Personalized Persuasion Services for Route Planning Applications

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***Abstract*— Current transportation practices are not sustainable as greenhouse gas (GHG) emissions from the transport sector are increasing at a faster rate than any other energy using sector, especially in urban environments. Technology based behavioural change interventions towards adopting transportation habits that rely more on the use of public transportation, bicycles and walking and less on private cars can provide the means to reduce GHG emissions, mitigate the effects on the environment and improve the quality of life in urban areas. In this paper, we present our approach to support sustainable transportation decisions and nudge users to select more environmental friendly routes through a set of personalized persuasion services which are embedded in route planning applications. The proposed services leverage a multitude of relevant information elements including user profile characteristics and contextual information in order to nudge users to follow green transportation routes.**

Keywords—Behavioural change, nudge, personalization, intelligent transportation systems.

I. Introduction

Current transportation practices are not sustainable as greenhouse gas (GHG) emissions from the transport sector are increasing at a faster rate than any other energy using sector, especially in urban environments [1]. Recent statistics show the magnitude of the transportation sector impact on the environment, which accounts for about 23% of total energy-related carbon dioxide emissions worldwide [2]. Moreover, modern cities suffer from mobility patterns that are highly dependent on private vehicles resulting to highly congested urban environments and conditions detrimental to the quality of life of inhabitants with adverse effects on public health and the environment.

In order to respond to these unsustainable conditions, a broad range of strategies is required, such as increasing vehicle efficiency, lowering the carbon content of fuels, and nudging travellers to shift to greener transportation modes. With respect to the latter, it's important to design and implement approaches that increase travellers' awareness of the environmental impact of travel mode choices and provide behavioural change interventions towards adopting transportation habits that rely more on the use of public transportation, bicycles and walking and less on private cars. Such approaches can provide the means to reduce GHG emissions, mitigate the effects on the environment and improve the quality of life in urban areas.

For delivering behavioural change interventions, technology can be utilized in order to raise individuals' awareness of their choices, behaviour patterns, the consequences of their activities and foster sustainable behaviours. Such technology is broadly defined as persuasive technology and refers to systems which are designed to change attitudes or behaviours of the users through persuasion and social influence, but not through coercion [3]. In the context of sustainable transportation, persuasive technology tailored for and integrated in ubiquitous applications that support mobility, including route planners, can affect travellers' decisions and guide them towards selecting routes that are environmentally friendly.

Persuasive technology for sustainable mobility is an active area of research and numerous systems and implementations exist which aim to motivate users towards making more eco-friendly choices. However, a main drawback of existing applications is the limited use or lack of personalization aspects that consider differences in users' susceptibility to persuasive strategies [4]. In this paper, we present our approach to support sustainable transportation decisions and nudge users to select more environmental friendly routes. The approach provides persuasive interventions, through a set of personalized persuasion services. The proposed services leverage a multitude of relevant information elements including user profile characteristics and contextual information. The generated personalized persuasive interventions urge users to follow environmentally friendly transportation routes and are incorporated within a multi-modal route planning mobile application. The application, is the first version and one of the main outcomes of the OPTIMUM EU funded H2020 project[1].

The remainder of this paper is structured as follows: Section 2 provides an overview of the related work; Section 3 describes our approach for supporting sustainable transportation decisions and nudging users to select environmentally friendly routes; Section 4 concludes the paper and provides our plans for future work.

II. Related Work

A number of applications have been developed over the last years which support users in shifting their behaviour towards more sustainable means of transportation by employing persuasive technology. One of the first mobile persuasive

[1] http://www.optimumproject.eu/

application is UbiGreen [5], which adapts the background graphics of the phone to provide visual feedback that aims to reduce driving and to encourage greener alternatives, including carpooling, public transport, and pedestrian modalities. Other examples of such applications include PEACOX [6], TRIPZOOM [7], Quantified Traveler (QT) [8], SUPERHUB [9], MatkaHupi [10] and IPET (Individual Persuasive Eco-Travel Technology) [11].

According to the literature review by [12], different persuasive strategies such as behaviour feedback, social comparison, goal-setting, gamification, personalized suggestions and challenges have been used so far, and new ones are being continuously developed. Indicative examples of how persuasive strategies can be used include behavioural feedback by tracking user behaviour and providing feedback on the emissions caused by her/his choices, social comparison by comparing one's own mobility behaviour to that of others and suggestion by providing system generated suggestions that urge users to follow more environmental transportation modes.

Similarly to the diversity of approaches, also the implementation details (e.g. mobile trip planner app versus web-based systems) are quite divergent. Findings from the literature review of [13] show that mobile devices are being prevalently used. Regarding the effectiveness of such applications in changing behaviour, a recent review of existing behaviour change support systems designed to promote sustainable travel behaviour [14], concludes that effect sizes are mostly small and methodologically robust studies are largely missing. Hence no definitive conclusion yet can be derived.

Existing applications that focus on personalized persuasion in mobility apps try to personalize specific aspects of a single persuasive strategy and not the persuasive strategy per se. For example, in [15] an approach of personalizing challenges (competition strategy) is described, while in [5] an application that persuades users to make more sustainable choices through personalized suggestions and self-monitoring is implemented. However, further exploration of persuasive strategies' personalization for behavioural change towards sustainable mobility is required. A main drawback of existing applications is the limited use or lack of personalization aspects that consider differences in users' susceptibility to persuasive strategies [4]. Personalized approaches can be more successful than "one size fits all" as they can adapt the selected persuasive strategies to specific users, rather than the general audience and can sustain users' interest over time while providing better results [16]. Although some existing studies on this topic have focused on personalization of persuasive systems in the health domain [17], to the best of our knowledge differences in users' susceptibility to persuasive strategies have not been considered in the transportation domain.

III. Personalized Persuasion services

We aim to support sustainable transportation decisions and persuade users to select environmental friendly routes by providing targeted persuasive interventions, on the basis of user characteristics, as well as contextual and routing information. Our approach is based on two complementary services: the route recommendation service, and the persuasive message generation service. Fig. 1 presents the conceptual architecture of the solution focusing on the main inputs and outputs.

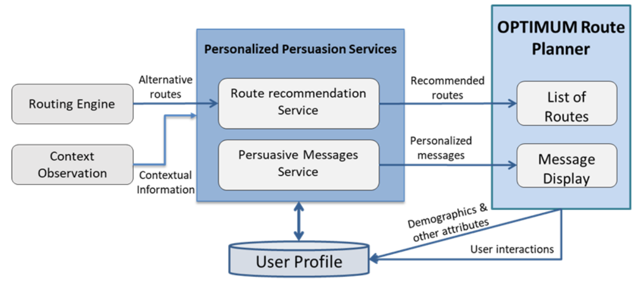

Fig. 1. Conceptual Architecture of Personalised Persuasion Services

The *route recommendation service* receives as input a list of alternative routes for travelling from origin A to destination B. The list is generated by a routing engine and contains an extended set of unimodal (e.g. taking a car or a bus) and multimodal (e.g. park and ride) options for reaching the destination. The service integrates functionalities for filtering and structuring the available routes, and returns a personalized list of recommended routes.

Filtering concerns the exclusion of routes based on preferences set by the user in her profile and other pre-defined restrictions. More specifically users set if they own a car or bicycle and the maximum walking and biking distance they are willing to travel. System defined restrictions include the filtering of routes that commonly do not make sense (e.g. taking a car for 100 meters).

Structuring involves ranking of the filtered routes in a personalized manner, and highlighting one route that is environmentally friendly and adheres to user preferences as well as the current context. A utility function has been defined for ranking the routes and selecting the one to be highlighted. It captures the effect of psychometric and demographic parameters on travel time and cost, user stated preferences, past user behaviour, active context variables and the environmental friendliness of the routes in terms of the emissions caused.

The highlighted route, which is displayed in a prominent position in the OPTIMUM application, is considered as the target for the persuasive attempts (see part 1 of Fig. 2 for an indicative capture of the routes presentation screen of the application).

Given a route with a primary transportation mode (e.g. public transport) as the target for user persuasion, the role of the *persuasive messages service* is to provide a short textual message that aims to nudge the user to follow that particular route. For the first iteration of the OPTIMUM route planner we focus on persuasive messages implementing the persuasive strategies of self-monitoring, comparison and suggestion.

The aforementioned strategies were selected among the nine persuasive strategies suggested by Orji [17] and by taking into account the appropriateness of the strategy for message-based persuasion, the user requirements elicited from potential users of the OPTIMUM application through questionnaires and qualitative face-to-face user interviews, with regards to user preferences to the various strategies, and the suitability of the strategy to the overall scope of the OPTIMUM application.

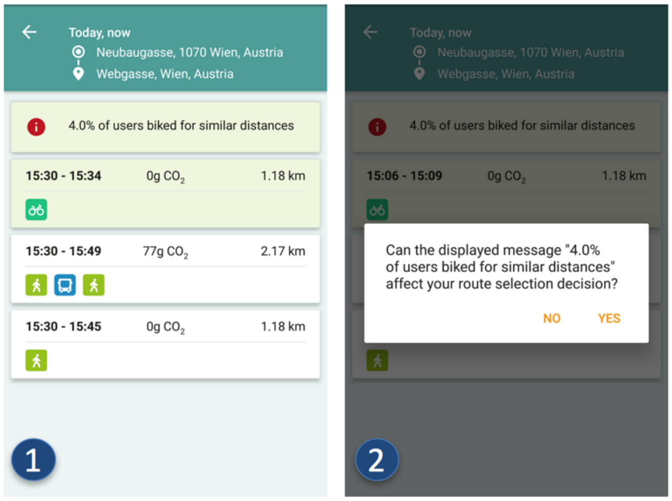

Fig. 1. Indicative example of route results in the Optimum application. Routes are filtered and ranked based on the user profile and a persuasive message is displayed (part 1). A popup asks users to provide feedback with respect to the effect of the message on their decision (part 2).

As mentioned above, past research has shown that users with different profiles are susceptible in different extents to persuasive strategies [16]. With this in mind, our persuasive message generation service is designed such that it adapts to different users and tailors the persuasive messages to the individual, aiming to maximize the impact of the persuasive attempts. The service makes use of a set of persuasive messages corresponding to different persuasive strategies, and selects the message that each individual user is more susceptible to, by also considering the current user profile, trip and environmental context. Fig. 3 provides an overview of the persuasive message selection process, whereas in the following we provide its details, including the persuasive messages design, the process for identifying the persuasive strategy that works best for each individual and the algorithm used for the selection of the personalized persuasive messages.

A. Design of persuasive messages

We have defined ninety-eight (98) persuasive messages with each one implementing a single persuasive strategy. Multiple messages have been designed per persuasive strategy, while all of them are context-aware, in the sense that they are valid for specific contexts. The contextual elements used in our pool of messages capture the context in which the travel behaviour takes place. We have defined seven binary contextual variables (i.e. their value can be true or false) as follows: i) three variables based on personal travel behaviour characteristics (increased car usage in terms of distance travelled over the previous period, increased public transportation usage in terms of distance travelled over the previous period, caused emissions increasing compared to other users); ii) three variables based on trip-related characteristics (the destination is in a biking or walking distance, the duration of the route is similar to driving); iii) one variable based on weather status (nice or bad weather). Note that for the calculation of trip related context variables, users provide their preferences, including the maximum walking and bike distance with which they feel comfortable as well the

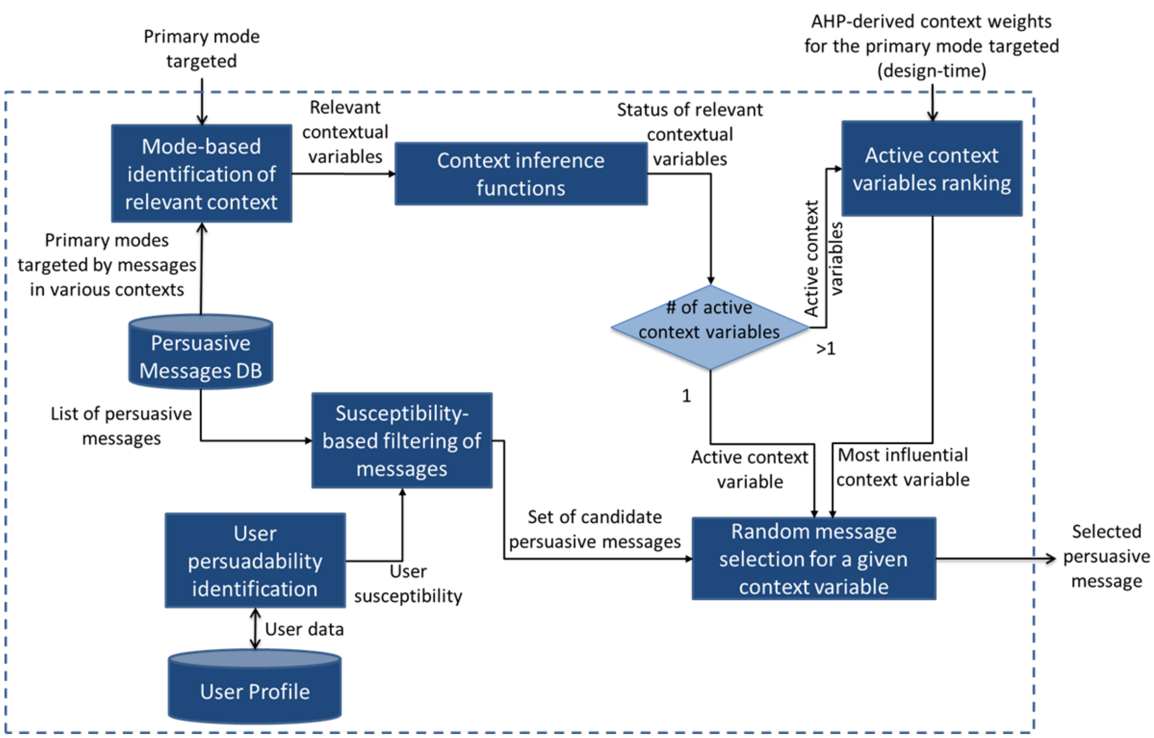

Fig. 3. Overview of the persuasive message selection process.

ownership of a bicycle during registration.

Making the messages context-aware enhances the ability of the personalized message generation service to provide tailored messages. Only messages with a context that is valid for a particular user with a particular profile, who is planning for a particular trip made under specific environmental conditions, are selected. Each context-aware persuasive message is associated to one or more transportation modes which the particular message tries to persuade the user to follow. Table I provides indicative examples of persuasive messages defined.

The messages may contain percentages or numbers as placeholders in the text of the message (bolded in Table I). The actual values of the placeholders are calculated in the runtime through a number of functions that have been developed for that purpose. Examples of functions include PBikeSD that calculates the percentage of other users that biked for similar distances and PCar that calculates the percentage of car routes for the user last week. The calculation is based on the mode detection of user activities through GPS monitoring. A specific module embedded in the OPTIMUM app [2] tracks users activities and infers their mode, duration and length.

TABLE I. INDICATIVE PERSUASIVE MESSAGES

Context	Persuasive Strategy		
	Suggestion	***Comparison***	***Self-monitoring***
Bike distance	It's not too far. Take your bike instead of car and reach your weekly goal [Bike]	**PBikeSD** % of users biked for similar distances [Bike]	Last week you caused **C02Em** g of CO2 emissions. Try to reduce it by biking [Bike]
Too many car routes	Take public transport to improve your C02 footprint [PT[a]]	Take public transport. **PReduceDriving** % of users have already reduced driving [PT[a]]	Last week in **PCar** % of your routes you were using your car. Consider using this route [PR[a]]
Nice weather	Today it's sunny! Take the opportunity to combine bike with public transportation to save CO2 emissions [BR[a]]	**PPtGW** % of users used public transport when the weather was as good as today! [PT[a]]	When the weather was good you used bike sharing **MinBikeSharing** minutes per day on average [BS[a]]

[a] PT: Public Transport, PR: Park and Ride, BR: Bike and Ride, BS: Bike Sharing

B. *Identification of user persuadability*

The user persuadability, i.e. the user susceptibility to the persuasive strategies of self-monitoring, comparison and suggestion is identified implicitly, i.e. without the need of explicit user involvement, and dynamically, i.e. after some attempts to persuade the user with the same strategy. The approach is based on previous successful persuasive interactions of that particular user and other similar users and builds upon the work proposed by [18]. More specifically, the effectiveness of a message implementing a single persuasive strategy for a particular user is estimated by considering the specific user previous responses to that same message and the known effectiveness of the message for other users. Note that a persuasive interaction is considered to be successful when the user declares that the message affects her/his route choice through a small popup that is presented in the application under the message as shown in part 2 of Fig. 3.

The probability of a single user selecting the recommended route on multiple occasions is regarded as a binomial random variable $B(n, p)$ where n denotes the number of tries to persuade the user using a specific strategy and p denotes the probability of success i.e. the probability of taking the route on which the message it attached to. Given S different strategies, we compute for each individual and each strategy, the probability $p = k/n$ where k is the number of observed successes after the presentation of the message implementing this strategy n times to a specific user. Every time that the system displays a message to an individual, the probabilities of success of each strategy are updated and the user is considered more susceptible to the strategy that has the highest p value for him/her. The higher the number of users receiving persuasive interventions and the number of persuasive attempts per user, the faster this dynamic approach converges.

However, this approach suffers from the so-called cold start problem, according to which the system cannot draw any inferences for users until it has gathered sufficient information for them. To address this problem and enable faster convergence of the algorithm, we have implemented a persuadability model that is used to explicitly identify user susceptibility to the different persuasive strategies on the basis of user personality. Data from this model are used as prior information in the aforementioned binomial random process to kick start the calculation of probabilities of success for all the strategies.

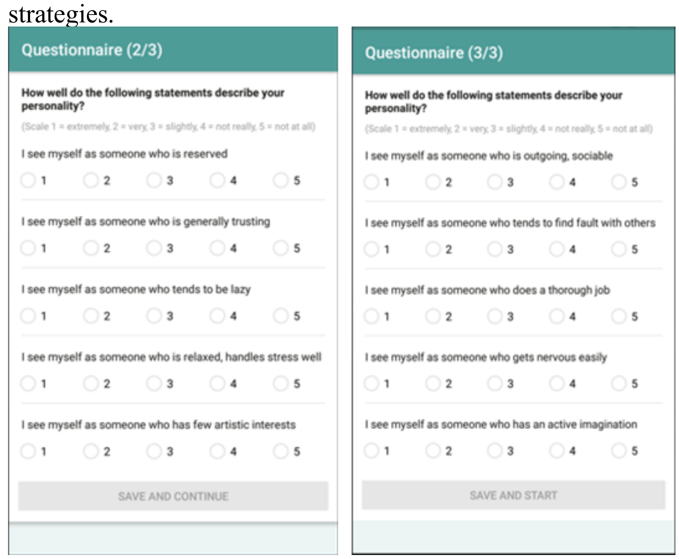

Fig. 4. The ten questions which are used to identify users' personality. The questions are answered upon user registration and are based on the Big Five Inventory proposed in [20]. Their analysis provides a measure of the user's personality over five dimensions: Openness, Conscientiousness, Extroversion, Agreeable-ness and Neuroticism (also known with the acronym OCEAN).

The persuadability model has been developed as part of our previous work [19] and is applied during user registration in

[2] http://jozefstefaninstitute.github.io/nextPin/server/spd/documentation/apidoc/index.html

the OPTIMUM application. The personality of each user is identified with ten relevant questions as shown in Fig. 4. User responses are used to estimate her/his five personality traits (i.e. openness, conscientiousness, extraversion, agreeableness and neuroticism - often listed under the acronym OCEAN). The calculations are based on the Big Five personality traits model defined in [20] and provide a score per personality trait. The trait with the highest score is the one that characterizes the user the most. That personality trait in turn feeds our persuadability model with the aim to derive the individual user's persuadability.

C. Selection of a persuasive message

Given a pair of a user and a route as the target for user persuasion, one persuasive message is selected, on the basis of a) user susceptibility to the different persuasive strategies, and b) the current context. User persuadability actually defines the selection space, since a message is selected among the set of messages implementing the persuasive strategy that works best with the particular user.

Since multiple messages have been defined per persuasive strategy, in order to select among the messages corresponding to a specific persuasive strategy, the current status of the various binary contextual variables for which context-aware messages have been defined, along with the primary transportation mode of the route that each message tries to persuade the user to follow, are taken into account. Since some primary transportation modes are only targeted by messages in particular contexts but not in others, some contextual variables may be irrelevant for a given primary mode. For example, the 'walking distance' context variable is irrelevant for all primary modes but walking.

Therefore, the message selection method identifies the relevant contextual variables for a given primary mode (see also Fig. 3). There are two possibilities depending on the number of the relevant contextual variables that are active (i.e. their status is true): a) if only one contextual variable is true, a message targeting the given transportation mode is randomly selected among the one(s) defined for that context variable; b) if more than one contextual variables are true at the same time, there is a need to select a message defined for the context variable that is considered more influential.

In order to rank context variables according to their potential for influencing users, we developed a model based on the Analytic Hierarchy Process (AHP), a Multi Criteria Decision Making (MCDM) method initially developed by Thomas L. Saaty in the 1970s [21] that has been extensively studied, refined and applied since then in several application domains. More specifically, we asked three domain experts in Intelligent Transportation Systems to evaluate by pairwise comparisons the relative influence that the contextual variables have on the user choice of the corresponding mode. Experts were asked to rate the relative influence of each contextual variable compared to its pair on a nine-point scale, ranging from equal influence (1) to extreme relative influence (9). Their responses were used to derive the individual context weights for seven conflicting cases which we identified (these are cases where two or more context variables can be active at the same time). The individual weights were aggregated by using the AIP (Aggregation of Individual Priorities) method [22]. It should be noted that the AHP-based generation of the contextual variable weights for the conflicting cases is performed once at design time and then used during runtime to identify the most influential context variable for each case.

IV. Conclusions and Future Work

We presented the OPTIMUM personalized persuasion services for route planning applications, aiming to support sustainable transportation decisions and nudge users to select more environmental friendly routes. Currently we are in the process of piloting and evaluating the services in real life, in the cities of Birmingham, Vienna and Ljubljana. Our goal is to gather feedback on the potential of the approach towards increasing personal environmental impact awareness and changing users' intentions, attitudes and practices with respect to environmental friendly transportation in different contexts. Moreover, we will be evaluating usability and user acceptance aspects.

Based on the results of our first evaluation we will fine-tune and optimize the personalized persuasion services. Moreover, we are examining ways which could extend the proposed persuasive services. These include the implementation of visual (in addition to verbal) presentation of persuasive strategies (e.g. through graphs), that will allow us to examine the combined effect of visual and verbal presentations on users' behaviour and compare it to that of solely visual or verbal presentations. Examples include graphs that provide visual cues of the CO2 emissions caused by a user's activities compared to those of the other users (comparison strategy) and graphs that show the CO2 emissions caused by the user in different time periods (self-monitoring strategy). Furthermore, we are looking into ways of extending the contextual variables and integrate knowledge that concerns users' next activity. Towards this direction the mode detection module is being extended to generate predictions of the users' next location. This information can provide hints regarding the type of the activity. For example, if the next location is a shopping mall there is a high probability that the user is travelling for leisure, information that can be used in order to intensify the persuasive attempts.

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