GERICO: A HUMAN CENTRED ECO-DRIVING SYSTEM

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Abstract: This paper presents the evaluation of a new onboard system designed to reduce fuel consumption and CO₂ production. GERICO system enables the driver to adopt the best driving behaviour, smooth speed and good gear management. We carried out 80 tests (40 baselines, 20 with training and 20 with GERICO) with 40 drivers in the Toulouse area. The main results show that training contributes to a 12% consumption reduction whereas using the GERICO system contributes to a 16% consumption reduction. Drivers consider that the system is useful, functional and a good aid to fight against the bad habits and reduce fuel consumption. Copyright © 2007 IFAC

Keywords: User centred design, Driving behaviour, Human-Machine Interaction, Eco-driving, Fuel consumption, Pollution.

1. INTRODUCTION

Currently automotive pollution is becoming a challenge for car manufacturers. Greenhouse gas emissions are increasing at the same rate as the number of vehicles on the road. Therefore there is a need for pollution reduction; the Alliance of European Automobile Manufacturers programme has a target of 140g/km for 2008 and of 120g/km for 2012. Different solutions are possible to reduce pollution: vehicle technology (develop hybrid engine, hydrogen engine...), environment (adapt road infrastructure and regulation) or the driver via training or onboard systems to change driving behaviour. The GERICO project “Global EnRgy management and driver Interface for a Citizen Optimal driving behaviour” involved different partners: Siemens VDO Automotive was the project leader, the LEEI laboratory as System control and optimization experts, Eurisco International as HMI experts, the High Commercial school ESC as analysts of the Marketing Mobility, the City of Toulouse and the CETE-ZELT organization as Experimental Centre for real Tests, and the IERSET institute as Testing and communication coordinator, all located in Toulouse.

The goal of this project was to contribute to the reduction of fuel consumption and CO₂ production by optimising on-board energy and designing an appropriate interface that enables the driver to adopt the best driving behaviour, smooth speed and appropriate gear management. The two main problematics of the project were what are the type of data that the algorithm needs to take into account to optimise fuel consumption during a given trip? And how to provide appropriate information to the driver without increasing his/her workload, attention demand and cognitive interferences?

There are three interconnected levels proposed by Michon to define the driving task (Michon, 1979; Van der Molens and Böttinger, 1988): operational, tactical and strategical. The operational level corresponds to vehicle control and concerns very short-term actions (according to the Rasmussen terminology this level can be defined as skill-based). The tactical level corresponds to vehicle guidance and concerns short-term actions (rules-based). The strategical level corresponds to following an itinerary and concerns long-term actions (knowledge-based). The goal of the GERICO system is to change the driving activity and driver behaviour. Consequently, the driving task changes. The first impact of the system is on the operational level because the system provides information influencing directly the control of the vehicle (speed and gear advice) and consequently influences the other levels. It was important to consider these changes during the design process.

The social impact of this system is also important to consider. This system acts on the “driving style” and tries to change the driver’s habits. In this sense the motivation of the driver to use the system is important. For this reason, if the system utility could be demonstrated to contribute to the reduction of fuel consumption reduction, the usability and the acceptability of this type of system is crucial.

This paper presents a description of the GERICO system designed, the methodology used for the road tests and the main results obtained concerning driving performance and system usability.
2. GERICO SYSTEM

The GERICO system was developed using a user-centred design and a participatory design approach (Boy, 2003) to avoid human errors and/or dysfunction in the “Human-Machine coupling” (Amalberti, 1992, 1996). This system is composed of three modules and a specific interface with visual information and vocal information (fig. 1). The navigation and vehicle module was developed to send the navigation and vehicle data to the other modules. The optimisation module was developed to calculate the optimal driving pattern and the interaction control module to manage the information with respect to the road context.

2.1 Optimisation algorithm

A global optimisation algorithm takes into account the whole environmental data via the navigation system (road type, topology, traffic, meteorology), and internal data from on-board computers (e.g., fuel injection, engine speed, electrical consumption). The algorithm processes this data to provide the driver with an economic driving pattern available on a hybrid vehicle and adapted to a standard vehicle. The optimisation algorithm involves two criteria: consumption and time spent on the road. The method used is a global recursive optimisation (Sans, et al., 2005). This algorithm enables the reduction of fuel consumption by 10-25%, depending on the type of vehicle and driving behaviour.

2.2 Interface control system (ICS)

Optimised data are contextualised in order to make the driver aware of the most favourable situations and optimise his/her driving activity. We take into account internal (vehicle propriety) and external (environmental situations) contextual parameters. Information sent to the driver has to be useful and well synchronised with the car’s position and driving context. Even if we send the right information, the way it is delivered is as important as the information itself. The ICS algorithm was developed to provide the driver with visual information (optimal speed and gear instructions) and vocal messages with respect to road context in order to reduce cognitive interferences, risk and human errors (Barbé and Boy, 2006).

2.3 Interface system

Four types of information are proposed to the driver via the LCD (liquid crystal display) dashboard and vocal messages integrated in the vehicle (fig. 3): navigation, assistance, advice and warning.

Visual information. All visual informations were proposed via a new dashboard designed (fig. 4). The speed indicator was designed to provide the optimal speed. This indicator is represented by a green zone of 10 km/h inserted in a speedometer. The gear indicator provides the state of the gear. When the gear is optimal, the indicator is green. Otherwise, the indicator changes to red and indicates the action (+ to shift up; - to shift down). The visual warning was implemented to alert the driver when he/she does not respect the optimal speed, or optimal gear, or both. The consumption indicator shows consumption estimation during the trip depending on driving performance with respect to the optimal reference value. Guidance visual information and distance to the next event is presented at the centre of the dashboard to help the driver follow the predefined trip.
3. METHOD

80 tests were carried out on a GERICO-equipped car in the Toulouse area with 40 end-users. These tests correspond to 40 tests without the system (baseline); 20 tests with driver training and 20 tests using the system. These tests were first performed to validate the hypothesis that the GERICO system reduces fuel consumption and consequently pollution. We then verified that the system enables changes in driver’s behaviour without distraction and interference on the main driving task and that all information provided by the system was well understood by the driver. We also carried out tests on driver behaviour after training to compare the driving performance when using the automatic GERICO system. We analysed the driving performance and the usability of the system with different criteria. Five types of data were collected to carry out the evaluation: vehicle, video, system, questionnaire and interview.

3.1 Users selection

40 drivers were selected at Siemens VDO automotive in function of different criteria (age and driving experience) and using a specific questionnaire created to select the driver with a “normal driving behaviour”, in other words, to exclude the person with a “sportive driving profile” or an “economic driving profile”. After the first test (baseline), this group was separated by a random distribution of the drivers in two groups of 20 (G1: test with training and G2: test with system).

3.2 Road course

A course of 70 kilometres was selected in the Toulouse area. This course was composed by different road types (urban road, ring road, motorway and rural road) with different regulatory speed limits and different relief that can impact fuel consumption. The same course was used for each test at the same period of the day, the morning from 10 to 12 and the afternoon from 14 to 16, to have the same traffic conditions on the road.

3.3 Protocol

The baseline test without the GERICO system and training was carried out to analyse the driving behaviour and the consumption of each driver. The test with training was carried out to show the training impact on the driving behaviour and to compare with the results of the system. The test with GERICO was carried out to show the system impact on the driving behaviour and on the consumption reduction.

At the beginning of each test, the driver had to familiarise him/herself with the vehicle. This was important to reduce the influence of the vehicle on the driving performance. The vehicle was a Scenic Renault with an automatic gear box used in sequential mode. For the baseline test, after this familiarisation step, the driver carried out the test on the course with just the recommendation to respect the road code and the navigation advice. For the other tests, the driver was specifically trained to learn the principal procedures to apply for economic driving performance. This training was composed of a theoretical part and a road situation part. The recommendation to the driver was to apply the procedure learned during the course. For the test with the system the driver was trained to use the system with a user guide and on a driving simulator. The recommendation for this test was to drive without voluntarily going beyond the designated limits of the system in order to reduce excessive driving behaviour. At the end of each test an interview was carried out and a usability questionnaire was carried out for the test with the system. This questionnaire was created based on different heuristic criteria to evaluate the usability of the system.

4. RESULTS & DISCUSSION

Fig. 4. GERICO dashboard view

Auditory information. The auditory information was implemented in addition to the visual modality to provide information to the driver. This modality enables better information management to avoid excessive workload in visual perception that can generate disturbances at the level of the main driving task (Wickens and al. 1983). There are four types of auditory messages: navigation messages are correlated to the visual information to provide guidance to the driver. Advice messages indicate actions when the driver deviates from the optimum speed and gear advice (for examples: «Shift up » and « Slow down »). These messages are provided 4 seconds after the visual information. Assistance messages are implemented to assist the driver when events occur. (examples: «Be careful, give way to the right, adapt your speed » or «Be careful, city zone, drive softly »). In town, no advice is provided to the driver for safety reasons, the system only provides a warning message to alert the driver when the engine speed is too high (> 2500 rpm): «shift up » and when the speed is over the regulatory speed limits.
4.1 Driving performance analysis

The main criteria for the driving performance were based on speed profile and gear management, consumption and time spent during the trip.

Speed analysis. We observed that during the tests performed after training or performed using GERICO, drivers considerably reduce their speed (fig. 5), especially on the ring road and motorway. Speed variations between various types of tests are lower in urban zones since optimal speed corresponds to the regulatory limited speed.

Fig. 5. Speed profile

Gear analysis. For this analysis, it is important to specify that the vehicle used had an automatic gear box used in sequential mode with four gear positions. Results on gear management show that drivers shift-up the gear in a better way with training and with the system, e.g. earlier than the baseline test (fig. 6) especially for gear third and fourth.

Fig. 6. Distribution of gear management

Consumption analysis. Results show that training contributes to a 12% consumption reduction whereas using the GERICO system contributes to a 16% consumption reduction (fig. 7). In relation to the speed limit and consequently the road type, consumption reduction is different. Results show that consumption reduction is higher in the zones limited to 30 km/h, on rural roads limited to 70 km/h and on the motorway.

Fig. 7. Fuel consumption gain

Time analysis. The results show that the time loss remains limited comparing to the baseline test. The principal time loss was observed on the motorway and on the urban zone (fig. 8). The total shows 8 % and 11 % of time increasing respectively for training and system comparing to the baseline test.

Fig. 8. Time loss during the trip

4.2 Usability analysis

System usability was analysed, based on questionnaires, interviews and different variables recorded on the GERICO system: number and type of messages sent during the trip, number of driver errors, interval of time to return to optimal driving behaviour and driver glances deviation.

Errors analysis. We observed that the highest number of errors (speed, gear, or both) occur in town. The duration of the errors was estimated at around 4 seconds in relation to the design-induced delivery time of the message (Table. 1).

Table 1 Errors analysis

<table>
<thead>
<tr>
<th>Regulator speed</th>
<th>Number of errors</th>
<th>Number of errors per kilometre</th>
<th>Number of kilometres in error situations</th>
<th>Average duration of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>87</td>
<td>1.9</td>
<td>6.7 km</td>
<td>7.1 s</td>
</tr>
<tr>
<td>50 km/h</td>
<td>345</td>
<td>0.7</td>
<td>19.5 km</td>
<td>3.7 s</td>
</tr>
<tr>
<td>70 km/h</td>
<td>157</td>
<td>1.6</td>
<td>7.6 km</td>
<td>2.8 s</td>
</tr>
<tr>
<td>90 km/h</td>
<td>160</td>
<td>1.3</td>
<td>11.2 km</td>
<td>4.5 s</td>
</tr>
<tr>
<td>110 km/h</td>
<td>87</td>
<td>0.3</td>
<td>5.9 km</td>
<td>3.3 s</td>
</tr>
<tr>
<td>130 km/h</td>
<td>61</td>
<td>0.2</td>
<td>4.9 km</td>
<td>3.2 s</td>
</tr>
</tbody>
</table>

Total 897 0.7 57.6 km 4.0 s

Auditory analysis. 412 auditory messages were diffused during the course. Both messages « Slow
down » and « Shift up » are the most delivered (fig. 9). This result was expected because speed decrease and gear increase correspond to best driving activity to reduce fuel consumption.

Fig. 9. Distribution of auditory messages

However, we can see (fig. 10) that the number of speed related messages is higher (51%) in town (50 km/h) and in a zone limited at 30 km/h (27%). This result is related to the difficulty of the driver to respect the regulatory low speed limit in usual cases.

Fig. 10. Distribution of « slow down » message

The results concerning the Shift up messages (fig. 11) show that this type of message can occurs in different situation with a repartition between the road at 50, 70, 90 and 110 km/h.

Fig. 11. Distribution of « shift up » message

Glance analysis. We observed a glance deviation increase on the dashboard when GERICO was used (fig. 12). These glance deviations are necessary for the driver to correctly take into account GERICO advices. The driving zones analysis show that the driver looks at the dashboard in the urban zone because the system provides only regulatory speed limit information and when the engine is too high (>2500 rpm) to avoid disturbing the driving activity. In the other zones, the driver has more time to take into account the information delivered by the system. Consequently, the number of glance deviations increase.

Fig. 12. Glance deviations analysis (Z1: Ring road, Z2: Urban road, Z3: Rural road and Z4: Motorway)

Questionnaire and Interview analysis. The main results of the usability questionnaire show that the graphic interface was appreciated and functional especially the optimal speed advice (green zone) inserted in the speedometer. The gear instructions and the fuel consumption estimator were useful. The auditory messages were clearly understood but the frequency was considered too high and uncomfortable by the drivers.

50% of the drivers believed to adopt an economic driving during the tests without training and GERICO. However, the results of the driving performance analysis showed that 100% of the driver reduces their consumption during the test with the training and the system. These results show the utility to train or assist the driver to improve their driving behaviour to reduce their fuel consumption. 100% of trained drivers thought that training is useful and necessary to act on automotive pollution. 85% of these drivers thought to have realised an economic driving performance and changed their “driving style” during the test.

All the drivers consider the GERICO system, as useful, functional, a good aid and like a possible training tool to adopt an economic driving pattern. For 85% it was easy to use the interface while driving and 75% thought adopted a good driving behaviour. Other drivers considered that it was not very easy to use the system while driving in specific situation because sometimes advices were not totally in respect with the driving situation. However, 40% found a little visual and auditory overload of the system due to combined messages of navigation and advices. This result shows that the system is little intrusive on the main driving task and the comfort of the drivers. Finally, 40% of drivers would use such a system, 40% said yes but with a reduction of the auditory messages and 20% not.

To conclude, the questionnaire and interview show that the main difficulties generated by the use of the system were essentially on the intrusion of auditory messages and frustration to drive at relatively low speeds. However, results show that a majority of GERICO users consider that this change of driving
behaviour is necessary to fight against automobile pollution and the bad habits of drivers.

5. CONCLUSION & PERSPECTIVE

We observed various advantages related to the use of the GERICO system. In particular, information available to the driver is increasing, there is assistance in the decision-making and an increase in road safety related to the respect of the regulatory speed limits and the assistance messages. Moreover, GERICO allows a reduction in consumption, cost and pollution. However, it is important to continue this research effort to decrease the possible dangerous effects, i.e. an exaggerated trust in the system may generate errors in particular when information is not well contextualised with respect to road situations. A possible reduction of driver’s vigilance, a perceptive and auditory overload disturbing driver comfort may then induce stress and human errors.

The training was very useful to the drivers and appeared as a possible solution to fight against automotive pollution. The driver’s training is necessary to educate the driver behaviours to adopt a driving style that can reduce fuel consumption and pollution. Currently, the improvement of the driving style is an effort required on behalf of the drivers. However, if the training is particularly adapted for the new driver, who do not have a bad driving style and bad habits, it is more difficult for the older drivers. It is necessary for that to set up information campaigns in particular to keep in a durable way the beneficial effects of the training. The development of this type of system can be useful and a good aid for the driver to change their driving behaviour.

The next step of this study will consist in adapting GERICO on peripheral mobile devices available on all types of vehicles. Thus it will be important to consider again the Human-Machine interaction in order to improve the safety, the comfort and the performance of the driver when he/she uses such systems. The evolution of this system could be an automation of main functionalities in particular the gear management to decrease the workload of the driver. Thus, it is necessary to clearly understand procedures and cognitive functions allowed by the driver in the driving situations. Cognitive function analysis should allow the design of new safe automated systems to fight against the pollution.

REFERENCES


n° 7 (Le pilote, l’automatisation et l’ingénieur), pp. 7-16.