EVERT – Energy Representations for Probing Electric Vehicle Practice

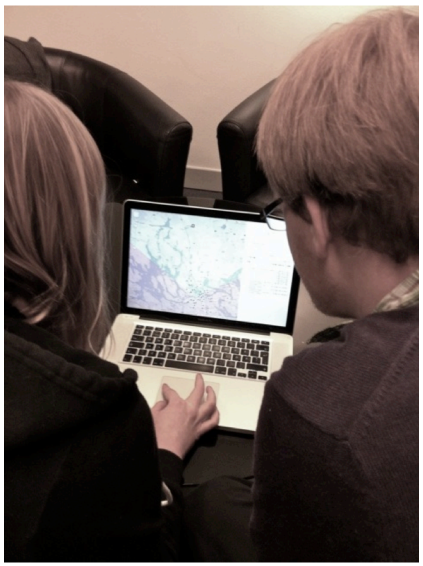

Figure 1. Study setup of using EVERT as a technology probe for exploring understandings of range and energy in scenarios and real world cases of driving electric vehicles.

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Abstract

Energy and design of energy-feedback are becoming increasingly important in the HCI community. Our application area concerns electric vehicles, we thus depart from home and workplace appliances and address range and energy anxiety caused by short driving distance capabilities and long charging times in mobile settings. We explore this topic by letting conventional fuel car drivers reflect on their current driving habits through an exploration tool that we use as a technology probe. Our preliminary results demonstrate the educational values of the energy representations in the tool, and we also identify a design tension for map-related energy representations.

Key words

Electric Vehicle; Sustainability; Energy; Range Anxiety; Interaction Design.

ACM Classification Keywords

H.5.2 [Information Interfaces And Presentation]: User Interfaces - Interaction styles;

Introduction

Energy and design of energy-feedback are becoming increasingly important in the HCI community, out of both sustainability and practical usability reasons. A major part of this work has been concerned with ways to visualize and materialize energy consumption with regard to home or workplace consumption to provide energy-feedback[1, 7, 11, 13]. Energy as such is a

Figure 2. A mockup based on real roads, showing the reachable area based on a fixed distance.

Figure 3. Typical in-car display showing the approximate distance left before the tank is empty.

peculiar material that is invisible, undifferentiated and intangible [12], and making it easy to understand this material is therefore a challenge that demands more focus from designers and researchers.

Our application area concerning energy is battery-only driven electric vehicles (EVs), i.e. without alternative fossil fuel extension units such as in hybrid electric vehicles. In this domain, energy consumption takes place in a mobile setting, 'in the wild'.

In the EV use context, where energy is tightly coupled with range, energy awareness takes a very concrete form in a phenomenon referred to as *range anxiety* [4]. 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. The main cause for this problem is that EVs have an average driving range of about 165 km (102 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 in the worst case, make the driver stuck if the mistake is discovered too late. There is hope for improving battery technology in the future, but current knowledge does not offer cheap manageable solutions for improved battery performance. Moreover, EV technology is new and unfamiliar to most car drivers, which in itself may cause anxiety and distrust. It is reasonable that anxiety regarding range might be eased with the use of energy feedback [3]. We address this problem by interaction design in the energy representation area, thereby contributing to this research topic by specific designs focused on maps.

Our aim is to contribute to the energy discussions in HCI through a research-through design approach inspired by Fällman [5] and Zimmerman et al [14]. This means that we are constantly reframing the problem through an iterative process in order to achieve a better result. Additionally we believe in the importance of gaining new insight about the peculiar energy material [12], as well as our users, through the use of prototypes. Our prototypes are of varying natures through the design process, from exploration and reflection tools such as EVERT presented here, to in-car and mobile driving and trip-planning support tools.

In this paper we present a high-tech range exploration tool (EVERT) that we have developed in the process to support understanding of energy, EV technology and planning of driving sessions. EVERT can be regarded as a technology probe [9] for increased understanding of the design space through users and designers exploring properties of the problem domain and materials. In what follows we will introduce EVERT and the preliminary results from a pilot study conducted using EVERT. The results will be used in the continuation of our ongoing design process.

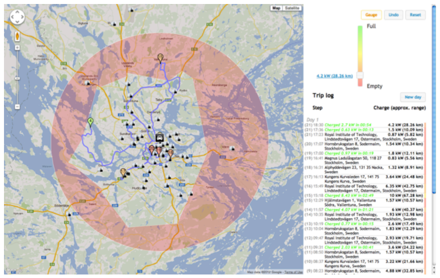

Figure 4. Overview of EVERT running in a browser, the left is the map, and to the right charging level

Figure 5. Screen dump of how EVERT displays the reachable area. If the user selects a location outside the reachable area, the application will tell the user that the selected target is unreachable.

EVERT – Electric Vehicle Exploration of Range Tool

EVERT (Fig. 4) is a tool for users to explore their own reality when driving an EV – to elaborate on driving plans and to test whether various trips are possible given their own context. The tool could also be used as a basis for discussion and articulation, as well as for shaping of meaningful activities and routes within pre-given scenarios. In that sense, EVERT might initially be considered a 'translator of thought' between us as designers and the presumptive or novice EV drivers [1]. However, the end result is expected to be something useful and meaningful for EV driving in situ (i.e. a tool for driving and planning). Our current design is intentionally slightly more informative in its nature to raise questions through retrospection among the participants [10].

Design scope: Who said something about a straight, flat and windless road?

Many aspects can influence energy consumption and driving range, some affect driving range in all directions, other only apply to certain roads and directions. Imagine that you enter an EV with a charging level that should be sufficient for driving 100 km (62 miles). It is easy to imagine a perfectly round circle on a map displaying the reachable area. This is however never the case since roads are rarely straight and the reachable area therefore need to be computed using the actual roads rather then the straight-line distance (Fig 2). This is perhaps not anything new and not that groundbreaking either. In fact, we can probably deal with this when it concerns locations that are important to us, for instance we often hear statements as "it is about 40 km (25 miles) to my parents' place", these types of statements are clear indicators that we are aware of the actual road distance rather than the straight-line distance between different points, at least to our most important locations. However, something that is rarely mentioned about is how factors like speed, elevation, slope of road, air resistance, rolling resistance, traffic, driver profile, carload and wind affect the reachable area. As an example, EVs are sensitive to temperature shifts, and unfortunate conditions might in the worst case bring down the average range of 165 km (102 miles) to somewhere around 30-50 km (20-30 miles). With all this in mind, it becomes important to explore how richer information than the usual "distance left to empty" meter (Fig. 3) might be displayed to ease driver anxiety and understanding of the situation, as well as how these factors affect everyday driving. One way of doing this is by visualizing the reachable area on a map, based on approximations of energy consumption using these factors while driving in any possible direction. The outer edge of this area then takes the shape of a polygon rather then circle (Fig. 2).

Overview of current functionality and implementation

EVERT is cloud-based and implemented for browsers using HTML, JavaScript, jQuery and the Google maps API. In its current implementation EVERT is distance-based and calculates a simple distance polygon based on remaining energy in the battery (i.e. for now without taking into account wind, temperature, traffic, etc.). The polygon displays the reachable area on a map and an outer circle shows the straight-line distance (Fig. 5). The user can select to go to a new location by clicking within the reachable area. The tool also shows the path and locations that the driver has previously driven to. Another part of the tool (Fig. 6) shows the current charging level, which is reduced while driving, and a trip log, as a resource for reflection. The user can

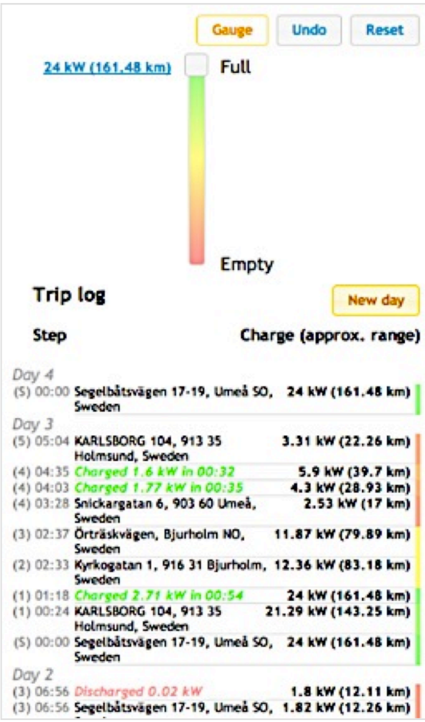

Figure 6. The charging level and trip log part of EVERT. The slider represents the charging level, which is adjustable to simulate charging and discharging. When the vehicle is charged or discharged a row in the log is displayed in green for charging and red for discharging along with required charging time in the charging case.

increase the charging level by moving a handle up and EVERT will display how long charging time is required for that operation. It is also possible to discharge to be able to setup tricky scenarios for the user or to simulate accidental battery discharge. All logs and previous location markers on the map are color coded with the remaining charging level at that particular point. The prototype also displays all available charging stations in Scandinavia to provide infrastructural awareness [8].

Pilot study and preliminary results

A pilot study was conducted to provide an extended understanding of current driving practices among ordinary fuel car drivers, and future challenges in EV usage, and to get feedback on our design concept and prototype functionality. There were 4 participants with varying levels of knowledge of EV technology, aged between 30 and 60, living in urban or suburban areas in major cities in Europe (Sweden and Croatia).

Each session lasted for 30-90 minutes and was structured in 4 parts: (i) basic questions about their life situation, the car they use, everyday driving practices and knowledge about EVs, (ii) basic information about EVs and a demo of the tool followed by a session (iii) trying out 4 different predefined scenarios based on their own driving practices in a think-aloud fashion, ending with (iv) open ended questions concerning how they believe an EV would function in their own life, attitudes towards EVs and reflections regarding EVERT. All session were conducted using a laptop and were recorded (Fig. 1).

Below is a summary of the most relevant results that were brought up in this study, focusing on 1) how the tool worked to elaborate on EV attitudes in the context of current driving patterns, as well as 2) how the tool worked as a potential resource for trip planning.

EV attitudes and everyday practice

All participants were positive to EVs, both before and after they had explored their everyday driving habits with EVERT, and stated that they would like to own one for everyday driving for *"city purpose"* or *"in Stockholm"* mainly for environmental and economical reasons, given that the EV was not too expensive in comparison to a regular car with combustion engine. More demanding weekend activities seemed to be manageable as long as the driver started the weekend with a fully charged EV, otherwise *it "might take a lot of planning"*. Longer holiday trips were practically impossible for all participants because they required too long time (due to long charging breaks); in some cases the desired destination even was impossible to reach because of poor charging infrastructure. One participant stated, *"holidays is impossible, I would rather rent a car"*, another said *"I rather choose the train"* which was the normal alternative for him anyway. A majority of the participants said that EVERT was *"good for exploring how driving electric car would be for me"* and that it *"gave me a good perspective on using electric cars"* with indication that the EV domain was a little bit unclear today, which suggests that EVERT helped to 'educate' the respondent about EVs.

Design concept and prototype functionality

On a question regarding what the participant thought about the tool one participant answered *"It is excellent, if I had an electric car with this tool I would feel more relaxed because I have an estimation of what I can do"*, another one said that it is *"good for planning and* *quickly test if a trip is manageable".* Overall the participants thought that the information on the map were useful for planning, although the outer circle representing the straight-line distance was questioned as not very useful, and one participant that was frequently experiencing traffic jams in his everyday life thought that *"if you put in traffic information than it is even better",* even though EVs are more efficient than fossil fuel cars, that information might be crucial as traffic jams might drain a lot energy on heating, cooling etc., particularly if the EV charge level is low.

Overall all participants struggled to some extent with finding particular locations on the map, for instance, 2 participants were really precise when selecting locations important to them and made comments like "that is not were I park my car (!)" or "that is my neighbors address (!)". These activities required frequent zooming in and out when interacting with the map-based interface to shift between details and overview. As an effect, one participant gave ideas for a *focus+context* [2] solution with an enlarged map around the pointer for staying in a more zoomed out view.

Discussion and Future Work

Representations of energy in interaction design are a growing topic in interaction design nowadays, with concerns such as sustainability and energy feedback [1, 7, 11, 13]. In the EV case, we contribute to this body of work by departing from the home and workplace concerns with energy feedback appliances and move into a mobile context. Furthermore we are aiming for a fusion between a well-known representation of the physical world (maps) and a lesser-known representation of energy (range). Also we provide for energy planning and reflection of energy use by allowing the users to view intermediate states of their EV use through the log and visual track on the map, and helping them to map distance and time to energy in both text and graphical representations (cf. [1]), we thus emphasize the importance of planning support in energy representation design, as planning is often important for effective EV use.

While our preliminary results show that our respondents used these features mostly as intended in order to project how they would use an EV in the future based on their current driving practices, we were still surprised by the educational value of our tool, both in terms of promoting EV, and in terms of deconstructing myths and misconceptions about EV technology. Educational aspects as a use quality for our tool provide new angles when considering interaction/representation design problems such as whether or not to keep the circle that shows the straight-line distance.

Furthermore our results show a great deal of user engagement with the tool concerning places important for their everyday life. While picking the right parking spot would not be crucial for range computations, most users put much effort in selecting precise places and seemed to value these aspects of the interaction. In this regard we identify a design tension for map-related energy representations: the concern about highly significant places requires zooming in to the minute detail, while the concern to provide an overview of energy mapping on the physical space requires overview-level zooming. Using several zooming factors concurrently may be a way to address this design tension, which we will address in future work.

We have consciously kept out several factors that affect range in our study, such as wind, elevation, temperature, traffic, driver profile, carload. Besides allowing us to perform a study earlier, this decision also allows current results to serve as a baseline for comparison in future studies where all such factors are included. Another strain of future work is putting EVERT to experienced EV drivers who may be familiar with EV limitations, yet have not benefited from our energy representations.

Finally, as EVERT evolves into an increasingly usable technology exploration tool, we are continuously considering how its energy representation elements can become part of a planning and driving tool. Designing and evaluating such a tool is the ultimate aim of our future work. We are conscious that usages in-car or on mobile devices pose very specific constraints [6], yet we expect that the main design aspects and tensions that we identified in our EV energy representations will be similar.

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