehicle performance information and improve driving efficiency. This is the case of brands such as Fiat, Nissan or Mercedes. Fiat has been a pioneer in this field through its Ecodrive project accessible in Fiat (2013). In the first stage, they designed an acquisition system which allowed the driver to download information about journeys undertaken, to be studied on the computer. A complete set of applications to analyze the efficiency was