Corcoba Magaña, Víctor; Muñoz Organero, Mario (2014).“The impact of using gamificacion on the eco-driving learning”, in *Ambient Intelligence - Software and Applications, Advances in Intelligent Systems and Computing*, Volume: 291, Pages: 45-52.
http://dx.doi.org/10.1007/978-3-319-07596-9_5

The Impact of Using Gamification on the Eco-driving Learning

Víctor Corcoba Magaña and Mario Muñoz Organero

Dpto. de Ingeniería Telemática, Universidad Carlos III de Madrid Leganés, Madrid, Spain
vcorcoba@it.uc3m.es

Abstract. This paper analyses and validates the impact of using gamification techniques for improving eco-driving learning. The proposal uses game mechanisms such as the score and achievements systems in order to encourage the driver to drive efficiently. The score is calculated using fuzzy logic techniques that allow us to evaluate the driver in a similar way as a human being would do. We also define the eco-driving tips that are issued while driving in order to help the driver to improve the fuel consumption. Every time the system detects an inefficient action of the driver to a previously known situation such as a bad reaction to a detected traffic sign or a detected traffic accident, it warns the user. The proposal is validated using 14 different drivers performing more than 300 drives with 5 different models of vehicles on 4 different regions of Spain. The conclusions show a positive correlation in the use of gamification techniques and the application of the proposed of eco-driving tips, especially for aggressive drivers. Furthermore, these techniques contribute to avoid drivers coming back to their previous driving habits.

Keywords: Eco-driving learning, Fuel Consumption Optimization, Gamification, Help systems, ITS, Intelligent Vehicle Systems & Telematics, Intelligent systems, User experiments.

1 Introduction

The emission of pollutant gases due to vehicles causes a large number of deaths [1]. On the other hand, the number of old vehicles in circulation have increased exponentially in recent years [2]. Fuel consumption depends on a large number of parameters that can be classified into three major groups: vehicle parameters (engine, aerodynamic and weight), environment (topology, traffic density and weather conditions) and driver (speed, acceleration, deceleration, gear, and air conditioning). Eco-driving is a driving technique based on the setting of the parameters that the user controls. This technique allows us to save fuel regardless of the technology [3] [4].

This paper focuses on two of the most important challenges in eco-driving: motivating the user to drive efficiently avoiding the return to its bad previous driving habits and helping drivers to acquire knowledge about eco-driving in an efficient way. One way to encourage the driver to learn and to apply the eco-driving rules is using

gamification techniques. This method consists of building a game in a non-game context to perform hard and repetitive activities, improving the engagement of user. In [5], we can see a review about gamification and the impact on teaching. There are many scenarios where this concept is applied. For example in [6], authors use emoticons and sounds to encourage the recycling of bottles. When a user throws away a bottle in the garbage, the emoticon smiles. Authors conclude that the proposed system increases the recycling rate by a factor of x3. This concept has also been applied in the field of transport systems. For example, in [7], the authors propose an application to report road accidents.

2 The Eco-driving Game

The proposed solution in this paper consists of an eco-driving assistant in combination with a gamification system. The eco-driving assistant continuously monitors the driver and the environment to propose improvements in his or her driving style in order to save fuel. The eco-driving recommender system is able to use the information coming from different sources (on-board telemetry systems, Internet Web Services and mobile device's embedded sensors such as GPS, accelerometers and camera) to detect the current driving conditions and to adapt the eco-driving tips. On the other hand, when the driver finishes the trip, the system evaluates the quality of the driving in eco-efficiency terms (using fuzzy logic) and assigns a score to the driver. The score can be shared with friends and other users. In addition, we have defined achievements to reward environmental actions and to encourage the continuous use of the eco-driving assistant. The aim of the proposal in this paper is that the user acquires the required knowledge about eco-driving in a user friendly and efficient way, applies the eco-driving tips while driving and does not return to their previous bad driving habits.

The eco-driving assistant runs on a mobile device and which is continuously monitoring the behavior of the driver and the environment. When the eco-driving assistant detects an inefficient action, it notifies the user in order to avoid the same mistake again. In addition, it anticipates upcoming situations on the road in order to avoid the waste of energy if there was a late reaction from the driver. The different recommendations provided by the eco-driving assistant are:

- Driving at a constant speed
- Avoiding sharp accelerations
- Avoiding sharp slowdowns
- Avoiding driving at high revolutions per minute
- Avoiding driving at high speed
- Reducing the intensity in decelerations by anticipating to upcoming situations (such a traffic signal)
- Adapting the speed to environmental factors (rain, wind or important slope angles) or traffic conditions.

Moreover, as noted above, it is essential to encourage and motivate the user to apply the tips and continue using the assistant. We evaluate the driver when it completes

the trip from the point of view of energy consumption and we assign a score to it. User scores can be shared with friends and other users establishing a ranking. The gamification techniques are designed based on the goal of obtaining the maximum score. Gamification is the use of game design elements in non-game contexts such as learning environments. The idea is to use concepts from games like: the challenge, the competitiveness and progression in order to motivate the user for improving the driving style from the point of view of energy consumption.

The score of the driver is obtained using a fuzzy logic system. This method allows us to simulate the human knowledge when carrying out certain tasks such as driving. The objective is to model the behavior of an efficient driver. In the model, a set of input variables (acceleration, deceleration, engine speed, standard deviation of vehicle speed, positive kinetic energy and vehicle speed) is involved and the output is the estimation of energy efficiency of a driver. The output variable is a number between 0 and 10. A high value means that the driver is applying the basic rules of eco-driving thoroughly. The proposed system is able to evaluate the driver's driving style based on a knowledge base and the information obtained through the vehicle's diagnostic port (OBD2) [8]. The OBD2 port allows us to obtain the vehicle telemetry. The knowledge base contains the rules that define whether driving is efficient or not. The rules have been obtained through observation of real samples. Our fuzzy system has six rules:

- IF stdSpeed is high AND (acceleration OR deceleration OR speed) is high THEN NonEfficient
- IF engineSpeed is high AND speed is low THEN NonEfficient
- IF acceleration is high and PKI is high THEN NonEfficient
- If engineSpeed is high AND speed is high THEN Efficient
- If stdSpeed is low AND acceleration is low AND PKI is low THEN Efficient
- If stdSpeed is low AND deceleration is low THEN Efficient

On the other hand, we have defined a set of achievements in order to motivate the driver to use the system frequently and in order to allow him to get familiar with ecological challenges. As an example, the user unlocks an achievement when he completes a trip without accelerating sharply. Achievements are a traditional gamification method used to accomplish a certain behavior or to compare the performance of users. Achievements do not normally imply monetary compensation, but they are based on an emotional reward.

3 Evaluation of Eco-driving Game

3.1 Experimental Design

In order to evaluate the improvement in the performance of the eco-driving rules when we use the proposed game, validation tests have been carried out using 5 different vehicle models and 14 driver. Drivers were divided into two groups. The first group did not have the achievement system and the eco-driving assistant only issued eco-driving tips when it detected that the driver was doing inefficient actions from the

point of view of energy consumption. The second group made tests with eco-driving game enabled. In this case, when the driver finished the route, the eco-driving assistant assigned a score to the user. The driver could check his score and compare it with the score obtained from friends and other users as well as to see his position in an eco-driving ranking. Tests were made in four different regions of Spain: Madrid, Seville, Granada and "Castile and Leon". However, all tests have performed under similar conditions (road type, number of stops, traffic density and weather conditions) in order to make a fair comparison between drivers.

The eco-driving game was deployed on a Galaxy Nexus mobile device equipped with an ArmV9 processor at 1.2 GHz, 1 GB of RAM and Android 4.1.2. The OBDLink OBD Interface Unit from ScanTool [9].Net was used to get the relevant data (vehicle telemetry) from the internal vehicle's CAN bus. The OBDLink Interface Unit contains the STN1110 chip that provides an acceptable sample frequency for the system. In our tests, we obtain two samples per second. Figure 3 shows an overview of the experimental setting.

3.2 Results

To assess the overall behavior of the driver from the point of view of fuel consumption, we use the fuzzy logic system described above. The score obtained allows us to determine to what degree the user complies with eco-driving rules. A lower score indicates that the driver does not apply the eco-driving rules. In contrast, a high score means that the user is driving efficiently. All drivers performed two tests. The first test is realized before using the eco-driving assistant. After, when the eco-driving assistant has been used 30 times, the second test is made. Table 1 captures the score obtained by drivers without using the eco-driving game feature, before (pre-test) and after (post-test) using the assistant. Table 2 shows the score obtained by drivers who have the game feature enabled on their eco-driving assistants. The score is a number from 0 to 10 where 0 means that the driver is totally inefficient and 10 which is very efficient. We can conclude that when the driver does not have activated the game feature (assistant issues only eco-driving tips), the driving style improves very slightly, and after a short period of time he returns to his previous driving habits. Furthermore, some drivers ignore the eco-driving advice like driver "F1" (aggressive and occasional driver). On the other hand, drivers optimize the driving significantly when the game is enabled and maintain the efficient driving style regardless of the user profile (aggressive, normal, occasional or usual).

In order to validate that the proposal improves the user's motivation to comply with the eco-driving rules and it is not due to random factors, the t-test has been used. Considering the null hypothesis as: "there is no improvement in user score when using the eco-driving game feature" and calculating the p-value we obtain a value of 0.004 (below the 0.05 threshold). Therefore, the null hypothesis (under the 0.05 threshold) can be rejected.

Table 1. User Score without using the eco-driving game

	Driver Profile	Pre-Test	Post-Test	Gain
A1	Aggressive Usual	1	1.5	0.5
B1	Normal Usual	2.1	4.1	2
C1	Normal Usual	2.1	7.8	5.7
D1	Normal Usual	0.9	7.9	7
E1	Normal Usual	1.4	8.7	7.3
F1	Aggressive Occasional	0.1	0	-0.1
G1	Aggressive usual	0.2	2.3	2.1

Table 2. User Score using the eco-driving game

	Driver Profile	Pre-Test	Post-Test	Gain
A2	Aggressive Usual	0,6	8	7,4
B2	Normal Usual	3,7	9,98	6,28
C2	Normal Usual	2,2	10	7,8
D2	Aggressive Occasional	1,3	8,9	7,6
E2	Normal Usual	1,5	9,6	8,1
F2	Normal Usual	2	7,5	5,5
G2	Aggressive Usual	0	8,3	8,3

Table 3 captures the number of drivers who earned each badge. Drivers with the game features enabled, unlocked more achievements than users without the game features active. In addition, they are the only ones who were able to unlock the most complex achievement (unlock all the achievements of the game).

Table 3. Unlocked achievements by drivers

Badget	Game disabled	Game enabled
Obtain 5 points	3 Drivers	7 Drivers
Obtain 7 points	3 Drivers	7 Drivers
Obtain 10 points	0 Drivers	1 Drivers
Complete a lap without decelerating sharply	4 Drivers	5 Drivers
Complete a lap without decelerating sharply over 0.5% of the trip time	6 Drivers	7 Drivers
Complete a lap without accelerating sharply over 1 % of the trip time	2 Drivers	5 Drivers
Complete a lap without accelerating sharply over 2 % of the trip time	6 Drivers	7 Drivers
Complete a lap with a standard deviation less than 2	2 Drivers	6 Drivers
PKI Value over 0.30	0 Drivers	4 Drivers
Average Fuel Consumption equal or less than the value approved by the manufacturer adding 0.2 l/100 Km	1 Drivers	2 Drivers
Unlock all achievements	0 Drivers	1 Drivers

Figure 1 and figure 2 capture the score and the fuel consumption obtained by four drivers while they were using the eco-driving assistant in order to analyse the progression on the learning of eco-driving rules using the proposed method. Two drivers have a normal profile, and the other two have an aggressive profile. These drivers drove in the same route under similar traffic and weather conditions. This route has urban road and highway. Moreover, these tests were performed at 8 A.M. The vehicle was a Citroen Xara Picasso when the game is disabled, and a Ford Fusion 1.4 HDI when the game is enabled.

Figure 1 shows that in the case of drivers with aggressive profile, users slightly improved their driving style when using only the eco-driving advice. However, after an initial improvement, they returned to their previous bad driving habits. On the other hand, when the eco-driving game feature is enabled, aggressive drivers maintain a more optimal driving pattern over the time compared to their initial driving style. Drivers with normal profile also optimized their driving style. The improvement obtained is higher with the game features active.

In figure 2, we can observe that the aggressive driver improves fuel consumption after he has used the eco-driving assistant around 12 times. He even gets, after the initial training, a fuel consumption level similar to that obtained by the normal driver (tests 12-26). However, after this initial improvement, the driver returns to demand the same fuel consumption than in the past. Drivers with normal profile maintained the improvement in fuel consumption over the time.

In the second case (eco-driving game feature enabled), aggressive drivers maintained the improvement in fuel consumption over the time and achieved to save up to 0.9 L/100 Km. Normal drivers decreased up to 0.69 L/100 Km (a lower value than aggressive drivers since they were driving more efficiently and therefore they could not significantly reduce their fuel consumption).

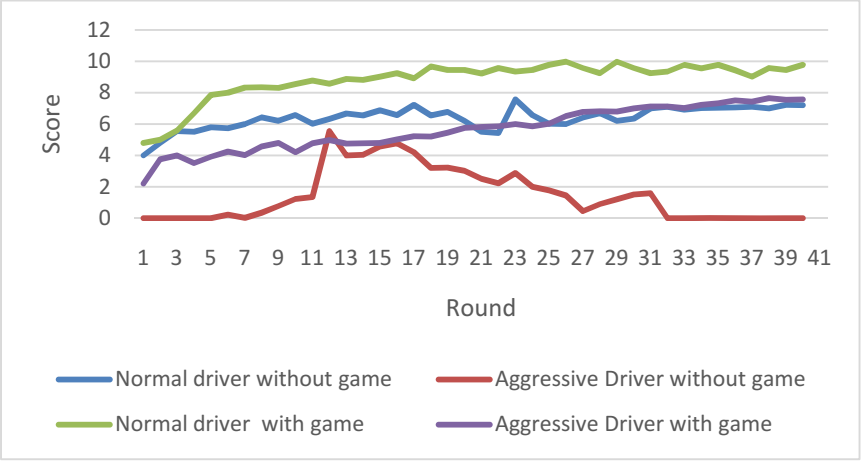

Fig. 1. Evolution of user score

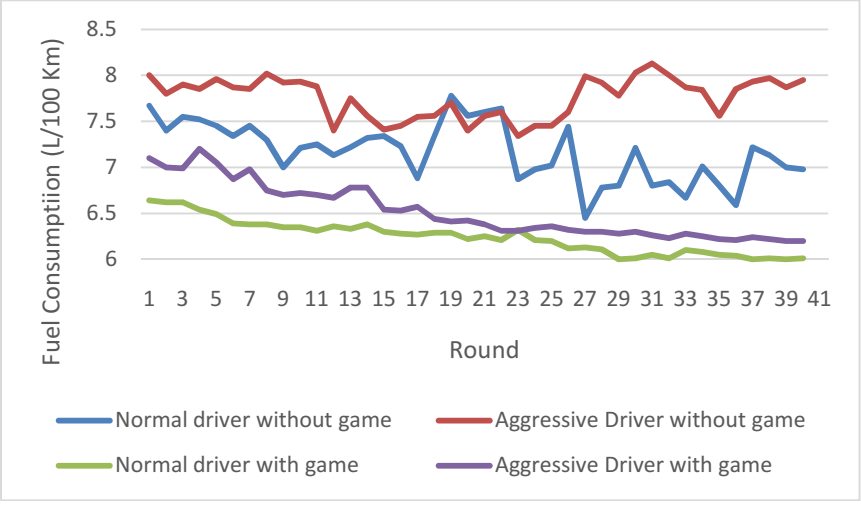

Fig. 2. Evolution of fuel consumption

4 Conclusions

This paper analyses the suitability of using gamification principles to encourage the user to drive efficiently and validates the impacts on fuel consumption obtained when

using an eco-driving assistant that, based on the observation of a driver's driving style and comparing it with widely accepted eco-driving rules, proposes recommendations to reduce fuel consumption. The results show that drivers with normal profiles do not need extra motivation to drive efficiently. The eco-driving advice given by the eco-driving assistant are enough to observe an important improvement in their driving style from the point of view of energy efficiency. However, when we use a method to encourage and motivate the drivers such as gamification, drivers tend to improve their driving style even more. Drivers with an aggressive profile fail to improve their fuel consumption and driving style, even if using eco-driving assistants, when not having a motivational reason. During testing, we have seen only a slight improvement during a limited period of time when aggressive drivers use our eco-driving assistant. Moreover, aggressive drivers return to previous bad driving styles after using the assistant. In this case, adding gamification techniques to our eco-driving assistant turned out very useful.

As future work, we want to assess the effects of applying different incentives in the motivation of the driver. The key to the success of the gamification is to identify what incentive is most important for each type of user. For example, on the eco-driving topic, the incentive can be monetary, ecological or safety.

Acknowledgments. The research leading to these results has received funding from the ARTEMISA project TIN2009-14378-C02-02 within the Spanish "Plan Nacional de I+D+I and from the IRENE (PT-2012-1036-370000), COMINN (IPT-2012-0883-430000) and REMEDISS (IPT-2012-0882-430000) projects all funded by the Spanish MINECO Ministry.

References

1. Ericsson, E., Larsson, H., Brundell-Freij, K.: Optimizing route choice for lowest fuel consumption – Potential effects of a new driver support tool. Transportation Research Part C: Emerging Technologies 14(6), 369–383 (2006) ISSN 0968-090X, http://dx.doi.org/10.1016/j.trc.2006.10.001
2. Statistical Office of the European Communities, http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/ (last access February 2013)
3. Barbé, J., Boy, G.: On-board system design to optimize energy management. In: Proceedings of the European Annual Conference on Human Decision-Making and Manual Control (EAM 2006), Valenciennes, France, September 27-29 (2006)
4. Koskinen, O.H.: Improving vehicle fuel economy and reducing emissions by driving technique. In: Proceedings of the15th ITS World Congress, New York, November 15-20 (2008)
5. Erenli, K.: The impact of gamification: A recommendation of scenarios for education. In: 2012 15th International Conference on Interactive Collaborative Learning (ICL), September 26-28, pp. 1–8 (2012), doi:10.1109/ICL.2012.6402106
6. Berengueres, J., Alsuwairi, F., Zaki, N., Ng, T.: Emo-bin: How to recycle more by using emoticons. In: 2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI), March 3-6, pp. 397–397 (2013)
7. Law, F.L., Mohd Kasirun, Z., Gan, C.K.: Gamification towards sustainable mobile application. In: 2011 5th Malaysian Conference in Software Engineering (MySEC), December 13-14, pp. 349–353 (2011), doi:10.1109/MySEC.2011.6140696
8. Godavarty, R., et al.: Interfacing to the on-board diagnostic system. In: 52nd Vehicular Technology Conference, IEEE VTS-Fall VTC 2000, vol. 4, pp. 2000–2004 (2000)
9. OBDLink Adapter, http://www.scantool.net/ (last access June 3, 2014)