Designing & Understanding the Impacts of Electric Vehicle Apps

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ABSTRACT
We are in the process of designing a series of apps for plugin electric vehicles (PEVs) with the goals of raising technology understanding and mitigating range anxiety. We targeted our apps at different moments in the user-car relationship: before, during and after driving. We are designing a study involving a number of PEV drivers to both assess their driving behavior over time, and to test our PEV apps. This paper presents our process and current status, for workshop discussion.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. See: http://www.acm.org/about/class/1998/

Keywords
Electric vehicles; range anxiety; Designing; App; Ambiguity; Study.

1. INTRODUCTION
In the plug-in electric vehicle (PEV) use context, range awareness, or lack thereof, may manifest itself through a phenomenon referred to as *range anxiety* [2, 7]. Range anxiety is the anxiety or fear of not reaching a location before the battery is empty, occurring while driving – or even prior to driving – as driver may worry about later planned trips. The main cause for this problem is that PEVs 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 up to 8 hours in normal power plugs and up to 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 planning mistakes, or even make the driver stuck if discovered too late. While there is hope for improved battery technology in the future, e.g. using supercapacitors like graphene [3], current understanding does not offer viable solutions for improving battery performance.

Range anxiety is considered to be one of the biggest psychological barrier for the PEV, and studies show a need for more energy information and better user interfaces to provide better means of handling and avoiding these unnecessary situations [4]. It is not unusual that these problems occure because the drivers expect the PEVs to work in the same way a conventinal car works [8]. Indicating that the information system is forced into the conventions and designs of conventional cars, rather than having its own design.

However, the majority of the commercially available PEVs have their driving range above 80 km, which is twice, and in most case three to four times, the daily driving habits of the general public in Europe, USA and Australia [1], showing that the PEV is well adjusted to the needs of people if rare occasions (long trips) are excluded. On the other hand, this assumes that the PEV is fully charged every morning, something that is likely to fail from time to time, as things tend to happen. I.e., fuses break, people forget to plug in over night or over lunch, unexpected trips occur in the last moment, unexpected traffic jams requires more power to run air-conditioning or heating, charging stations are occupied or broken, there is a blackout in the area, the driving style or topography requires more power than expected and so on.

The objective of our position paper is to show the current status of our interaction design work in the PEV area, focused especially on addressing such contingencies. We will describe our design concepts, and the design sensitivities we developed during the process (especially the need for ambiguity as a counter-balance for contingency). We will also describe a study that we are preparing with drivers on the field and hope to discuss our study plan at the workshop.

2. A series of apps
Our work is in large part driven from explorative stance, investigating possible futures using design methods.

In earlier work we have been trying to address range anxiety by exploring how distance-left-to-empty information could be visualized in more accurate and intuitive ways, using maps and parameters of the world [5].

This design concept represented the range as a polygon (which we later found is not original to us) and was used without an electric vehicle, by users who assessed, in interviews with us, *what it would be like* to own an EV, and the five respondents in our study reported that the prototype helped them understand the new technology. The design concept can be used also after driving to reflect how the EV has worked, and what were the effects of different factors like traffic jams, etc., during driving. However we have not yet tested the concept in these conditions as yet.

One reason we did not continue with the "range-in-all-directions" idea is that such interfaces need to make lots of map API calls which are increasingly restricted (by means of quotas) by the map API providers (e.g. Google maps).

Another concept we worked with focused on helping people make a decision whether to hire an electric car or a conventional gasoline car. A car hire operator that we cooperate with has indicated that the customers ask the (not unexpected) "will I make it to this destination" (and back) question, with its more elaborate version of driving "via" certain places. Our design provide the possibility for the customer to play with a number if via points in between the start and stop location (the rental station). When the customer plays with the route, the system provides a

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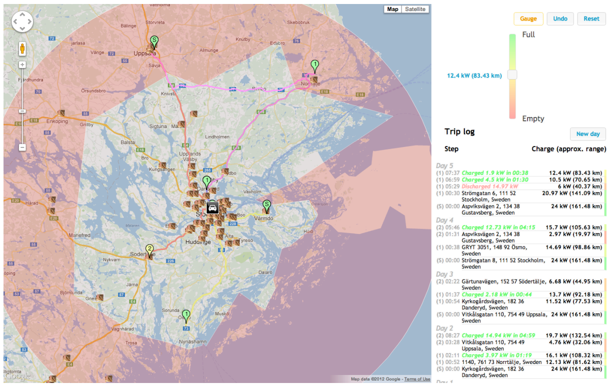
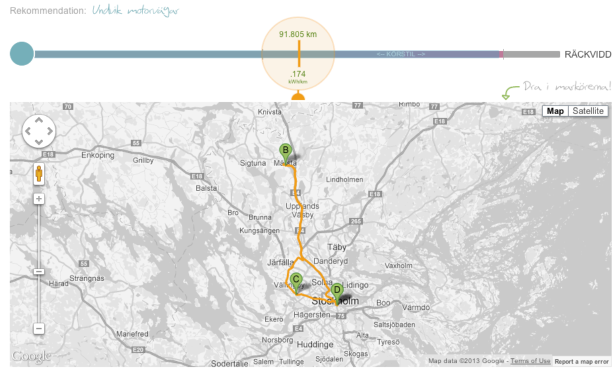


Educational app.



Car rental app

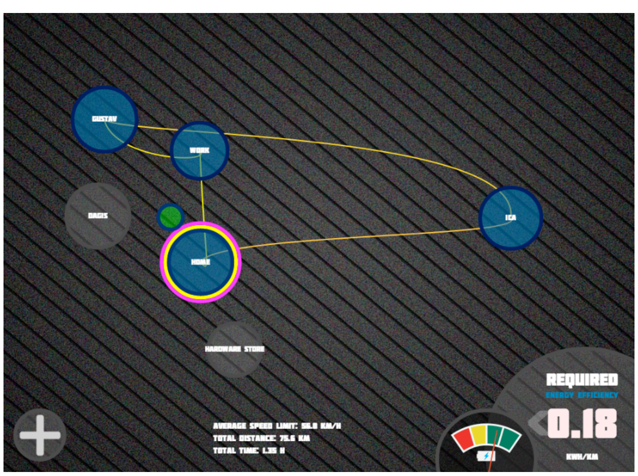
recommendation by giving an approximate degree of confidence (from "this route is easy", through "drive slow and you will make it", and all the way to "don't even think about it".

Since we cannot know exactly in advance how a trip will go, it is important to leave space for ambiguity in our design. We have thus decided to show the recommendation as part of a continuum, rather than a precise border (in range/not in range) as employed in our first prototype. Of course, the main difference is that we focus on a given trip rather than "trips in all directions" which is rarely a need, yet it is good for educating users about new technology.

Our app for driving aims to take into account the contingencies that one may face during driving and adapt its recommendation to the user depending on the energy left in the battery. This design is grounded in observations of different ways of coping with range problems among experienced PEV drivers [6]. One such coping strategy was to calculate the approximate *kWh per km* that one can use during driving in order to make it to a destination.

This design omits the map, yet it presents a quasi-geographical representation of several places that the user needs can select in a preferred sequence. During driving it detects "deviations from plan" in relation to the energy spent and helps the driver by e.g. decreasing the "target" kWh per km if too much energy was consumed.

Ambiguity is important in this case as well, since it is difficult to drive with a constant kWh/km, and this indicator, while useful, does not cover aspects such as future needs for heating/air conditioning in a traffic jam, or future climbing slopes which should require building an energy reserve (thus driving with even higher kWh per km to be able to spare for the coming slope).



In-car app.

We are in the process of instrumenting this app with the on-board-diagnostic connections necessary to test the app during driving. As we will start driving around with this and other apps, we are certain that design improvements will be needed as well as new concept ideas will come about.

During our app design process, we came to see a parallel between driving an electric car on a proposed route with a given amount of energy and riding a bicycle on a proposed route, with the energy expenditure a certain human can usually exert. There are common aspects such as the importance of terrain elevation, as well as differences such as e.g. traffic jams. We are considering designing user interfaces for both cases in parallel and see how the two processes can feed into each other.

3. Design of a field study

Our current status is that we have recently got a grant for testing our designs and strategies in practice to verify the impacts that smart apps can have on driving practices and the understanding of range. We hope that the apps can provide better and quicker understanding of energy consumption, range and of how driving style affect these parameters.

Our current study design is a controlled study with half of the informants driving without (an elaborated version of) our driving app, and half of the informants driving with it. Our hypothesis is that drivers using our app use the PEVs to a higher extent and, as they understand and trust the technology more, dare to use the PEV for longer routes or on lower battery levels with less range anxiety.

In order to gather data during the study, but also for our app to work correctly, we have designed our own hardware platform that collect and transmit on-board diagnostic (OBD), as well as position (GPS) information, and uploads this to the cloud.

Data collection will be followed by reflective and contextual interviews with the informants.

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