Development of an Eco-Driving Simulation Training System with Natural and Haptic Interaction in Virtual Reality Environments

Konstantinos Gardelis, Aris S. Lalos and Konstantinos Moustakas
Department of Electrical and Computer Engineering, University of Patras, Greece

Keywords: Eco-Driving, Virtual Reality, Augmented Reality, Gamification, Unity, Simulator, Training.

Abstract: Road transport is one of the major causes of the environmental pollution. Among the actions individuals can take to reduce their green-house gases associated with personal transportation, there is to operate their current vehicles more efficiently. Behavioral theory strongly confirms that the most important educational element in changing driver behavior is the direct feedback while driving on an immediate and continuous basis. Gamification has been positioned as a powerful approach, tool, or set of techniques that guides targeted behavior change and improves the way that various activities are undertaken so that those involved begin to take the desired actions while they experience more fun, enjoyment, and pleasure in their tasks. Building on this direction, we present conceptual approach of an eco-driving simulation system that aims to train drivers to follow eco-driving rules simulating the augmented reality technology in virtual driving games. The proposed system provides: i) an efficient way to study the effect of AR games responsible for monitoring driving behavior and delivering action personalized plans that will help user to maintain a green driving style without distracting them from safe driving and ii) a multiplayer gaming environment where users can monitor the eco-driving score evolution, set missions and invite other to participate collaboratively or competitively.

1 INTRODUCTION

A recent study (Alessandrini et al., 2012) shows that road transport is responsible for about 30% on the total emissions of CO2 into the atmosphere. Among the actions individuals can take to reduce their greenhouse gases associated with personal transportation, there is to operate their current vehicles more efficiently (Barkenbus, 2010). In certain situations, the driver's driving style can result in differences in terms of fuel consumption (and therefore CO2 emissions) from 2 up to 35% between a calm driver and an aggressive one (Alessandrini et al., 2009)(Wengraf, 2012).It is crucial to educate drivers to adopt a driving style that is as eco-friendly as possible, in order to reduce the environmental impact caused by road transport. At this point, it should be also mentioned that numerous studies have underlined the substantial ecological (Mensing et al., 2014), economic but, also, road safety adverse benefits that can be derived from adopting eco-driving behaviors (Barkenbus, 2010)(Mundke et al., 2006).

As expected, a plethora of people motivated to further research the promotion of eco-driving. A way to educate drivers to improve their driving skills is by providing the necessary feedback about their driving style in real time. Eco-driving training programs have been implemented in numerous countries and they have proven extremely efficient from both ecological and financial aspect (Barić et al., 2013). But a crucial problem still persists. Multiple countries actually banned (Bell, 2013) the use of technological means, like head-up-displays, during driving due to the fear of driver's distraction (Strayer et al., 2011). There is strong evidence which indicates that the development of a simulation system is fundamental in order to confirm and prove the safety of usage of such systems in real life scenarios.

Our eco-driving simulation system aims to train drivers in the use of Augmented Reality applications during driving in a virtual environment with the help of gamification methods. Gamification is an umbrella term for the use of video game elements to improve user experience and user engagement in non-game services and applications (Deterding et al., 2011). Studies show positive results from adoption of gamification (Hamari et al., 2014). The results of this training method will be evaluated to answer scientific questions about its usability, efficiency and potential risks which the driver could face when driving a real

Gardelis, K., Lalos, A. and Moustakas, K.
Development of an Eco-Driving Simulation Training System with Natural and Haptic Interaction in Virtual Reality Environments.
DOI: 10.5220/0006619500940101
In *Proceedings of the 13th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2018) - Volume 2: HUCAPP*, pages 94-101
ISBN: 978-989-758-288-2
Copyright © 2018 by SCITEPRESS – Science and Technology Publications, Lda. All rights reserved

vehicle.

In fact, we refer to the design of two separate applications, a Virtual Reality one, which is a driving simulator system, and an Augmented Reality one that will be implemented in the non-real world of the first application, for research purposes. The implementation of the augmented reality application aims to improve driving behavior (i.e. reducing fuel consumption and atmospheric pollution by CO2 emissions).

Direct use of the Augmented Reality application while driving a real vehicle, without proper study and evaluation with real users, may cause even fatal accidents. In the driving process, disorienting the driver's attention or reducing visibility by displaying digital elements could be very dangerous. Poor interface and interaction design of such an application is very likely to lead to these results. To avoid such undesirable consequences, and ensure the safety of drivers and pedestrians, a simulation system is required.

The use of a driving simulator has many advantages over similar real-world driving research, including experimental control, efficiency, expense, safety, and ease of data collection (Alm and Nilsson, 1994) (Yan et al., 2008). The simulator experiments are possible to reproduce dangerous driving conditions and situations in safety. Therefore, driving simulators have a potential to analyze further certain events and explore effective countermeasures without endangering a human life.

In conclusion, with the use of such a simulator system for training in eco-driving behaviors the following benefits are expected:

- Significant reduction of fuel consumption and therefore CO2 emissions
- Decrease in accidents due to the embrace of a safer, less aggressive, driving style

This paper is structures as follows, in section 2 we give an overview of the existing eco-driving assisting systems, in section 3 we analyze the details of our approach and finally in section 4 we end with discussion, conclusion and future direction related to this topic.

2 RELATED WORK

The promotion of eco-driving is separated in two major categories. Eco-driving real-life applications and simulators. There are numerous approaches already available. The most representative are presented below:

2.1 Real-Life Applications

Smartphone Applications

Studies have shown that eco-driving smartphone applications have impact on fuel efficiency (Tulusan et al., 2012). Greenmeter (research & technology, 2008), FuelGood (Trust, 2016), TEXACARe (Texa, 2016) and Geco (Nouvelles, 2014) (Figure 1) are good examples of smartphone applications that have been developed in order to track fuel consumption and increase efficiency. Some of them works in real time since others provide a summary at the end of each journey. TEXACARe and Geco provide a score based on actions that have impact in fuel consumption and driver's behavior.

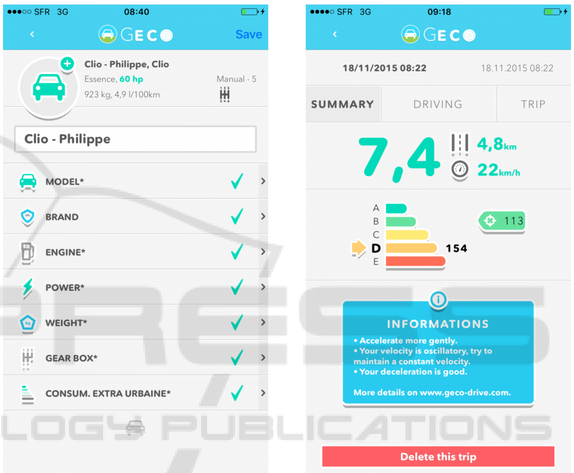


Figure 1: Screenshots of Geco - The eco driving guide. (from ifp Energies nouvelles, 2014).

Remote Control Solution

WeNow (WeNow, 2015) is a solution mainly aimed at vehicle fleets and aids them in increasing their overall fuel efficiency. The device of the platform is connected to the OBD II interface of the vehicle in order to be able to collect the relevant vehicle data such as mileage, fuel consumption, etc.

Advanced Driver-Assistance Systems

FIAT®eco:DRIVE APP (Fiat, 2014), Ford Smart Eco Driving (Ford, 2013), BMW Eco Pro (BMW, 2012), Honda®Insight Eco Assist system (Honda, 2017)(Figure 2), Nissan Eco-Drive Support Technology (Nissan,), Subaru Ecology (Subaru,) and Mitsubishi ECO Drive Support (Mitsubishi, 2013) are fully implemented systems. Some of them are based on apps that communicate directly with the car which purpose is to improve the driving style, lowering fuel consumption and tracking the carbon dioxide emissions. Others are build-in systems providing feedback in real-time for maximizing the fuel efficiency. Finally, one approach acts as a medium between driver's actions and car's engine inputs to avoid non-eco behaviors, although the system turns this functionality off in cases of emergency.

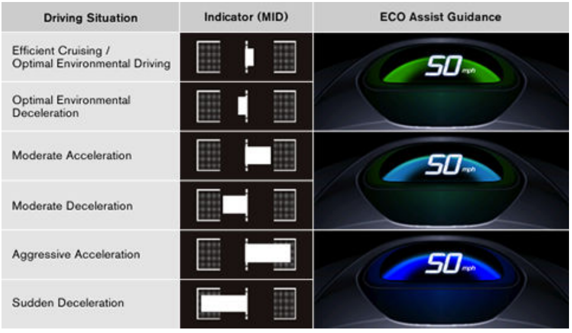


Figure 2: Honda®Insight Eco Assist driving style efficiency indication. (from Honda Motor Co., Ltd., 2010).

2.2 Simulators

The ST Software Simulator Systems Eco Driving Package (Systems, 2007) (Figure 3) teaches how to save up to 20 or 30% of fuel by applying an eco-friendly style of driving. DriveSim simulator (DriveSim, 2014), in the other hand, is a more realistic simulator which includes real traffic and pedestrians. This program offers the possibility of doing different tours with any climatic settings, timing and traction (e.i. driving at dusk, on slippery surfaces, snowy environments etc.). In this simulator, eco-driving is just an extra feature. Additional examples include an eco-driving simulation system which also focus on slowing the wear of car's consumables (Seung Yoel Kim, 2016), and Mcllroy *et al.'s* (McIlroy et al., 2017) experimental evaluation of an in-vehicle eco-driving support system that provided auditory, visual, and vibrotactile stimuli.

Figure 3: Screenshot of ST Software Simulator Systems Eco Driving Package. (from ST Software BV, 2007).

Games

EcoDriver (Eco-Drive, 2015) (Figure 4) is a mobile game which tests the players driving in an endless, randomly generated environment, in an attempt to demonstrate the advantages of driving safely, economically and in an environmentally friendly way to the player.

Figure 4: Screenshots of EcoDriver. (from Google Play Store, 2015).

3 SYSTEM DESCRIPTION

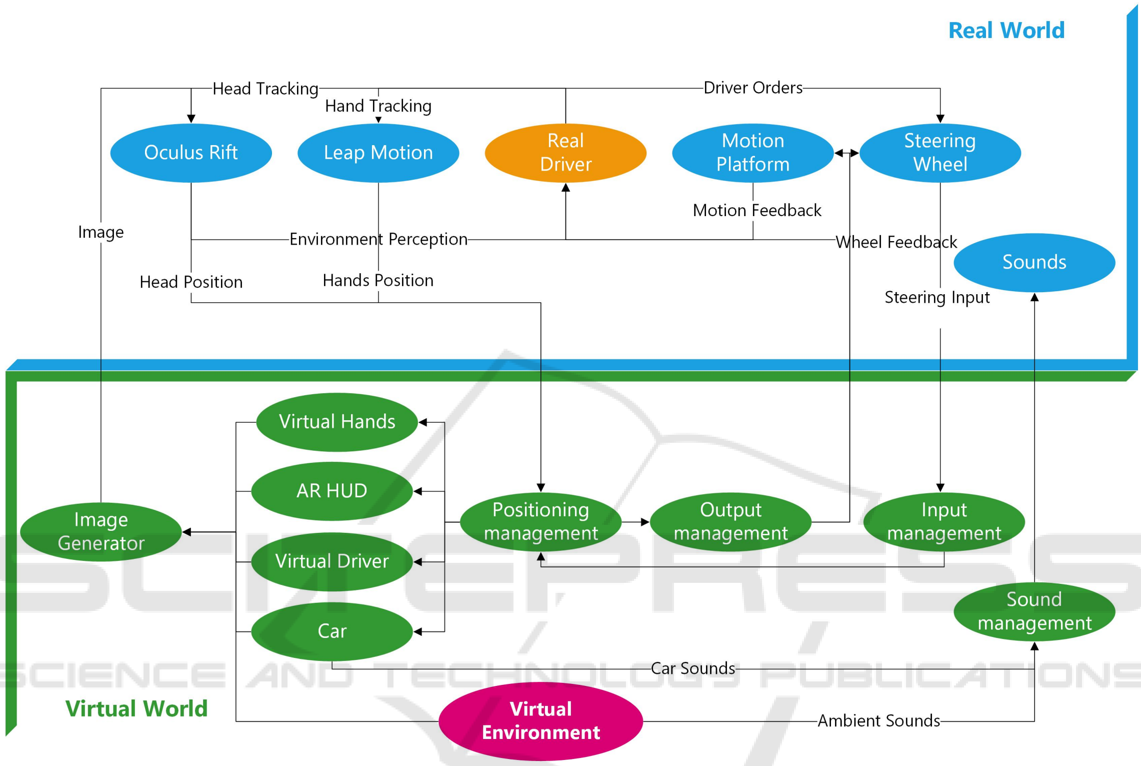
In this paper we propose conceptual approach of an eco-driving simulation system that will combine all the useful characteristics of the above-mentioned implementations. The development of a realistic driving simulator system which is focused on training drivers to improve their driving behavior via real-time feedback presented through an Augmented Reality HUD. All the crucial information will be presented within their field of view though a minimal design in a way that they will not get distracted. In Table 1 are the "golden rules" of eco-driving (as defined in ECOWILL project (eco, 2010)) that we used as a staring point of which information should be consider crucial. Furthermore, a summary of their performance will be available after the end of every session for self evaluation and recapitulation. In the near future plan, when the use of AR HUD while driving is permitted, we can use the gamification technique to encourage more and more people to become eco-friendly drivers.

3.1 Architecture

As can be seen in Figures 8 and 9, the simulator is a one-person simulator system including an adjustable seat mounted in a full motion platform, a steering

Table 1: The ”Golden Rules” of eco-driving.

Rule	**Instruction**
1. Shift up as soon as possible	Shift up between 2.000 and 2.500 revolutions per minute.
2. Maintain a steady speed	Use the highest gear possible and drive with low engine RPM.
3. Anticipate traffic flow	Look ahead as far as possible and anticipate the surrounding traffic.
4. Decelerate Smoothly	When you have to slow down or to stop, decelerate smoothly by releasing the accelerator in time, leaving the car in gear.



SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

Figure 5: Architecture Diagram.

wheel, a gear shifter, the clutch, gas and brake pedals. The player is immersed in the simulated environment by means of Oculus Rift and Leap Motion Sensor.

In the upper half, the real-world part, of Figure 5 we can see all the above-mentioned hardware and how each one interacts with the driver and software of the system. The driver is handling the steering wheel, shifter and pedals. This steering input is sent as a signal to the input management module of the program. The input management module is communicating with the positioning management module which is also getting input signals from Oculus Rift and Leap Motion sensor with head and hands position respectively. By having all the required data, positioning management can now update the position and rotation of all our active objects in the virtual world, the driver's virtual hands and body in order to get better immersion experience through absolute position matching of real and virtual world's objects. We also update the virtual AR HUD and car's position and rotation so we can continue to the image generator module where we render the image that will be projected in the Oculus Rift for the driver to get the virtual environment perception. The positioning management module is also communicating with the output management module which is responsible for the feedback that will be simulated to the driver through the motion platform and the steering wheel. The motion platform is following the car movement according with its speed and acceleration. On the other hand, the steering wheel is simulating the forces that are being applied to the car's tires from the road surface, the reinstatement of the wheel in its zero rotation position and possible conflicts with hard objects like walls, houses or other cars. Finally, we have the sound management module which is receiving environmental ambient sounds and the car's sound related to its rpm, current gear and tires' traction.

3.2 Gameplay

The simulator system has multiple different tracks with different difficulty levels based on track's length, inclination, sharp turns etc. For simplicity's sake, the gameplay will be explained using the easiest of the tracks. Due to its small size, the track is divided in only three segments (as seen in figure 6). The data kept from driver's performance will be independent in each segment, by doing this the provided results will be more accurate.

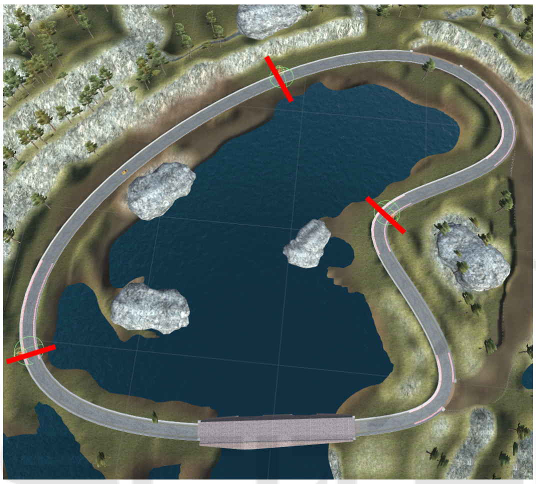


Figure 6: Track's partitions pointed with red lines.

The trainee driver is assigned to complete at least two consequent laps. In the first lap, the driver's performance will only be recorded in order to be analyzed and create a personalized driving profile. From the second lap and onward, the driver's current performance will be compared to the previous lap performance in the same track's segment providing real-time feedback on how the eco-driving behavior could be improved. Furthermore, to make eco-driving even more appealing to the public, we tried to gamify the training process by adding a ranking system. Every trainee will be ranked according with the evaluation of his performance, enabling him to compete with the other drivers alone or as a team by inviting his friends.

The real-time feedback will be provided via the AR HUD simulated system enabling the driver to self-evaluate instantly without being distracted due to the minimal layout that is being used. The presented eco-driving related data selected based on numerous studies such as (Andrieu and Saint Pierre, 2012) and are the following:

- Average Revolutions Per Minute (RPM) during gear ups
- Average RPM during gear downs
- Percentage of time when there is no input given to the car (throttle or brake) over the total driving time. (Engine Break)
- Cruising speed while having the highest gear engaged and relatively stable speed.
- Number of recorded sudden breaks
- Average car acceleration.

Except the eco-driving related data, there is also presented:

- Vehicle's current speed
- Vehicle's current RPM
- Vehicle's current gear
- Ranking table

As seen in Figure 7, the above-mentioned data seems to be projected at the car's windshield. The left image (a) shows the AR glasses that are virtually mounted in the driver's head. Through each lens is slightly visible the AR viewport for each eye. The right image (b) shows all the data that are being presented to the driver every moment. As referred previously, the data layout is designed in a way to not block the road visibility.

3.3 Prototype

Unity Game Engine used for the virtual world implementation of the prototype. For hardware, we used a steering wheel with shifter and pedal which were mounted on a motion platform. Then, using the special mount, we placed the Leap Motion sensor in the center of Oculus Rift to accurately detect the driver's hands. Finally, using a tripod, the Oculus Sensor was placed in front of the drive platform. A viable alternative tested was the use of 3D projector instead of Oculus Rift.

4 DISCUSSION & CONCLUSION

To conclude, our conceptual approach indicates positive results of the use of eco-driving simulation training systems in order to test projects which is still under development and its consequences are uncertain in real world cases. Though it is a beneficial solution, the use of such simulation systems is not without challenges and limitations, most notably that of realism gap due to the vast number of parameters that needs to be implemented. But there are still obstacles to overcome, even if the simulation system was flawless there are still lots of steps to be taken before the use of AR driver-assistance systems in real life, such

(a) (b)

Figure 7: (a)Viewport window of the AR glasses (b) All the AR data that are being projected in the windshield.

Figure 8: Leap motion sensor placed on Oculus Rift.

Figure 9: Right side view of the prototype.

as ethical issues like the ban of using technological means while driving. Additionally, AR HUD are not yet fully capable of coping tasks like that, the limited field of view and the low refresh rate are two examples of the functionalities need to be improved as soon as possible. Ultimately, the AR technology has a limited target group, people that have a driver's and they are in early adulthood since it is challenging for someone older to get used to cutting-edge technologies. On the other hand, the driving simulation system is a favorable way to teach teenagers how to drive using the AR drive-assistance system from the very beginning.

4.1 Future Direction

A basic attribute of good simulator systems is not only the simulated model of the vehicle but also the surrounding environment in which the model is moving. The key element is great detail and realism. With the addition of more parameters the system will be a better approximation of real-world cosmos that will lead us in a realistic fuel consumption metric, by using the Orfila *et al.* (Orfila et al., 2017) fuel consumption model. Moreover, the implementation of an Artificial Intelligence System is fundamental to control the other drivers' behaviors based on real drivers' reactions in unexpected events. The system will also control pedestrians accordingly. Therefore, we will be able to create controlled scenarios in order to study the driver's behavior. For example, a virtual child could suddenly appear in the middle of the road to check the driver's reaction. A comparative study can be carried out between driving using the augmented reality system and without using it. By gathering quantitative and qualitative data through such studies, we can expect results on how much the use of the augmented reality system affects the reaction time of each driver. In conclusion, the purpose of our studies is to result in solutions that will ensure the safety of pedestrians and drivers while using the AR system. For example, the use of a warning indication in the augmented reality system could alert the driver of an upcoming unexpected danger. These indications should be designed and evaluated, with corresponding experiments.

The AR driver-assistance systems are still an uncharted area, with results that do not yet have implementations in commercial level. In our days, the only limitation on applications that can be developed in this field is the limits of human imagination. Bearing this in mind, high priority in our list of future extensions has the modification of the present system into

SCIENCE AND TECHNOLOGY PUBLICATIONS

(a) (b) (c) (d)

Figure 10: GameCar Mobile Application Mockups (a) Main Menu (b) Boosts (c) Race Preparation (d) DrivingLog.

a platform where any developer will be able to develop and test such applications in our simulator before testing it real-world conditions. By building a driving simulator to be used as a testing base for AR applications, the developing time will be improved due to the decrease of evaluation and testing time which will lead in higher quality results.

Finally, we are already working on making more appealing the whole idea of eco-driving to the public by gamifying the training process. By using an OBD II Scanner the drivers will be evaluated while driving and through a rewarding system they would be able to redeem their rewards in a driving management simulation game that will be available all platforms. In Figure 10 are presented the game's mockups. The driver will collect coins, points and boosts according to his real-world driving sessions with which he will improve his in-game driver skills and car parts. Improvement of statistics will help him to climb the ranking ladder and emerge as an example in the eco-friendly driving community.

4.2 Conclusion

Current self-management systems related to eco-driving, despite their complexity and sophisticated nature, are practically proven inefficient, since they do not take into account a mixture of complex characteristics including age, sex, social status, financial status, physiological measurements, driving behavior measurements and vehicle characteristics. The proposed simulator is designed to fill this commitment gap by introducing an innovative and interactive Serious game that guide targeted Driving behavior changes to improve the way that various eco-driving activities are undertaken so that the drivers involved will be educated to take the desired actions and more importantly will be familiar with AR displays and applications while driving.

ACKNOWLEDGMENTS

This work has been supported by the H2020-ICT-24-2016 IA project GamECAR (Grant No. 732068).

REFERENCES

(2010). Ecodriving - widespread implementation for learners and licensed drivers (ecowill). https://ec.europa.eu/energy/intelligent/projects/en/projects/ecowill.

Alessandrini, A., Cattivera, A., Filippi, F., and Ortenzi, F. (2012). Driving style influence on car co2 emissions. In *2012 International Emission Inventory Conference*.

Alessandrini, A., Orecchini, F., Ortenzi, F., and Campbell, F. V. (2009). Drive-style emissions testing on the latest two honda hybrid technologies. *European Transport Research Review*, 1(2):57–66.

Alm, H. and Nilsson, L. (1994). Changes in driver behaviour as a function of handsfree mobile phonesa simulator study. *Accident Analysis & Prevention*, 26(4):441–451.

Andrieu, C. and Saint Pierre, G. (2012). Using statistical models to characterize eco-driving style with an aggregated indicator. ifsstar. In *2012 Intelligent Vehicles Symposium, Spain*.

Barić, D., Zovak, G., and Periša, M. (2013). Effects of eco-drive education on the reduction of fuel consumption and co2 emissions. *PROMET-Traffic&Transportation*, 25(3):265–272.

Barkenbus, J. N. (2010). Eco-driving: An overlooked climate change initiative. *Energy Policy*, 38(2):762–769.

Bell, L. (2013). Google glass probed by six more countries amid mounting privacy fears. https://goo.gl/25kX2z.

BMW (2012). Eco pro. http://www.bmw.com.af/com/en/insights/technology/efficientdynamics/phase_1/measures_ecopro.html. [Online; accessed June-2017].

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., and Dixon, D. (2011). Gamification. using game-design elements in non-gaming contexts. In *CHI'11 extended abstracts on human factors in computing systems*, pages 2425–2428. ACM.

DriveSim (2014). Drivesim simulator. http://drivesimsimulator.com/en/. [Online; accessed July-2017].

Eco-Drive, Q. A. (2015). Ecodriver. http://www.play-ecodriver.ch/ en/. [Online; accessed June-2017].

Fiat (2014). eco:drive app. http://ecodrive.driveuconnect.eu/. [Online; accessed June-2017].

Ford (2013). Smart eco driving. https://ford.devpost.com/submissions/16640-smart-eco-driving. [Online; accessed July-2017].

Hamari, J., Koivisto, J., and Sarsa, H. (2014). Does gamification work?–a literature review of empirical studies on gamification. In *System Sciences (HICSS), 2014 47th Hawaii International Conference on*, pages 3025–3034. IEEE.

Honda (2017). Insight eco assist system. http://world.honda.com/INSIGHT/eco/. [Online; accessed July-2017].

McIlroy, R. C., Stanton, N. A., Godwin, L., and Wood, A. P. (2017). Encouraging eco-driving with visual, auditory, and vibrotactile stimuli. *IEEE Transactions on Human-Machine Systems*, 47(5):661–672.

Mensing, F., Bideaux, E., Trigui, R., Ribet, J., and Jeanneret, B. (2014). Eco-driving: An economic or ecologic driving style? *Transportation Research Part C: Emerging Technologies*, 38:110–121.

Mitsubishi (2013). Eco drive support. http://www.mitsubishi-motors.com/en/innovation/technology/library/eco_drive.html. [Online; accessed July-2017].

Mundke, R., Malewar, S., and Arya, K. (2006). Use of data recorder for driver rating. Technical report, SAE Technical Paper.

Nissan. Eco-drive support technology. http://www.nissan-global.com/EN/ENVIRONMENT/CAR/FUEL_COST/GASOLINE/. [Online; accessed June-2017].

Nouvelles, E. (2014). Geco. https://www.geco-drive.fr/. [Online; accessed July-2017].

Orfila, O., Salgueiredo, C. F., Saint Pierre, G., Sun, H., Li, Y., Gruyer, D., and Glaser, S. (2017). Fast computing and approximate fuel consumption modeling for internal combustion engine passenger cars. *Transportation Research Part D: Transport and Environment*, 50:14–25.

research & technology, H. (2008). Greenmeter. http://hunter.pairsite.com/greenmeter/. [Online; accessed July-2017].

Seung Yoel Kim, Y. S. K. (2016). A virtual driving simulator for eco-driving training.

Strayer, D. L., Watson, J. M., and Drews, F. A. (2011). 2 cognitive distraction while multitasking in the automobile. *Psychology of Learning and Motivation-Advances in Research and Theory*, 54:29.

Subaru. Ecology. http://www.subaru.com.mt/eco_driving.html. [Online; accessed July-2017].

Systems, S. S. S. (2007). Eco driving package. https://www.stsoftware.nl/. [Online; accessed June-2017].

Texa (2016). Texacare. https://texa.care/en-EN/functionality-apps.html. [Online; accessed June-2017].

Trust, E. S. (2016). Fuelgood. http://www.energysavingtrust.org.uk/scotland/businesses-organisations/transport/fuelgood-driver-training. [Online; accessed July-2017].

Tulusan, J., Staake, T., and Fleisch, E. (2012). Providing eco-driving feedback to corporate car drivers: what impact does a smartphone application have on their fuel efficiency? In *Proceedings of the 2012 ACM conference on ubiquitous computing*, pages 212–215. ACM.

Wengraf, I. (2012). Easy on the gas: The effectiveness of eco-driving. *Royal Automobile Club Foundation, Tech. Rep.*

WeNow (2015). https://www.wenow.com/. [Online; accessed July-2017].

Yan, X., Abdel-Aty, M., Radwan, E., Wang, X., and Chilakapati, P. (2008). Validating a driving simulator using surrogate safety measures. *Accident Analysis & Prevention*, 40(1):274–288.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS