Advice Provision for Energy Saving in Automobile Climate Control Systems

(Extended Abstract)

Amos Azaria, Sarit Kraus
Department of Computer Science, Bar-Ilan University, Ramat Gan 52900, Israel
{azariaa1,sarit}@cs.biu.ac.il

Claudia V. Goldman and Omer Tsimhoni
General Motors Advanced Technical Center, Herzliya 46725, Israel
{claudia.goldman,omer.tsimhoni}@gm.com

ABSTRACT

Reducing energy consumption of climate control systems is important in order to reduce human environmental footprint. We consider a method for an automated agent to provide advice to drivers which will motivate them to reduce the energy consumption of their climate control unit.

Our approach takes into account both the energy consumption of the climate control system and the expected comfort level of the driver. We therefore build two models, one for assessing the energy consumption of the climate control system as a function of the system's settings, and the other, models human comfort level as a function of the climate control system's settings. Using these models, the agent provides advice to the driver considering how to set the climate control system. The agent advises settings which try to preserve a high level of comfort while consuming as little energy as possible. We empirically show that drivers equipped with our agent which provides them with advice significantly save energy as compared to drivers not equipped with our agent.

Categories and Subject Descriptors

I.2.m [**Computing Methodologies**]: ARTIFICIAL INTELLIGENCE—*Miscellaneous*

Keywords

Human-Agent Interaction, Sustainability Technologies, Persuasion

1. INTRODUCTION

In the increasingly industrialized world, various facts imply that energy consumption levels may no longer be overlooked. In addition to long term reasons, saving energy while driving electrical cars has an additional short-term benefit - it extends the range of travel. This is desirable since electric cars often have a shorter driving range than fuel-powered cars per full battery charge. Thus, in this paper, we propose an automated agent that advises a driver on saving energy. In particular, we consider a summer environment in a Chevrolet GM Volt car, in which the car is very warm and the driver would like to turn on the climate control system in order to cool down the car and drive comfortably. An agent advises the driver how to set the car's climate control system. In this scenario the computer agent and human user do not share the exact same goal. While the agent may care mostly about the car's energy consumption, the driver, on the other hand, is usually more interested in his own comfort level while less interested in the car's energy consumption. Thus, the agent faces the challenge of providing advice that will reduce energy consumption while taking into consideration the driver's comfort level.

Our agent has to overcome two sources of uncertainty. First, it should try to model the preferences of the driver, estimating his comfort level in a given climate control setting. Second, it should estimate the energy consumption of a given setting. Both the drivers' preferences and the car's energy consumption are very noisy and difficult to estimate. Both models were built using data collected by running experiments in the Chevrolet Volt. The data for building the drivers' model was collected from only 15 participants. Based on the constructed models we formalized the optimization problem of the agent, which wishes to minimize the energy consumption while maintaining a reasonable level of estimated comfort. We also designed a GUI that allows the agent to provide the advice in a convenient and attractive way for the driver. In order to evaluate our agent, we ran extensive experiments with 49 human users who were required to set the climate control parameters of the Chevrolet Volt when it was very hot outside. We show that when using our agent, the subjects saved approximately 17% of the energy consumption of the climate control system. To the best of our knowledge, this is the first study to develop an automated agent aimed at persuading a person to take an action in a physical environment even when they do not share the exact same preferences. Current computer systems which provide advice in physical systems have the same preferences as their user, e.g., route guidance systems.

2. THE CLIMATE CONTROL SYSTEM

The study in this paper was based on the Volt's climate control system. In this system the drivers can control the settings S as described in this tuple (T, F, D, M) where: **Temperature** (T) is associated with a temperature in Celsius and can receive values between 16 and 35 degrees; **Fan**

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Figure 1: A screen-shot of the GUI accompanied with CARE's advice. In this example, the driver set the temperature to $18°C$ (rather than $21°C$ as advised by CARE), the fan to 4 (rather than 1), the air delivery to both face and feet (rather than face-only) and the mode to 'comfort' (rather than 'eco'). This resulted in an energy consumption level of 63% of the maximal energy consumption level (right green circle), rather than only 25% if the driver would have followed CARE's advice (left purple circle).

strength (F) is associated with the fan blower and can receive values between 1 and 6; **Air delivery** (D) may either be set to face (in which D is set to 0) or face and feet (in which D is set to 1); and **Mode** (M) may either be set to 'eco' (when M is set to 0) or to 'comfort' (when M is set to 1). According to the Volt's user manual, the 'eco' mode tries to reduce energy consumption while the 'comfort' mode aims at maximizing the user's comfort level.

3. CARE

In this section we present our Climate control Adviser for Reducing Energy consumption (CARE). CARE requires the composition of two models, one for modeling the climate control's energy consumption as a function of its settings and the other for modeling human comfort level as a function of the climate control's settings. CARE uses these models in order to provide a driver with advice regarding the settings of the climate control system, taking into account both the expected energy consumption and the expected comfort level. CARE provides the driver with advice that yields an expected comfort level of at least 7 while minimizing the expected energy consumption of the climate control system. In our scale a comfort level of 7 means that the driver is comfortable.

4. GRAPHICAL USER INTERFACE

We implemented a panel based on the original climate control panel in the VOLT car, with additional add-ons. We have three different methods of advice, each with a different Graphical User Interface (GUI): (1) The first GUI is identical to the original climate control panel in the VOLT car. This option was used for the control group and is associated with a driver that does not receive any advice. (2) The second GUI has an additional information circle, which supplies the driver with an estimate of the current energy consumption level. This information appears as the percent of the current energy consumption from the maximum energy consumption obtained in the training data (the lower the better). This GUI will be referred to as CAREless. Note that CAREless does not provide any active advice either. (3) The third GUI is equipped with the full functionality of CARE. The driver is presented with both the advice provided by CARE and an estimate of the current energy consumption (similar to the information provided by CAREless). Figure 1 shows a screen-shot of a case in which the driver set the climate control differently from CARE's advice.

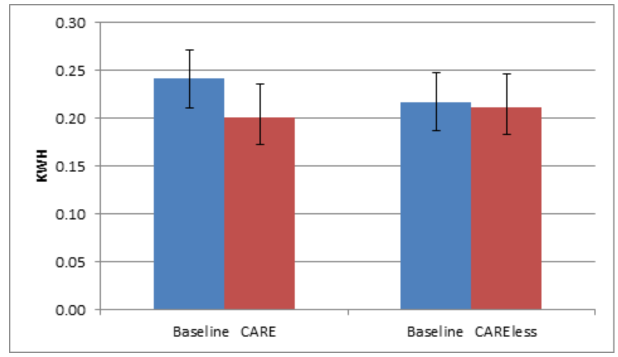

Figure 2: The mean energy consumption level of the subjects who received advice from CARE and CAREless, compared to the mean energy consumption levels of the subjects when they did not receive any advice.

5. EXPERIMENTAL EVALUATION

In order to evaluate the performance of CARE and CAREless we recruited 49 subjects for the evaluation phase, of which 33 were males and 16 were females. Each of the subjects was randomly assigned an advice provider, which was either CARE or CAREless. 24 subjects were assigned to receive advice from CARE, while 25 subjects were assigned to receive advice from CAREless.

When subjects were given advice by the CARE algorithm, their total energy consumption significantly decreased from 0.24 KWH to 0.20 KWH, an improvement of 17% ($F(1, 21) = 7.6, p < 0.05$). Figure 2 presents the mean energy consumption level of the climate control system which was obtained by the subjects when receiving advice from CARE vs. CAREless, compared to the mean energy consumption level of the same subjects when they did not receive any advice.

6. CONCLUSIONS

In this paper, we presented a method to persuade a driver to reduce the energy consumption of the climate control system of his electrical car. We showed via extensive experiments that the proposed methodology leads to a significant reduction of energy consumption. The methodology requires the collection of data on the energy consumption of the climate control system and on the drivers' behavior, but is effective even with a small number of examples (15 drivers in our experiment). We designed a GUI for presenting the advice that facilitates easy understanding of the advice. The reported work is the first step in the process of the deployment of a persuasive agent in a car.