Peacox – Persuasive Advisor for CO2-reducing cross-modal trip planning

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Final Decision Making Support

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Abstract

This deliverable reports work performed in task 5.5 of the PEACOX project and summarizes our experiences gained from the implementation and evaluation of persuasive technologies for environmentally friendly transportation. Our focus in T5.5 was on studying a choice architecture approach which assists users to uncover transportation options with lower emissions as well as persuasive mechanisms for feedback through messages and proper communication of CO2 consumption.

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1. Introduction

1.1 Background

The work described in this deliverable is the outcome of task 5.5. In this task identified ways to nudge commuters towards the environmentally friendliest transportation decisions while considering their situational and individual range of acceptable travel choices. To this end, we applied concepts from behavioural science and choice architecture that provide positive reinforcements and indirect or direct suggestions for non-forced compliance. Our motivation was that the integration of behavioural science concepts in route planning applications can influence the motives, incentives and decision making of groups and individuals. Furthermore we examined methods for the generation of persuasive messages that provide feedback and suggestions to the user in the route selection process. Last but not least, specified algorithms for communicating CO2 consumption to users in an efficient and understandable manner while proving motivation for self-improvements. These algorithms have been used in tree-like visualizations which grow or shrink according to the emissions that users cause.

1.1.1 Scope of this Deliverable

The deliverable is structured in three main sections with each section analysing the theory and background, implementation details and main outcomes of the persuasive technology at hand i.e. the recommender system in Section 2, the persuasive messaging system in Section 3 and the eco-feedback interfaces in Section 4.

2. Behavioural Choice System

Population in urban areas is rising at unprecedented values. In Europe alone, over 72% of the population lives in urban areas and an increase is expected in the near future (Population Reference Bureau, 2008), whereas worldwide, mega-cities (i.e., cities with a population of more than 10 million people) are estimated to rise to 25 until the year 2025 (United Nations, 2007). Within urban areas people mobility is constant and an important factor of growth and employment. Nevertheless traffic and mobility are also proven and major sources of environmental pollution due to carbon emissions. Urban traffic is responsible for 40% of CO_2 emissions and 70% of emissions of other pollutants arising from road transport (Cofaru, 2011). This problem can be addressed by means of better infrastructures (e.g., adequate public transportation options) and urban design but it is of great importance for citizens to adopt sustainable behaviours. Intelligent decision technologies, tailored for and integrated in route choice applications, can assist urban travellers and commuters to select transportation options which are comfortable, yet friendly for the environment. In the long term, such applications help urban travellers in making better choices and may result to behavioural changes and sustainability. Intelligent decision systems for behavioural changes (Fogg, 2002) can help by trying to 'nudge' users towards decisions that serve their own or the society at large long-term interests and may take various forms, including gamification systems (Deterding et al., 2011), visual feedback systems or systems (Hargreaves et al., 2010) that properly structure the available choices in decision making situations. The latter approach is also known as 'choice architecture' (Thaler et al., 2010) and is the corner stone concept of our approach. It refers to designing and incorporating small features, or nudges, in the choice making process in order to highlight the better choices for the users and assist them to overcome cognitive biases, while not restricting their freedom of choice.

Nudging in our case means to make individuals who use mostly their car to begin using public transportation, those who already use public transportation to consider the use of bicycles as well as sustain their current habits, and assist cyclists in identifying the routes that they like. In big cities identifying alternative and more ecologically friendly trips is not a trivial task due to the many options offered by improvements in public transportation including metro, bus, trams, and bicycle infrastructures. Furthermore there are options for multi-modal transportation which refer to using more than one means of transportation to reach a destination (i.e., routes that involve the use of more than one transportation means, for example reaching the destination with a combination of car, bus and walking) and can be cumbersome to plan.

2.1 Background

Our focus is on recommender systems as a tool for nudging users towards eco-friendly travelling decisions. To perform this task, the recommender generates a list of suggested routes which reside within the limits of users' preferences and presents choices with low carbon emissions. The problem can be formally expressed as follows:

For a user *u*, find a subset *S* from the available routes such that *S = PresentedRoutes* and the choice of *S* provides a good balance between the user perceived route utility and CO_2 emissions. Routes are properly structured in order to allow for meaningful comparisons, whereas the environmentally friendly options are ranked higher in the list.

Route planning applications allow users to find ways to reach a destination. The most common process is to enter a start and a destination address or point in a map and then a routing engine calculates alternative ways or trips to reach the destination. Recent developments guided by advances in routing algorithms and availability of alternative transportation means has resulted in the development of multi-modal route planners. The concept is to calculate trips that involve the use of more than one transportation means, such as metro and bus, as well as any combinations of car, bike walk and public transportation. Common terms used for these combinations are 'park and ride' which refers to taking the car to a parking spot and then continuing with public transportation and 'bike and ride' which refers to using the bicycle to reach public transportation means and then either parking the bicycle or taking the bicycle along.

Moreover route planning applications offer a number of options that allow to fine tune the calculation of the trip results as well as filter them. Options may refer to the type of trips (e.g., shortest, most comfortable), the desired number of transportation means changes, elevation level (when walking or cycling is involved). Figure 1 depicts the user interface of a route planner. Users select the means of transportation they want to use and the application finds uni and multi modal trips.

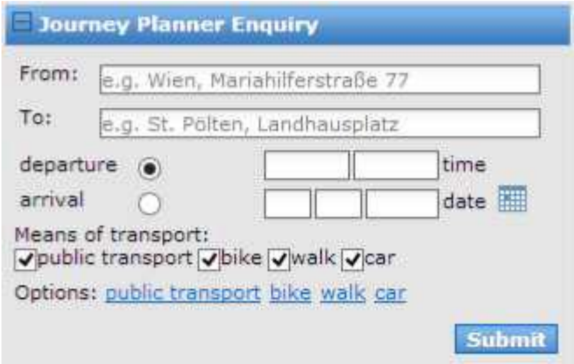

Figure 1: Indicative Journey Planner options (adopted from the Austrian anachb.at web application).

Note that in the following we will be referring to routes, trips and segments. A route is defined by a start and destination and is comprised of one or more trips. A trip is defined by a sequence of segments with each segment referring to one transportation mode. Uni-modal trips comprise of one segment whereas multi-modal trips can have two or more segments.

2.1.1 Overview of Choice Architecture strategies

Human decisions are influenced by numerous noticed or unnoticed factors (Thaler, 2010) enforced by the environment where the decision is being made. This is because of humans' bounded rationality which refers to the notion that humans cannot always evaluate all available alternatives due to cognitive limitations and the finite amount of time they have to make a decision (Cremonesi et al., 2010). This results to decisions which are taken by applying the bounded rationality and after having greatly simplified the set of available choices. The decisions are perceived as satisfactory although they are not necessarily optimal.

In our case, information regarding transport-related attributes such as travel time, travel costs and carbon emissions has been shown to lead to changes in travellers' choices (Avineri and Waygood, 2011). The reason is that individuals base their choices on the content and attributes of the choice set but also on the presentation and context of information (Ben-Akiva, 1985).

So if we properly design and incorporate small features or nudges in the choice making process, we can assist individuals to overcome cognitive biases, without restricting their freedom of choice. This is known as a 'choice architecture' process. Effective choice architecture is based on a set of principles which when applied carefully can guide human decision making. Namely, following Thaler et al. (2010) these principles are:

- *Defaults* refer to preconfigured options people usually make use due to laziness, fear or distraction.
- *Structure Complex Choices* is about helping users to identify the alternatives that correspond to their preferences.
- *Understanding Mappings* refers to weighing decisions and aligning them with personal welfare.
- *Expect Error* is based on the fact that humans make errors, thus choices have to be designed such that they are error forgiving.
- *Give Feedback* assists users to understand when they are doing well and when they are making mistakes.
- *Incentives* provide motivation towards optimal decisions.

The choice architecture task which is the focus of our work refers to the proper structure of the available route choices. Our approach leverages the first two principles mentioned above and considers aspects of choice overload and information filtering in order to facilitate the decision task of selecting the best route. In the following we provide the theory behind these principles and show how we adopt them in our recommender (see also Table 1 for a summary).

Table 1: Overview of the proposed approach.

Sustainable choice Problem	Description	Our Approach
Defaults	The tendency of individuals to remain with the default option even when there are potentially better alternatives (Madrian, 2001)	Provide by default options with low CO_2 emissions
Structure Complex Choices	The inability of users to make effective comparisons of the available alternatives (Levav et al., 2010)	Group alternative trips based on transportation modes
Choice Overload	Limited cognitive capacity of individuals that does not allow to consider every available option (Jacoby, 1984)	Filter alternative trips based on user preferences and heuristics

2.1.2 Defaults and decision inertia

Decision inertia is the tendency of individuals to remain with the default option even when there are potentially better alternatives. The underlying causes can be transaction costs due to switching to another option and procrastination due to behavioural self-control problems (Madrian et al., 2001). The effects of decision inertia and defaults has been proven on a variety of real-world choices in domains such as investment (Cronqvist and Thaler, 2004), organ donation (Johnson et al., 2012), marketing and beyond (Goldstein et al, 2008).

The ease of use as well as the ability to guide choice while preserving the freedom of choice renders defaults a powerful and popular tool for choice architects. Defaults can take a number of forms including simple defaults (choosing one default for all), random defaults (assigning a configuration at random e.g., for experiments), forced choice (force the user to make an active choice before giving a product or service), sensory defaults (where the defaults is set according to what can be inferred about the user) and predictive defaults (which are intelligently adjusted based on user observation) (Wilson et al., 2013).

We follow a forced choice approach in which we include options with public transportation, walking, bicycle and park and ride by default, even if the user selection does not include these options. The conditions upon which these defaults are applied are as follows:

- If a user selects the option of public transportation, the option of walking to the destination will be displayed whereas if the user owns a bicycle, the option to use a bicycle will be included as well.
- If the user selects the option of car, then the option of park and ride and the option of public transportation will be included in the choice set as well.

2.1.3 Structuring complex choices

The structure of the choice set has been proven to affect the way decisions between choice options are made and has implications on the exploration of the option space including the information and attributes examined as well as the information and attributes to ignore (Wilson et al., 2013). Although this feature of a choice environment may seem trivial, it can greatly impact choice selection.

For decision tasks that involve configuration decisions over a number of options, users are prone to resolve to different strategies. For example, consumers are more likely to choose predefined levels of attributes when they face a high number of configuration options than when they have a smaller number of options (Levav et al., 2010). Furthermore, individuals first screen alternatives on a subset of attributes and after this initial screening resolve to comparisons for the remaining set of alternatives (Hauser and Wernerfelt, 1990). This means that by facilitating comparisons, during the screening stage, on a small set of attributes can lead to a stronger preference for options favoured by these focal attributes (Diehl et al., 2003).

Another important aspect of choice structuring is the sorting of alternatives, which can be an effective way to improve choice outcomes (Dellaert and Hadubl, 2012). In addition, the provision of upfront information about the distribution of choice attributes, can be helpful to users who are not familiar with the decision task (Rosenfield, 2008). Our approach is to group the available options in order to allow for optimal comparisons. To this end, we group trips based on one of the major transportation modes, i.e., walk, bicycle, public transportation (this group includes multi-modal trips with bicycle and public transportation) and car (this group includes multi-modal trips with car and public transportation). Moreover, in order to infuse a nudge and urge users to consider and examine the environmentally friendly options, first we rank the groups according to the CO2 emissions. This normally leads to a ranked list that begins with walk and bicycle and ends with public transportation and car trips.

2.1.4 Choice overload

The state when users are overwhelmed with alternatives is known as choice overload (Jacoby, 1984). Past research has examined the effects of the number of alternatives on decision behaviours (see e.g., (Scheibehenne, 2010)) but there is no generic recommendation of how many alternatives to present. Nevertheless, intuitively, the number of alternatives should encourage a reasoned consideration of trade-offs among conflicting values and yet not seem too overwhelming to the user (Johnson and Goldstein, 2003).

In our case, given a user u we want to find a subset S of AvailableTrips(u) such that |S| = PresentedTrips and the choice of S provides a good balance between the user perceived trip utility and CO2 emissions. Our approach is based on utility-based recommenders and leverages users preferences provided through the route planning application, which are then transformed to a user perceived trip utility value. The utility and the CO2 emissions of a trip are provided as input to an algorithm (see section 3 for a detailed description) that selects |S| trips to be presented to the user.

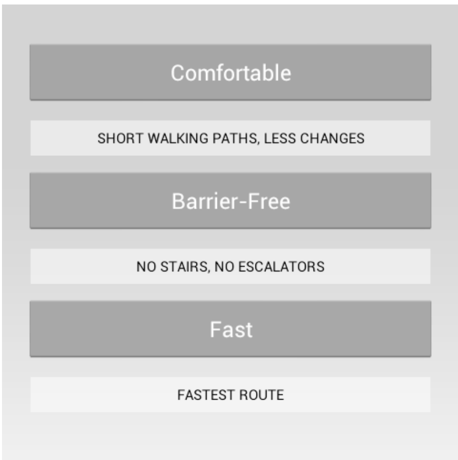

Figure 2: Preferences users set in our application.

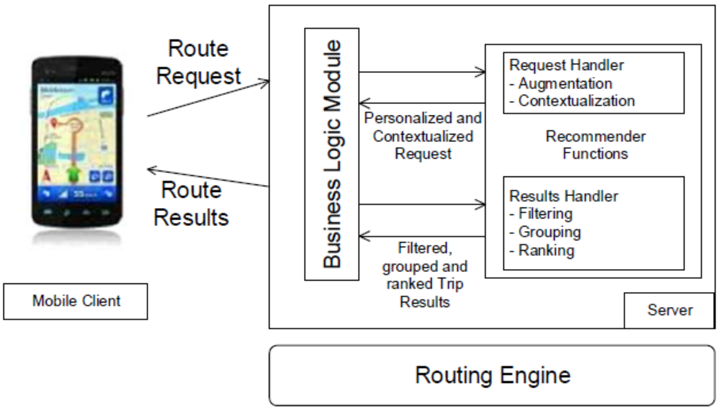

Figure 3: Behavioural Change Support System architecture.

2.2 Implementation

Our recommender is seamlessly integrated in a legacy routing engine. It makes use of the available routing options, which can be set by the user, as well as the route attributes and route characteristics provided by the routing engine. Following this implementation approach, there is no cognitive overhead or additional learning curve from the user's perspective. The process of finding alternative trips towards a destination is the following. First users set the start - destination points. Then a set of quick options are offered to determine the desired trip characteristics: fast, comfortable and barrier free (see Figure 2). The barrier free option optimizes the routing options such that stairs, long walks and many transportation mode changes are avoided and can be used by e.g., persons with disabilities or persons who carry bags. Users can fine tune the option set by setting preferred transportation modes (car, public transportation, bicycle, walk) as well as other fine grained options such as the preferred number of changes in the case of public transportation or the preferred walking and bicycle speed. For a thorough list of available options see http://www.anachb.at/.

The architecture of the system and the recommender is depicted in Figure 3. The client application contains the front-end and is implemented for android based smartphones. User requests are sent to an application server where a centralized business logic component handles the communication between the client, the routing engine and the recommender. The latter is comprised of two functions the RequestHandler and the RouteHanlder.

First, a client request is forwarded to the RequestHandler function of the recommender, where it undergoes contextualization and augmentation. In a second step it is sent to the routing engine that generates a number of alternative trips from the requested route. The results of the routing engine are delivered to the RouteHanlder function of the recommender. This function filters and ranks the results with an aim to present the most relevant, structure and rank them according to CO2 emissions.

2.2.1 Request Handler

The main functionalities performed in this function are request contextualization and augmentation. Contextualization is currently dependent on weather information retrieved from a publicly accessible weather service. When cold or hot temperatures (we consider the context to be cold when temperatures are < 5◦C and hot for > 30◦C) and rainy conditions are detected the maximum walking and bicycle time are set to low values below 15 minutes in the route request. The request augmentation overrides existing restrictions and includes always walk and public transportation as selected modes of transport. Furthermore in cases where the car has been selected, the request is augmented to include park and ride routes. Note that our aim at this point is to retrieve an increased number of results from the routing engine. At a later stage results that are not relevant are filtered and are not presented to the user.

2.2.2 Results Handler

This function filters and ranks the available trips provided by the routing engine. In order to select an optimal set of trips to present, we infer a utility value per trip. A trip in our setting is being annotated by the routing engine to belong to one transportation mode as follows: walk, bicycle, bike take along (i.e., carrying the bicycle within public transportation means), bike and ride (i.e., parking the bicycle and not carrying it within public transportation means), public transportation, park and ride (i.e., parking the car and then taking public transportation), car. Since the number and utility of the results per transportation mode for given start and destination points vary we choose to group results according to one of the major transportation modes, i.e., walk, bicycle, public transportation (this group includes bike take along, bike and ride, public transportation, park and ride) and car.

Our tests have shown that the walk, bicycle and car groups comprise of one or two trips whereas the public transportation group contains more than 4 different trips (tests were performed for a selection of ten start destination points with varying distances). This grouping allows us to compare, rank and filter trips within groups as it would not be feasible to compare the utility of a trip that includes only walking with a trip that includes only the use of a car. Moreover from the user's perspective, choices are structured and can be easily compared.

Before calculating the trips' utility value, we normalize results and prune those whose values exceed certain thresholds under the assumption that for total trip duration and total walking/bicycle time criteria, the shortest values will be preferred by the majority of the users. The pruning process begins by identifying the minimum duration, minDur per group of trips and those which duration exceeds minDur by 1.5 times are omitted.

The approach is based on the Ordered Weighted Average OWA multi-criteria method with the use of the neutral operator (see Rinner and Raubal (2004) for a detailed description of the method). Based on the trips attributes and characteristics we define the following four criteria with corresponding values:

Total trip duration which refers to the estimated time which is required to reach the destination for the specific trip. This criterion can take the values highDuration, mediumDuration and lowDuration. In order to calculate the per trip value we identify the mean and maximum total duration per group of trips (meanDur and maxDur) and assign the trip specific options: lowDuration for trips with durationminDur < tripDuration < meanDur − 0.3 < meanDur, mediumDuration for trips with duration meanDur − 0.3 < meanDur < tripDuration < meanDur + 0.3 < meanDur and highDuration for trips with duration meanDur + 0.3 < meanDur < tripDuration.

Total walking and bicycling time which refers to the estimated time that will be consumed in walking and/or cycling for the specific trip. This criterion takes the same values as the total trip duration and the per trip values are calculated with the same manner.

Comfort which we define as the number of transportation mode changes within a trip. The assumption here is that when users need to change a high number of transportation modes, the comfort of the trip reduces. With this in mind a highComfort value is set for trips with less than 2 segments, mediumComfort for trips with 3 segments and a lowComfort for trips with higher than 3 segments.

Trip emissions which is an estimation of the total CO_2 emissions that will be generated if the specific trip is followed. The values of the emissions criterion depend on what we call ´nominal emissions´. Considering that walking and bicycle have the lowest possible CO_2 emissions (zero) and that car (on average) has the highest, we define the nominal emissions of a trip as the CO2 that would be produced if the whole trip distance was covered by an imaginary transportation means which emits CO2 equal to the average metro emissions (this is estimated at 20 CO2 grams per km based on data from the Vienna transportation authorities).

In order to calculate trips utility, following the OWA multi-criteria method, we define a high, medium and low preference level per criterion value. These preferences levels are inferred by the options users select when planning a trip. Table 2 shows our mapping of preference levels and criteria values based on user options.

Each preference level is mapped to a numeric value for later processing: 1 for low, 2 for medium and 3 for high. Once user preferences are identified and all the criteria values are selected, we calculate the total utility per trip as a weighted average of the criteria values and the trip emissions:

$$U_{trip} = (tD + WB + C) * \alpha + E * (1 - \alpha) \quad (1)$$

Where tD is the value of the total duration criterion, WB the value of the walking/ bicycle duration criterion, C the value of the comfort criterion and E the value of the emissions criterion. We set a = 0.6 in order to weigh higher the characteristics of the trip.

In order to achieve good coverage with respect to the set of displayed trips and not overwhelm the user with choices, we limit the number of trips to one that involves walking, one that involves bicycle, up to three that involve public transportation, one that involves car and one that involves park and ride. This means that the maximum alternatives displayed to the user are seven.

Table 2: Criteria Mappings.

Criterion	Values	Preference for option 'fast'	Preference for option 'comfortable'	Preference for option 'barrier-free'
Total trip duration	lowDuration	high	medium	medium
	mediumDuration	medium	high	high
	highDuration	low	low	low
Total walking and bicycling time	lowWBDuration	high	medium	high
	mediumWBDuration	medium	high	medium
	highWBDuration	low	low	low
Comfort	lowComfort	high	medium	low
	mediumComfort	medium	high	medium
	highComfort	low	low	high

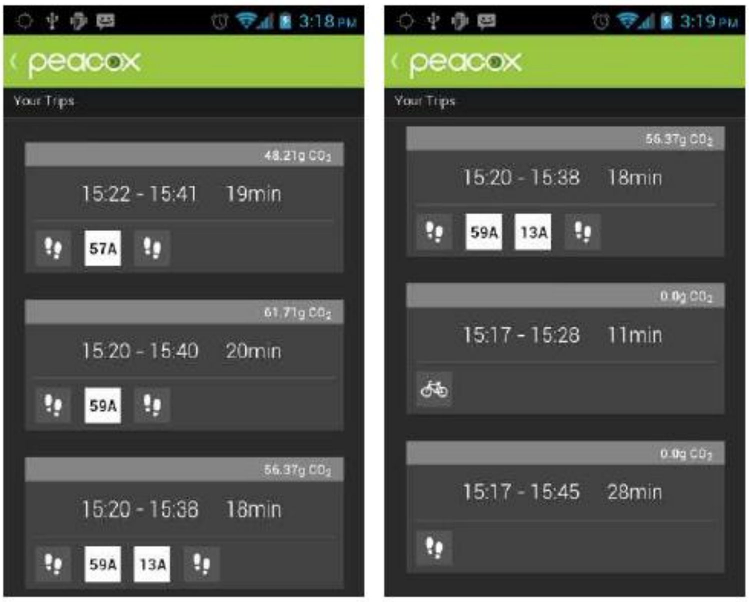

Figure 4: Indicative Screenshots of the PEACOX app.

3. Persuasive Messaging System

3.1 Background

The PEACOX Persuasive Messaging System (PMS) is designed to increase the effectiveness of PEACOX persuasion attempts when users are about to select a trip to follow in order to reach their destination. This persuasive component combines contextual and information personalization elements with active technology-initiated coaching to highlight to users the most eco-friendly trips. We use automatically generated persuasive messages, i.e. messages that implement persuasion principles.

3.1.1 Persuasion Principles

The array of persuasion principles or influence tactics that can be used to change attitudes and behaviours of users can be overwhelming. Both researchers and practitioners have made extensive use of the categorization of persuasive messages as implementations of more general influence principles. Theorists have varied in how they individuate these influence principles (see also the work reported in PEACOX D5.4.1): Cialdini (2001, 2004) develops six principles at length, Fogg (2003) describes 40 strategies under a more general definition of persuasion, Kellermann and Cole (1994) gather 64 groups from several taxonomies, and others have listed over 100 (Rhoads, 2007). These different counts result from differing levels of exhaustiveness, exclusivity, emphasis, and granularity (Kellermann and Cole, 1994).

For our work we selected the following eight principles to focus according to the framework of Oinas-Kukkonen and Harjumaa (2008). The selection of the principles is also based on the relevance to the PEACOX application and the availability of information in the system which can be presented to the users.

<u>Principles related to primary task support:</u>

Simulation: System should provide means for observing the link between the cause and effect in regard to their behavior.

Self Monitoring: System should provide means for users to track their performance or status.

<u>Principles related to dialogue support:</u>

Suggestion: System should suggest users certain behaviors during the system use process.

Praise: By offering praise a system can make users more open to persuasion.

Reminders: System should remind users of their target behaviour during the use of the system.

Principles related to system credibility support:

Authority: When a request or statement is made by a legitimate authority, people are more inclined to comply or find the information credible.

Principles related to social support:

Social Comparison: System should provide means for comparing performance with the performance of other users.

3.1.2 Related Applications

Persuasive Messaging Systems are emerging as a new way to influence user behaviours in various domains. One of the major factors for their consideration is the proliferation of ubiquitous and pervasive technologies including the widespread usage of smart phones. Application domains span from energy efficiency to marketing and advertising. In the following we present recent work and applications.

Gamberini et al. (2012), describe EnergyLife, a mobile application that provides feedback to encourage electricity conservation practices. The proposed system relies on real consumption data which are automatically fed into the application by individual electric devices, and returns consumption information along with tips, quizzes, historical data, and a social community. The design of EnergyLife is fully oriented to make its feedback both action-based and actionable as a way to apply the principle of tailoring in persuasion (i.e., making persuasive information relevant to the specific characteristics of the recipient and as a strategy to make feedback more effective. The authors explore smart advice tips that are triggered by specific usage patterns and that include customized text. The tips are generated through 13 ‘smart advice templates’ which were defined during the design phase of the system.

Kaptein and van Halteren (2013) focus on message and persuasive strategies adaptation according to the users’ actions. They define adaptive persuasive systems as ‘‘systems that select the appropriate influence strategy to use for a specific user based on the estimated success of this strategy.’ And ’propose a framework for designing such systems. Their framework comprises of three main elements: user identification, representation of different persuasion strategies and measurement of their effectiveness.

In terms of user identification, available means include for example cookies in web environments or bluetooth keys used by mobile devices (Kostakos, 2008), face recognition (Hazen et al., 2003), or fingerprints (Caplan, 1990) in ubiquitous environments.

Representation refers to the selected persuasion principle For example, a digital exercise coach can influence users to exercise more by having users set targets (commitment principle), coupling users to others (consensus principle), or by providing advice from a fitness instructor (authority principle).

Measurements of success are applied to individual users and determine whether an appeal was successful, or what a measure of success would entail.

In order to personalize and adapt the employed persuasive strategies, the authors employ a Bayesian approach where prior information on past user behaviour is included in a Beta-Binomial distribution. The strategy with the highest expectation value is selected and a message is drawn from a pool of messages.

3.2 Implementation

The architecture of the PEACOX PMS is presented in Figure 5. The context probes gather contextual, the user profiles holds user preferences and behaviours and the messages pools contains a list of messages already mapped to persuasive strategies. The synthesis and adaptation component consolidates the available information and selects which message will be presented to the user. Note it is not mandatory that a messages will always be presented. A description of the components is provided below.

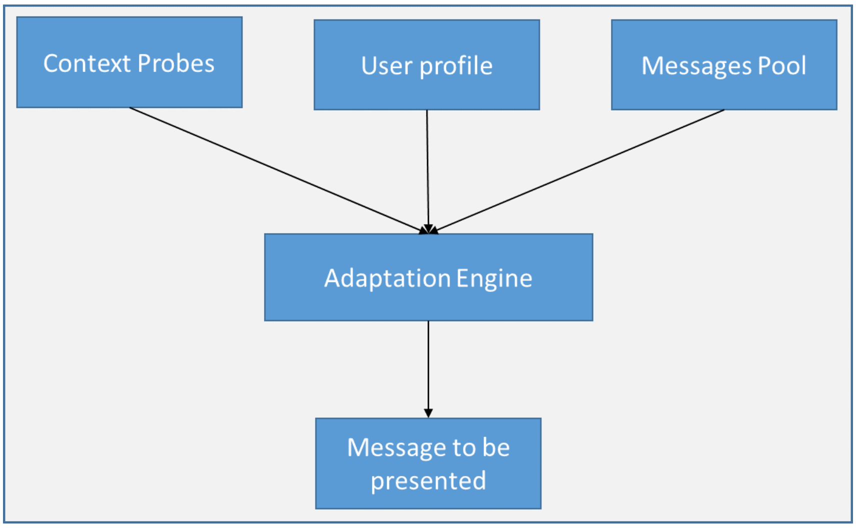

Figure 5: Architecture of the PEACOX PMS.

3.2.1 Context probes

We have implemented eight context probes positioned in various places of the trip filtering and trip selection process that gather information regarding the trips' characteristics and emissions, user and peers behaviour as well as the status of the weather.

Probe 1: DestinationInWalkingDistance: This probe analyses the duration of the trips and estimates whether the destination is in a walking distance. For this purpose a configurable by the administrator threshold is used which is checked against trips that involve walking. This means that in case the duration walking trip is lower than the threshold, the destination is considered to be in a walking distance and the probe is set to true. The value of the threshold is currently set at 15 minutes.

Probe 2: ComparableCarAndPTRouteDuration: This probe identifies cases where the duration of the trips with the use of a car and trips with the use of public transportation are comparable. The checks are applied to the recommended trips and the probe is set to true when the percentage difference is lower than a threshold which can be parameterized by the administrator. The value of the threshold is currently set at 20%, whereas the percentage difference is provided by the following formula:

$$\frac{|MaxDurationForCar - \mathrm{MaxDurationForPT}|}{(MaxDurationForCar + \mathrm{MaxDurationForPT})/2}$$

Probe 3: HighEmmissionsDifferenceBetweenCarAndPT: With this probe we quantify the difference of the emissions between the car and public transportation trips. Again we use a configurable factor that indicates if the projected emissions by reaching the destination with a car are too high compared to those by using public transportation. The factor is currently set to 2.

Probe 4: TooManyCarRoutes: The probe queries the user profile and recorded stages of trips the user has followed in the past. We calculate and identify if the user has a habit of using a car at the specific time of day when the PEACOX app is used. For this purpose the day is divided in four quarters with each having a six hour duration. The probe is set to true in cases where the car is identified as the most used means of transportation and can be used to inform the user to change her habits and consider to use public transportation for a change.

Probe 5: TooManyPTRoutes: This is a similar probe to the previous but considers the public transportation trips and is set to true when in cases where public transportation is identified as the most used means of transportation and can be used to inform the user to change her habits and consider to use bicycle and/or walking for a change.

Probe 6: EmmissionsIncreasing: This probe analyses user habits and infers whether there is a tendency in the users' habits that causes increase in the emissions caused by the specific user. The check is performed on a sliding window of the last fourteen days. The window is then divide to two equal parts each consisting of seven days. In case the emissions of the last 7 seven days are higher than the previous seven days, we infer that there is an increasing tendency of emissions generation.

Probe 7: EmmissionsHighComparedToOtherUsers: With this probe we check the performance of the user against social peers. In order to normalize the user behaviours we rank users according to their calculated emissions as indicated by past and tracked behaviour and compare the current user's behaviour against the median of the monitored users. If the position of the current user is higher than the one of the median then this context probe is set to true.

Probe 8: NiceWeather: The probe is related to the current state of the weather and is set to true in cases when the weather conditions are within comfortable limits and allow users to walk, take the bicycle or public transportation without problems. We take into account the temperature and the precipitation.

3.2.2 User Profile

For the purposes of the PMS we relied on existing elements of the PEACOX database and defined a set of new elements which support message personalization and adaptation. In more details we employ the following elements:

- Users' travel history recorded through the smartphone GPS and analysed by the PEACOX ETHZ client. The PEACOX database contains a list of stages and the corresponding mode of transportation the user took for the specific stage.
- Users' travel habits captured through a questionnaire before the trial which act as a profile seed until the system has enough information recorded through GPS monitoring.
- Persuasion attempts logged each time the user is presented with a message. By analysing the logs we can infer which attempts work best and adapt the system on a per user basis.

3.2.3 Messages Pool

The messages pool contains a set of text – based messages with each one up to 65 characters long. The 65 characters limit is set in order to be able to display the message in the PEACOX application trip selection screen as show in Figure 6.

In order to define the messages which will be used, perform queries and select the proper messages to display as well as set the basis for further extensions we defined a conceptual model as depicted in Figure 7.

The core concept is the message which is associated with one or more context elements, means of transportation, user types and persuasive strategies. When the domain experts define a new message, they have to select the message attributes include the context for which the message is relevant, the user type, the transportation means and the persuasive strategy that is represented by the specific message. We have selected seven persuasive strategies to implement.

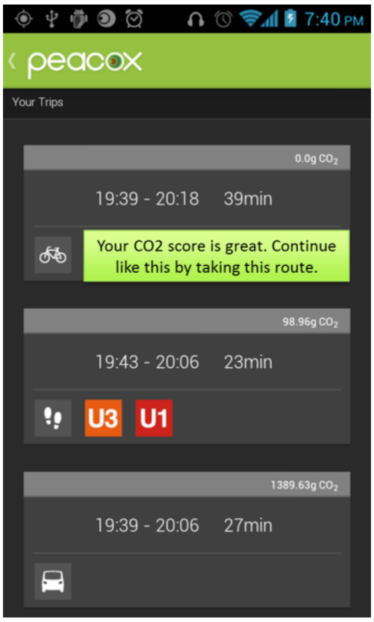

Figure 6: PEACOX application trip selection screen.

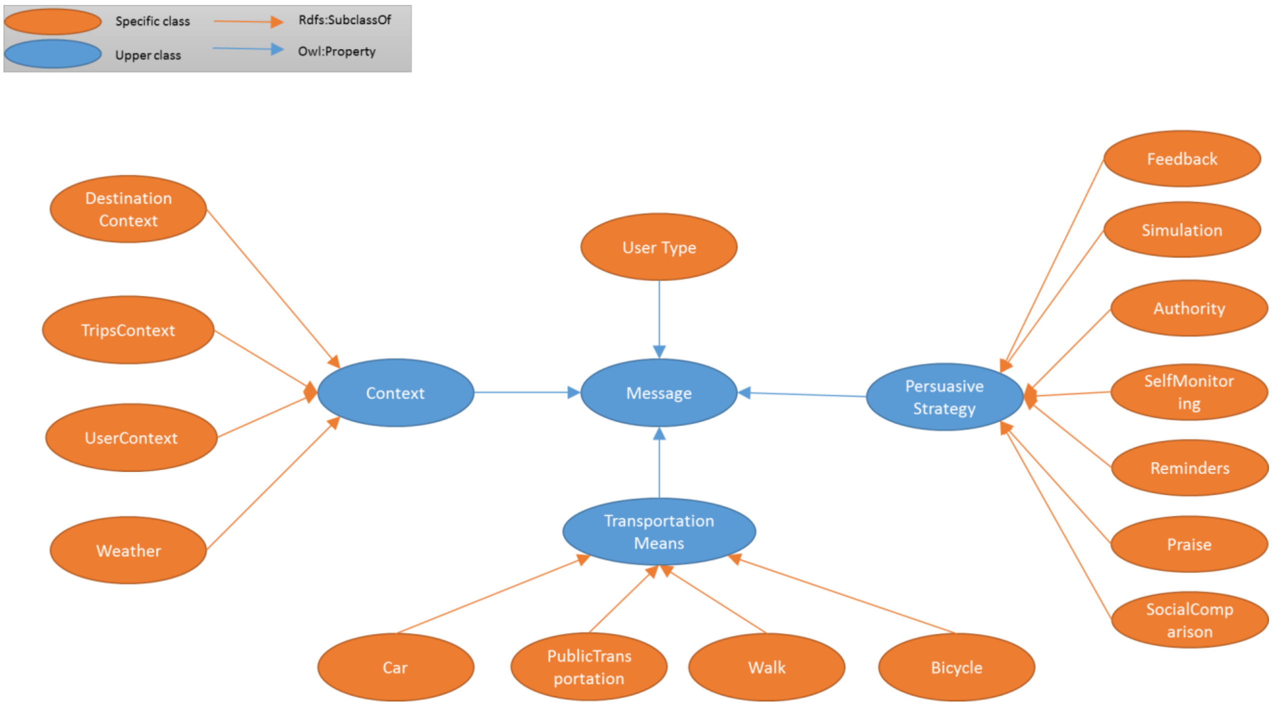

Figure 7: Conceptual model of the PMS messages.

After having the conceptual model in place we defined a set of twelve relevant messages which are stored in the PEACOX database as shown in Table 3. The message selection algorithm defines a utility value per message and the message with the highest utility is selected each time a user is presented with a list of trips. The utility is the sum of relevant context values, strategies which are most probable to affect the user and

Table 3: List of messages we are using in the trip selection process.

ID	Text	Strategy	Context	Transportation Means
1	Destination is in a walking distance.	Feedback	Destination in walking/bike distance	Walk
2	Destination is in a biking distance.	Feedback	Destination in walking/bike distance	Bike
3	Why don't you walk? It's not too far!	Suggestion	Destination in walking/bike distance	Walk

4	Why don't you take a bike? It's not too far!	Suggestion	Destination in walking/bike distance	Bike
5	You have been using a car a lot the past days.	Self-Monitoring	Too many car routes	Car
6	You have been using public transportation a lot. Good job.	Praise	Too many public transportation routes	Public transportation
7	Your emissions are decreasing!	Praise	Emissions decreasing	Public Transportation
8	Take this route to save CO2.	Simulation	Comparable Car and Public transportation duration.	Public Transportation
9	PEACOX sees that PT and car options have similar duration.	Authority	Comparable Car and Public transportation duration.	Public Transportation
10	Your peers are saving more. Consider using this route.	Social Comparison	Emissions increasing compared to others.	Public Transportation
11	The weather looks fine. Consider this route!	Suggestion	Weather	Public Transportation / Walk / Bike
12	Take the opportunity to save some CO2 today.	Reminder	Any	Public Transportation / Walk / Bike

4. Persuasive Eco-Feedback

4.1 Background

Eco-feedback and Eco-visualization technologies aim to provide feedback on individual or group behaviours and promote greater understanding of site-based environmental data in order to encourage conservation of energy and reduce environmental impact (McCalley and Midden, 1998; Holmes, 2007).

Eco-feedback may be seen as an extension of research in persuasive technology (Fogg, 2002), although related studies extend back to more than 40 years in fields such as environmental psychology and applied social psychology. Related research initiated from two major problems: the energy crisis of the 1970s and 80s and the climate change era beginning in 1995 (Ehrhardt-Martinez et al., 2010). Examples include, Kohlenberg et al. (1976) who found that a light bulb, which illuminated when households were within 90% of their peak energy levels, changed energy usage behaviours as well as numerous papers providing evidence that real time feedback has been shown to increase levels of energy conservation both at home and in the workplace (see e.g. Bittle et al. 1979, McClelland and Cook 1979, Dobson and Griffin 1992, Parker et al. 2009).

The focus has been mostly on energy studies which have revealed that displaying daily or continuous load levels in various text-based formats has the capacity to increase conservation behaviour. For example Bittle et al. placed daily feedback cards in residential mailboxes that reported the kilowatts used per day an action that resulted to an average of 1-9% less electricity compared to those did not receive feedback (Bittle et al 1979). Moreover, users in homes where a device called "Residential Electricity Cost Speedometer" reduced electricity consumption by 12.9% (Dobson and Griffm 1992). A similar approach was followed by a Canadian power company who gave to 500 Ontario homes the PowerCost Monitor from mid-2004 to early 2006. The results showed an average 6.5% drop in total electricity use when compared with a similarly sized control group.

For more detailed reviews of related eco-feedback studies see Darby, 2000; Abrahamse et al. 2005; Fischer, 2008; and Ehrhardt-Martinez et al., 2010.

Recently a new set of studies emerged where range of presentation mediums for feedback are employed, including: ambient displays (e.g., Arroyo et al., 2005; Gustafsson and Gyllensward, 2005; Paulos et al., 2006; Pousman et al., 2008), mobile phone applications (e.g. Petersen et al., 2009), desktop games (e.g., Bang et al., 2007), and social websites (Mankoff et al., 2007).

Figure 3.4 is adopted from Froelich (2011) presents interfaces used in related systems. In (a) uses a camera and a projection system is used to project the inside of a trashcan outwards (Paulos and Jenkins, 2006). In (b) a display uses sensors and living plants to provide feedback on recycling and waste disposal (Holstius et al., 2004). In (c) a power aware cord provides an ambient energy usage display (Gustafsson and Gyllenswärd, 2005). In (d) mobile phones are used for home energy feedback (Petersen et al., 2009). In (e) eco-feedback is provide through a virtual game environment (Bang et al., 2006). In (f) pro environmental behavior tracking is performed through a social website (Mankoff et al., 2007b). In (g) an ambient public display shows the environmental impact of printing (Pousman et al., 2008).

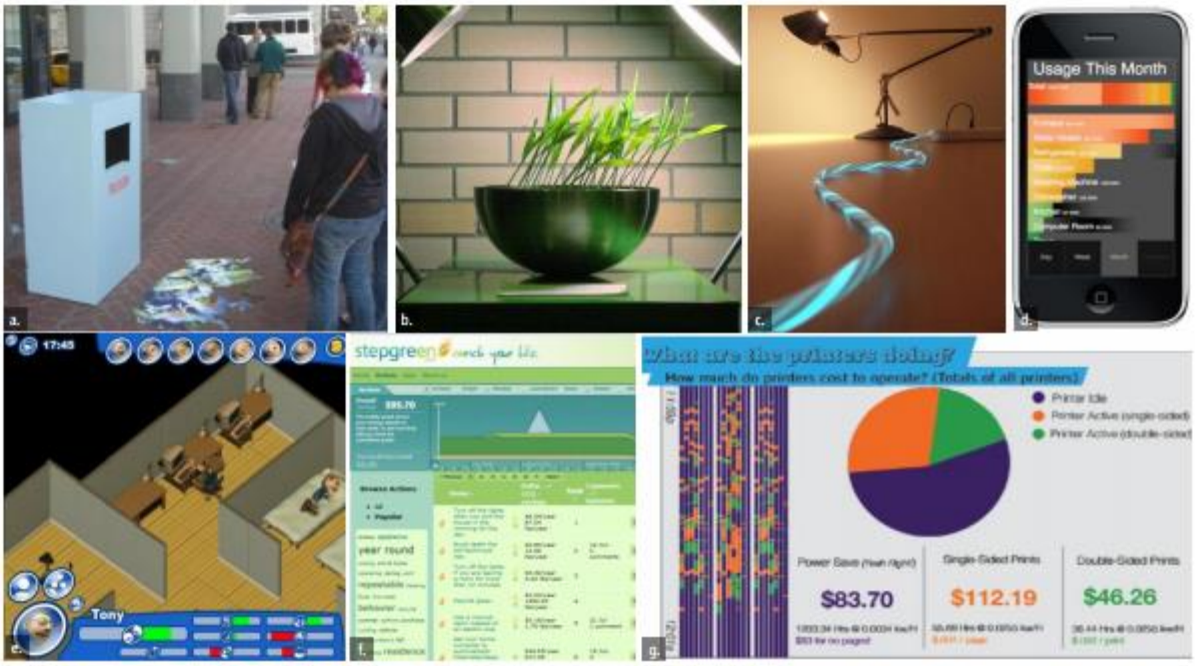

Figure 8: Examples of interfaces used in HCI systems for energy efficiency and sustainability.

To our knowledge only the ubigreen application (Froehlich et al. 2009) has provided an approach for personal awareness about green transportation behaviors through iconic feedback the app shows small graphical rewards are earned by taking “green” transportation such as riding the bus or train, walking, biking, or carpooling. However the app only counts these activities once sensed and modifies the background (wallpaper) of the user’s phone is updated accordingly. As we describe in the next section, our approach considers the actual CO2 emissions users cause in their trips.

4.2 Implementation

The PEACOX CO2 tree is a simple means for users to track their personal CO2 emissions (self-monitoring). It's an eco-feedback interface and offers a visualization of past CO2 emissions in the form of a tree that is losing or growing leaves depending on a user's previous behaviour. Its key strength is the simple visualisation of the eco-friendliness that can be understood at a glance.

The tree is centrally placed on the home screen of the application. Every time the app is launched, the tree is visible to the user, providing quick information about their personal CO2 status. The tree shows a varying number of leaves that fill up or get removed depending on the user's emission behaviour.

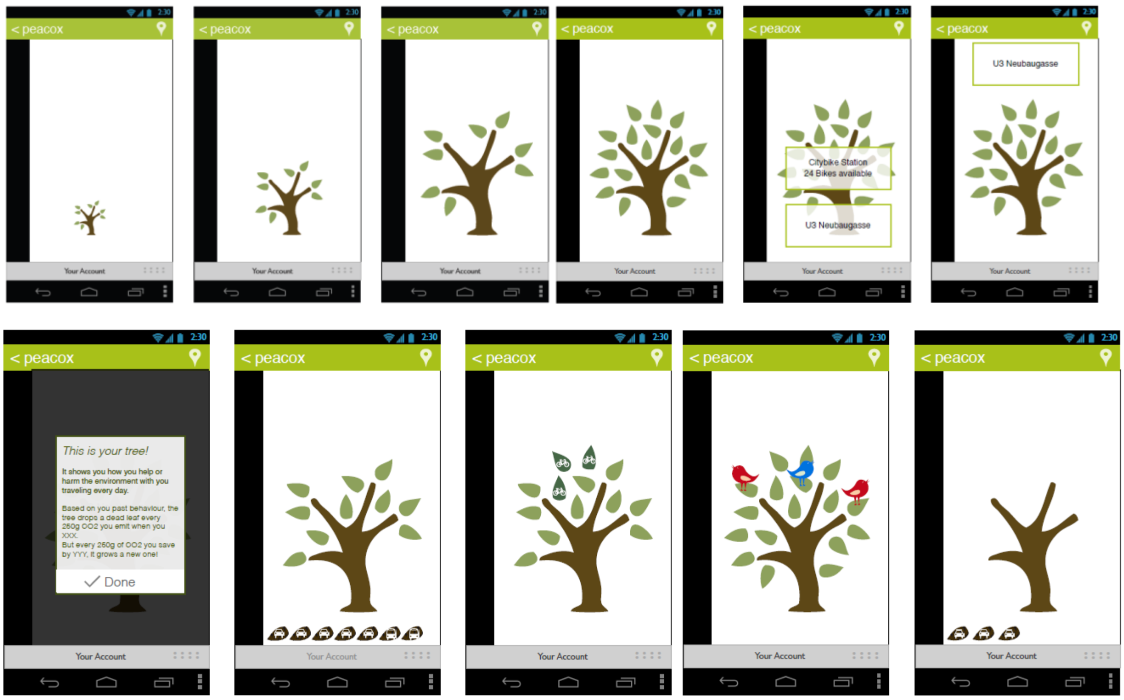

Figure 9: Early prototypes of the PEACOX tree eco-feedback mechanism.

Figure 9 shows some of our early design prototypes for the tree visualization. After a number of design rounds we concluded with the design presented in Figure 10. At a minimum, the tree has only a stem and no leaves. At a maximum level, all 74 leaves light up.

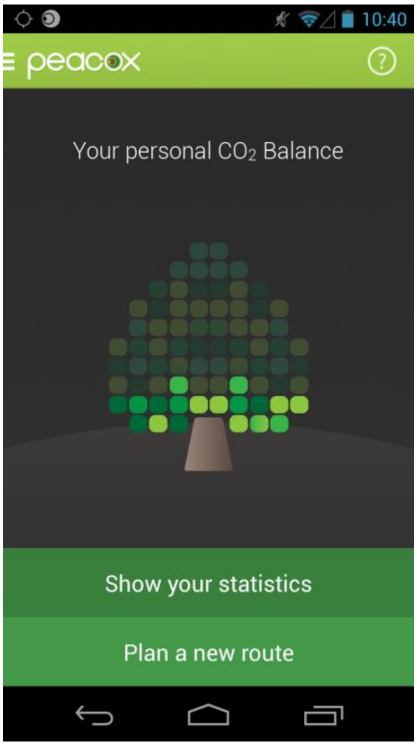

Figure 10: Final design of the PEACOX tree.

For the implementation of the tree we considered that the CO2 feedback needs to accommodate a range of behaviour types. For example, a person that is primarily cycling will have almost zero emissions. On the other hand, a person that has to drive a car every day for their job will in comparison have a lot of emissions. The issue of what are "sustainable" emissions or not is very complex and involves a number of factors outside the control of the individual, including the length of their intended journey.

Based on the above rational, we initially selected the following emissions thresholds for the PEACOX tree to lose or gain leaves:

- 0-50 grams/km gains a leave
- 50-100 grams/km gains no leave
- over 100 grams/km loses a leave

However, if such static thresholds are applied, this will result in an always-full tree for the cyclist and an always-empty tree for the car driver. The aim of PEACOX is, however, not to punish car drivers for their behaviour, but to support and encourage positive behaviour changes. Thus, also small improvements should be reflected in the tree. This means that the conversion of grams of CO_2 emitted into leaves on the tree needs to be adaptive.

While emissions are usually measured in absolute mass terms, e.g. grams of CO_2 produced, it is important to treat these values on a per km basis for the tree. Otherwise a user taking a short trip will gain points for all options even if they drive.

Based on these considerations, we developed an algorithm for the tree that presents a combination of rewarding users when they are doing well on an absolute scale (i.e. having low emissions) and on a relative scale (i.e. reducing their emissions, even if on a high level). The algorithm is presented in the following table as pseudo code:

Table 4: The pseudo code for the tree algorithm

Define: variance = 0.05	//we compensate for 5% variance in emissions to avoid random (positive and negative) rewards due to measurement errors
avg_emission7 = get average emissions for last seven days	//This is a sliding window (i.e. if today is the 22nd, from the 15th to the 21st) and divide it by the total travel distance during that time frame
If emission7 is between 0 and 50 grams/km then: user gains a point	//User is doing well on an absolute level.
else:	
avg_emission7_14 = get average emissions for seven days before that	//i.e. if today is the 22nd, get emissions from the 8th to the 14th and divide it by the total travel distance during that time frame
difference = avg_emission7_14 – avg_emission7	//is there a difference between the last 7 days and the 7 days before? If positive, emissions have decreased.
if difference >= avg_emission7 * variance then: tree grows a leave	//is this difference larger (or equal) than the allowed variance?
else:	
if difference < avg_emission7 * variance OR avg_emission7 is between 50 and 100 then: tree grows no leaves	//is this difference smaller than the variance or even negative, or are the emissions between 50 and 100 grams? This means the emissions are stable or within the zero-reward range on an absolute scale

`else:`	
`tree loses a leave`	`//the user loses a point only if emissions are increasing AND are above 100 grams/km. This ensures that if the user is improving emissions, the tree grows a leave, even if emissions are higher than 100 grams/km. If emissions are changing but are within a certain range (+/- 5%) the user does not get rewarded or punished.`

The algorithm was the implemented in Java and a simple API was designed in order to provide the current score of the user to the interface. Whenever the user opens the PEACOX app, a request is sent to the server to get the current score of the users. The algorithm described in Table 2 runs and a normalized score value ranging between 0 and 100 is provided as a response. This number determines which state of the tree will be presented to the user.

5. Conclusions

In this report we described the work performed in task 5.5 of the PEACOX project. We summarized our experiences gained from studying a choice architecture approach which assists users to uncover transportation options with lower emissions as well as persuasive mechanisms for feedback through messages and proper communication of CO2 consumption. We hope that the results and outcomes of our work help to improve persuasive systems and to develop new ideas and approaches in this area of research.

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