CarCOACH: A Driving Tutor for the Road

ABSTRACT

This paper describes the design and evaluation on the road of a context aware driving advisor designed to promote better driving behavior. CarCOACH uses the blackboard architecture to implement conflict resolution to appropriately comment on driving. It takes the information gathered from various sensors in the car and identifies common driving mistakes (such as, turning without blinking, erratic steering, accelerating and breaking abruptly). Monitored information includes brake pressure, RPM, speed, steering wheel position, etc. The system presents scheduled feedback controlled in terms of quantity of total feedback and feedback with regards to a specific stimulus, and driver current state. Its goal is to reduce driver's stress while maximizing the effectiveness of the feedback presented.

Author Keywords

Context-Aware computing, COACH, Driving tutor.

ACM Classification Keywords

H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

INTRODUCTION

We all have learned to drive well enough to pass tests and keep out of accidents, but we don't always apply all of our skills to the daily task of driving. Most driving safety approaches attempt to assist people. Radars make us not have to turn to look and cameras might even drive the car. Such devices are some examples of the assistive direction many manufacturers are taking. In contrast, the COACH approach provides feedback and advises people based on their performance to enhance their understanding and skills [7]. The high levels of computerization in cars allow us to monitor several aspects of vehicle activity with few modifications. Black boxes are already available that allow parents to track where the car has been and its driving conditions [6]. Rather than just being a logging tool CarCOACH uses sensors together with models of driving behavior to monitor driving successes and mistakes. It uses these models to predict cosntructive times to intrude and present feedback, reminding people to drive their appropriately. CarCOACH is oriented towards driving schools where timely and appropriate feedback helps retain newly learned behaviors. Support and warning systems have been developed to assist un-educated drivers [2]. These systems suggest that technological solutions can provide feedback on driving ability, warn about dangers, and ultimately improve driving performance [3] [5].
CarCOACH is a persuasive system that presents "just-in-time" [1] context-sensitive feedback to users with the goal of reminding users of appropriate driving techniques and promote behavior changes regarding driving habits. CarCOACH is a car-integrated computerized agent designed to give the driver timely and appropriate feedback on his driving performance. CarCOACH presents direct feedback using non-obtrusive interaction modalities in the form of subtle tactile and auditory reminders. These modalities were selected because they allow the system to present information without interfering with the user's task at hand. A message plays when the user performs a correct driving maneuver. When a mistake is made by the driver, a warning is presented. Positive and negative reminders refer to messages presented by a female voice saying "thank you for signaling", "please signal", and so on. Tactile reminders are associated with the surfaces that control the action being commented on. Tactile feedback includes steering wheel, brake and acceleration pedals vibration.

CarCOACH monitors information from sensors in the car (RPM, speed, throttle position, brake pressure/position, steering position angle, cup holder state, and on-board system status) and makes decisions about informing the driver of mistakes or correct driving. CarCOACH is able to identify common driving behaviors, as well as good and bad driving conditions, such as excessive braking force, extreme acceleration, turning without signaling, driving erratically, and turning speed.

CarCOACH's design is based on behavioral modification theories. Application of persuasive theories to user interface design for ubiquitous computing has been shown to be very effective at generating sustainable changes in behavior [1]. Prompts are an effective technique to encourage sustainable behavior because they remind people of actions that they are predisposed to do. Computer technologies now make it possible to deliver reminders and prompts right at the point of behavior in response to user activities. The point of behavior for driving cars is the car itself: People driving on the road and performing common driving tasks. CarCOACH was developed on the 300M IT-Edition, a concept car built through collaboration with Chrysler. It is an instrumented research vehicle equipped with many additional driver monitoring sensors, data loggers, and network capabilities [8]. Simulators are often found not to provide a vivid experience as compared to real driving conditions [2]. The use of a real car allowed evaluation in a natural setting.

IMPLEMENTATION

CarcCoach is designed so that it does not distract the driver visually or with sounds. It is possible to switch it off without affecting the control of the car. And a system failure does not result in unsafe driving conditions.

Hardware Architecture

The purpose of the data analysis and feedback system of CarCOACH is to take the information gathered from various sensors in the car and make decisions about informing the driver of mistakes and/or correct driving. An embedded Ethernet controller solution provides sensor data streamed out over the network. Individual boards perform signal and distributed data processing. A low cost, master-less, and single-level bus vehicle communications network interface (SAE J1850) monitors RPM, speed, throttle position, and on-board system status. Additional monitored information includes brake pressure/position, steering position angle, and cup holder sensor. The system architecture supports wireless 802.11b to separate the computers used to collect and interpret received sensor data.

Software Architecture

Data analysis and feedback in CarCOACH are based on the blackboard architecture [4]. Agents in the system monitor sensors measuring the acceleration, braking, turn signal use, turn speed, and how erratic the driver's steering is. These agents normalize the data they collect to fall within the same range for ease of analysis. Further, the data is normalized in such a way that a greater magnitude (negative numbers may be used, so zero is the smallest value) indicates absolutely a greater current significance to the system than any other agent whose data normalizes to a smaller value. For example, if the acceleration agent produces the largest normalized data of all agents, then the acceleration agent is the most significant agent in the system at the moment. Data normalized this way is called an attention score, since it directly represents the amount of attention an agent, and hence an aspect of driving, currently requires. The central mediator continually queries the attention scores of the agents, and when agents or combinations of agents possess an attention score above a certain threshold, the mediator determines that a situation has arisen demanding a corresponding feedback to be given.

When the mediator determines that a form of feedback is required, however, it does not immediately provide that feedback. It first consults with a scheduler, which is responsible for ensuring that drivers do not experience sensory overload and are not given feedback in a dangerous situation or while they might be busy. Feedback need not always be given to the driver for every stimulus, as this would quickly become cumbersome and overbearing for the driver. So, to prevent sensory overload, the scheduler examines the total quantity of feedback with respect to time and the quantity of feedback from a specific stimulus with respect to time given to the driver. To ensure feedback is not given in a dangerous situation, the scheduler examines the attention scores of the agents, and if they are so high that the driver might be in a dangerous situation, such as very high braking and turning speed scores, potentially indicating a skid, the scheduler may alter the timing of feedback. If the scheduler determines that immediate feedback may cause sensory overload or that the current situation is too dangerous, it may delay or cancel the feedback.

FEEDBACK GENERATION AND SCHEDULING

A description of the architecture serves to enlighten the technical details of CarCOACH, and some sample hypothetical scenarios help to show how it behaves in real-world situations.

In the normal course of driving, when the driver is driving within normal parameters, the system provides no feedback. However, suppose that the driver suddenly presses the brake pedal too hard. The agent monitoring the break pedal, which monitors the pressure applied on the brake, increases its attention score in concert with the increase in brake pressure to a level above the threshold for needing attention, telling the central mediator that the brake has been pressed hard. Assuming no other agents increase their attention scores, the mediator then decides that the brake being pressed too hard is the major problem, and interacts with the scheduler to arrange for feedback to be given. If the driver has not been given too much feedback about braking or overall lately, and the situation is not dangerous, then the driver receives feedback.

However, suppose the driver has been making a lot of mistakes lately and been receiving a lot of feedback. To reduce the likelihood of cognitive overhaul and frustration with the system, the scheduler may postpone or cancel feedback. Feedback is rarely postponed due to this reason, as by the time the fears of cognitive overload have past, the driving situation is changed. Only when two separate events requiring feedback occur within seconds of each other, such as rapid acceleration followed by braking, is the feedback postponed, since the driver will hear the audio feedback nearly sequentially and easily be able to connect his actions with the feedback received. Otherwise, as is usually the case, the feedback is canceled to prevent confusion with what exact the feedback concerns.

In another situation, the mediator may decide feedback is warranted, but consultation with the scheduler shows that immediate feedback may be dangerous. For example, the driver may have pressed the brakes so hard he is in a skid and therefore immediate feedback may only prove distracting. To assess the danger level of situations, the scheduler examines the attention level of the agents, and also factors in other characteristics such as driving speed steering wheel position. If speed is very high and the agent monitoring the brake pressure has a very high attention score, then the situation is very dangerous, more dangerous than if the speed were very low and the brake pressure very high. Likewise, a sharp angle on the steering wheel combined with a high attention score from the agent monitoring the acceleration of the car may also be dangerous. If these or other similar dangerous scenarios are the case, then the scheduler will not allow any feedback to be given to the driver until the system is no longer dangerous.

The scheduler also ensures that no feedback is given to the driver while he or she might be unusually busy with a particular task not generally performed while driving on the road. For example, a sensor indicates if the car is in reverse, then the scheduler delays or cancels all feedback, because the driver is looking behind the car and probably concentrating more than usual. Another sensor in the cup holder of the car senses if an object which was in the cup holder has been removed. If so, the scheduler assumes the object was some sort of drink, and delays or cancels all feedback until the object is replaced in the cup holder. If the object is not returned within thirty seconds, the scheduler assumes the object has been discarded and no longer considers the driver to be busy with it. The cup holder of course assumes the driver does not trick it into believing he has a cup when he doesn't, or vice versa, and drivers attempting to gain benefit from CarCOACH will not do so.

A final situation CarCOACH may be involved in is a dramatic event such as an accident. As the accident is happening, CarCOACH will continue to provide feedback in an effort to prevent the accident if the scheduler does not believe the situation is too dangerous. However, if the situation is too dangerous and the accident cannot be avoided, no feedback will be given because the driver has enough to concentrate on in trying to avoid or prepare for the accident.

EVALUATION

The primary goal was to test whether CarCOACH had beneficial effects on driver's performance. An exploratory experiment examined how effective CarCOACH is at improving driver performance when compared to continuous feedback and no feedback at all. The experiment also examined (user acceptance) how users would react to a systems presents feedback politely while providing feedback on the road.

An experiment was conducted to examine the effects of feedback type and scheduling schemes on driving performance and elicited frustration. An exploratory experiment examined the interaction between type of feedback presented and its schedule in composite variables for performance and frustration.

METHOD

Eighteen volunteers were compensated for participating in the experiment (9 women and 9 men, ages 20-32). Subjects were randomly assigned to a positive feedback or negative feedback conditions. Positive feedback thanked and acknowledged the driver after performing a proper driving maneuver whereas negative feedback pointed out mistakes while driving. Feedback was presented according to three feedback schemes: no feedback, continuous feedback and CarCOACH scheduled feedback. The order of presentation was counterbalanced on across the three parts of the trial.

Dependent variables for performance (driving score and driving on target) and frustration (self-reported frustration, and anxiety state) were collected. Frustration was measured using a modified version of the NASA Load Index NASA-TLX. Anxiety level was measured using the State-Trait Anxiety Inventory STAI.

PROCEDURE

Before the experiment, subjects performed a test drive in a low traffic neighborhood to acquaint users with the driving characteristics of the car. Subjects drove for at least 15 minutes until they felt confident handling the car. The experimental sessions were performed from 10:am to 3:pm in order to control for rush hour. Similar weather conditions were also controlled. During the test drive, the system collected performance data in order to calibrate the feedback presented by the system at later stages. After the practice session, subjects drove on a predefined route for about 20 minutes. Once this session finished, subjects filled two questionnaires. One of them tested their self-reported frustration and the second tested their anxiety state. For the second part of the trial, subjects continued to drive and were presented with another set of NASA-TLX and STAI questionnaires. Subjects resumed driving through the predefined route and were presented with a final set of questionnaires after finishing the route.

RESULTS

A 2 (feedback) X 3 (schedule) mixed multivariate analysis MANCOVA was performed on two measures of users' anxiety: STAI score and reported frustration (with pre-test scores serving as covariates). The analysis yielded a significant main effect for feedback type and schedule and a significant feedback by schedule interaction F(2,13)=15.4) p<.001 (eta^2=.703). Evaluation of the interaction for the two DVs with an adjusted alpha level to compensate for inflated type I error showed that only the interaction effect for frustration was significant F(1,14)= 25.4 p<.0001 (eta^2=.645). For STAI F(1,14)=.710 p=.4 (eta^2=.048). The interaction indicates that the effect of feedback on frustration depends on the type of schedule used. Positive feedback reduced frustration levels when presented continuously and scheduled. Negative feedback increased frustration levels; more so, when presented continuously

Two univariate 2 (feedback) X 3 (schedule) mixed ANOVAs were performed on dependent variables for performance: driving score, good driving,. The alpha levels was adjusted to control for type I error with the bonferroni correction for multiple comparisons α/5; α = .01. This adjustment had an impact on power, reducing the expected power from .64 to .38, increasing the possibility of type II error.

Obtained F-values were evaluated based on adjusted degrees of freedom using the Geisser-Greenhouse correction. The univiariate analysis yielded a significant main effect for feedback on driving score F(1,15)=14.9 p<.001 and a significant feedback by schedule interaction F(1,15)=21.9 p<.001 (eta^2=.59). The significant interaction between feedback and schedule precedes the main effect. The significant interaction indicates feedback schedule has an effect on performance dependent on the type of feedback used. Significant effects are described including the main effects and interaction for ease of interpretation. Negative feedback decreased performance slightly when using scheduled feedback and decreased it even further when presented continuously F(1,7)=.391 p=.55. On the other hand, positive feedback doesn't have an effect on performance when scheduled, but increases performance when presented continuously F(1,7)=15.45. p<.05

The results indicate that positive feedback increases performance when presented continuously while producing low frustration levels on drivers. If used on a scheduled basis, positive feedback doesn't have any effect on performance or frustration.

Negative feedback proved to be the worst by decreasing performance significantly when presented continuously while eliciting high frustration levels on drivers. Scheduled feedback had the effect of controlling how annoying the feedback is perceived. No frustration was induced when positive feedback was presented and only low frustration was induced when negative feedback was presented.

CONCLUSION

This paper describes a system that presents scheduled feedback controlled in terms of quantity of total feedback and feedback with regards to a specific stimulus, and driver current state. A variable schedule of feedback for remarks about driving behavior is compared against continuous feedback.

Demonstration level evaluations had shown that in short-term circumstances, negative feedback seemed effective, immediately getting people to pay more attention to their driving behavior. A longer driving experience in a controlled experiment did not demonstrate that effect, and did show considerable differences between positive, and negative style feedback.

Negative feedback proved to be the worst by decreasing performance significantly eliciting high frustration levels on drivers. This negative effect can be reduced by scheduling the feedback presented and introducing scheduled positive feedback. The results indicate that the best combination for feedback and schedule is positive feedback on a variable schedule. If negative feedback needs to be presented, scheduling feedback could reduce its elicited higher frustration. The results appear to conform to what would be expected, nevertheless, they should be viewed with caution.

This paper demonstrates that even in a car, peoples' performance can be improved by giving advice now and then to make them aware of their driving performance. Adaptive agents can help people by replacing their actions with assistant or teaching and improving their performance with advisory agents. This paper furthers the evidence that advisory systems can be used in complex environments competently The use of agents that use a task, system and user model can be used together to make a system that competently knows how to provide encouraging feedback to improve driving performance.

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