COPE1 – Incorporating Coping Strategies into the Electric Vehicle Information System

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ABSTRACT
Sales of Electric vehicles (EVs) are estimated by the industry to increase in the future, as they are an important step towards more energy efficient transportation and to lower CO2 emissions. A problem is that available battery technologies for EVs limit the driving range and might cause range anxiety, and as technology stands now, this problem will be present for many years to come. As a result, it is important to re-design the electric vehicle information system (EVIS) to include tools that could easily help users overcome range anxiety issues. Design of such technology can take advantage of the experience accumulated by drivers who have already coped with this problem for many years. In this paper, we describe a coping strategy observed among some more experienced EV drivers, describe why this strategy is powerful, and demonstrate a first attempt to utilize it in design.

Author Keywords
Electric Vehicle; Electric Vehicle Information System; Coping Strategies; Sustainability; Energy; Energy Management; Range Anxiety; Interaction Design; Information Visualization.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

1. INTRODUCTION
Conventional combustion engine cars have been in traffic for quite some time by now. Problems have been solved along the way, and the user interface and information system has been gradually refined and redesigned to better suit driver and passenger needs and to incorporate new technology, infrastructure and increased security. A similar endeavor has just begun for the electrical vehicle (EV), and it is likely that the EV might look much different to the conventional car in the future. However, a problem today, is that we are using the combustion engine vehicle information system as a reference for the electric vehicle information system (EVIS).

In the EV use context, where energy is tightly coupled with range, energy awareness, or lack of it thereof, manifests itself through the phenomenon referred to as *range anxiety* [1, 3]. Range anxiety is an anxiety or fear that one may not reach a target before the battery is empty, which can occur while driving or prior to driving as the user worries about later planned trips, or indeed completion of the current trip. The main cause for this problem is that EVs have a more limited driving range (e.g. Nissan Leaf has a claimed range of about 160 km (100 miles) in combination with charging times of approximately 8 hours in normal power plugs and a minimum of about 2 hours in fast charging stations for a fully charged battery. This is due to available battery technology and limitations of the electrical grid. This means that it might take hours to correct a trip-planning mistake, or even make the driver become stuck if the mistake is discovered too late. While there is hope for improving battery technology in the future, current knowledge does not offer cheap manageable solutions for improving battery performance.

Figure 1. An experience EV driver demonstrate how he calculates the required energy efficiency for traveling 10 km using 1 battery bar (1,5 kWh) in a Nissan Leaf.

We address this problem by doing interaction design based on coping strategies developed among experienced drivers and reshape the EVIS to meet the need of overcoming range anxiety. In earlier work we have been trying to address range anxiety by exploring how distance-left-to-empty information could be visualized in a more accurate and intuitive way, using maps and parameters of the world [2]. However, these types of calculations are problematic, as they tend to require knowledge about the future. Therefore, we are now researching alternative ways of dealing with range anxiety.

We will first describe the coping strategy we encountered with experienced drivers. This strategy is complex to apply with current EV interfaces and requires calculation on non-vehicle devices such as smartphones, and input data and results must be transferred manually between the device and the EVIS. Integrating this strategy in an EVIS is therefore a natural choice, so we will illustrate our current interaction design sketches that are based on this strategy.

2. Observations of a Coping Strategy

When conducting a one day field study meeting 2 experienced EV drivers, we encountered a range-anxiety-coping strategy that appeared efficient to us, although yet relatively simple to perform. With "more experienced" we mean EV drivers that have at least a few months experience of electric driving. One of them had driven EV for more than 5 years driving a 1998 Toyota RAV4. The other for a few years through contacts, as he was a board member of the Swedish national EV interest group, he had also owned an Nissan Leaf for 3 months at the time. Both of them could be regarded as pioneers of EV owning and driving practice in Sweden.

The coping strategy can be described by the following vignette. The experienced EV driver was going to drop off the researcher at the airport and then drive home again. First, he looked up the distance back and forth to the airport (total distance). Secondly, he checked how many "bars" he had left in his Nissan Leaf user interface (Figure 1), each of those is worth 1.5kWh and there is a total of 12 (+2 hidden ones that provide sufficient security, as known by Nissan Leaf expert drivers [4]), which means he could approximately calculate how much energy he got in the battery. Thirdly, he used his smartphone to do the following calculation:

[energy in battery(kWh)] / [total distance (km)] = [required energy efficiency (kWh/km)]

Lastly, he reset the "Energy Economy" (also kWh/km) figure in the existing Nissan Leaf "EVIS". After this, he was ready to drive to the airport. In this particular case, he had calculated that he needed to drive with an energy efficiency of a maximum of 0.15kWh/km to be able to do the trip safely. When we arrived at the airport, he had 39km home and the cars own distance-left-to-empty estimation (often called the guess-o-meter) signaled 43km. This would normally be a typical cause for range anxiety, and the first author definitely felt embarrassed about luring the driver into this disastrous situation. However, when we talked about this fact and range anxiety, he quickly replied,

"as long as I stick to the 0.15 (kWh/km) I will make it…don't worry about it".

In this situation, we believe that this strategy really demonstrated its potential in terms of easing range anxiety. It is also notable, that the strategy somewhat looks beyond the complexity of the world as in elevation, wind, number of passengers and so on, as the user always can continuously adjust the driving in relation to the required efficiency. In this sense, the strategy becomes a proactive and continuous tool, rather than a guess about how far one could reach (as the distance-left-to-empty meter) or our earlier work [2].

However, to be able to execute such a strategy, the user needs to know a few things about the EV and the world.

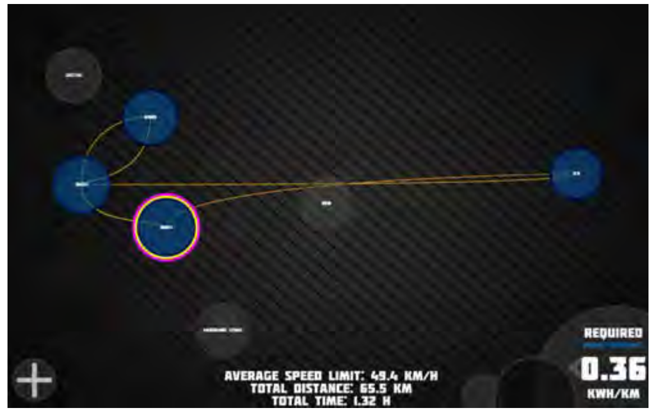

Figure 2. COPE1. The circles represent locations, blue locations have been selected in a sequence connected with the yellow to purple lines. Users can add new locations by pressing the plus sign in the lower left corner. Required energy efficiency can be viewed in the lower right corner.

1. Know about the strategy in the first place.
2. How long is the desired route?
3. How much energy do I have?
4. How do I execute the calculation?
5. Where in the EVIS can I see my energy efficiency for comparison?

All of which, could be easily supported by the EVIS to support both new and experienced EV drivers.

3. Design rationale

Based on our observation, we decided to design a prototype to begin to explore how this coping strategy could utilized in design and to further explore the values of such a strategy in the EVIS. We also assume the following to help set a direction of the design:

a) People have a limited set of locations relevant for driving and they have a good understanding of where they are. Therefore exhaustive map solution like our EVERT system [2] and many others are not relevant for everyday driving (yet they are still important for driving in unknown areas, where range anxiety is more prone to occur)

b) Users do not want to spend time on planning for everyday driving; therefore this type of tools should be effortless. Users are not prepared to do the kinds of calculations (and transfer of their results) that our EV enthusiasts performed.

c) The planning can be done both in-car or on an external device connected to the EVIS. This builds on our previous experience that "by the time you're in the car, it may be too late". The coping strategy illustrated provides a good way to adapt to the situation even as late as when sitting in the car, however taking advantage of it outside the car should do no harm but only add to the "range safety" felt by the driver.

4. COPE1 – A Coping Strategy Prototype

Our prototype COPE1 (Figure 2) is implemented using HTML5 and Processing.js and runs in any browser. In its current state we have mainly ran it in a browser on our computers to try out the idea, but it is intended for use on an iPad or similar tablet devices.

The prototype provides the user with the possibility to add locations important to them using a map. We imagine that important locations might be anything from the user's home and workplace, to the supermarket and perhaps charging stations frequently used. A circular area in the design represents each location and the distribution is loosely based on the real map location. With loosely we mean that we try to put them on the right location, but if two areas intersect they will slowly move away from each other, similar to the London Underground topological maps designed by Harry Beck in 1931 [5]. This is done to avoid "hidden" locations and thereby improve accessibility and the interaction with regards to our rationale: it should be effortless and quick to set up a plan. Every time the user adds a new location, the prototype queries OpenMapQuest and stores a distance and time matrix between all locations so that the prototype quickly can determine the length and approximate time required to travel between the locations.

When the user has added some locations it is possible to tap on a location to set a starting point that will be highlighted purple. When a starting point is set, the size of the other locations are updated in relation to the distance between the starting point and each location, in other words, the further away, the smaller location. This is done to provide some feedback on the distances and thereby also a hint on the amount of energy required to reach them.

After the starting point is set, the user can begin to form a route by adding a sequence of locations. The end location will be highlighted yellow and the route will be connected with a line. The line connecting the locations will gradually shift in color from purple (start) to yellow (end) to provide some feedback on directions. If the user wants to drive back and forth between to locations these lines will be separated so that the user have a clear visual of all fare-stages.

In the lower right corner the prototype displays the energy efficiency required to complete the whole route based on the amount of energy in the battery of the EV and the total distance of the selected route. In its current state of the prototype, the EV is always fully charged, however, latter this will be updated with the actual state of charge of the EV.

All in all, setting up a route can be done in seconds, even more complex routes, and the system automatically computes the distance and required efficiency for the route.

4.1 Current work

We are currently investigating the placement of a moving object (the car) on the topological map. This has a flexible location, so that it needs to be located at a position related to the other locations. In other words, it needs to be close to nearby locations, yet not overlap them. When this is done, the starting point will be automatically set based on the location of the EV. This also requires that the sizes (representing the distance) of the locations need to be updated as the EV moves.

Another challenge we are currently addressing is the lowest energy efficiency that is actually manageable theoretically, taking into account the factors that affect energy efficiency and are not depending on distance, such as heating and lighting. Also we are considering the lowest energy efficiency manageable practically, i.e. a low energy efficiency might require that the user drive unacceptably slow, which may also be illegal on some roads.

5. Discussion

The range anxiety coping strategy that we are considering in this paper shows an important potential in that the driver can get a measure to continuously adapt to and in some sense gain control over the EV range. This is a great advantage in relation to other forms of range anxiety help, that often tries to estimate a guess of the range without providing something to relate to in driving in terms of how much energy could be spent per kilometer [2].

However, the calculated required energy efficiency do not in itself provide feedback and comparison to what energy efficiency is actually manageable in the real world, where traffic jams, hills and cold conditions truly exists. Therefore, without such comparison, this coping strategy might fool the driver into an attempt of driving a distance with an energy efficiency that is below what is required to move a specific mass to a specific location using required features of the EV (i.e. A/C), in other words, practically impossible. We are currently looking into that problem and how to provide such feedback to the driver.

6. Future work

We intend to complete our prototype and test it with real users in real life to evaluate the value of such tools in the EVIS. Furthermore, we are planning to investigate more coping strategies to inform future designs.

7. REFERENCES

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