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Personalizing Mobile Travel Information Services

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Abstract

Research on Advanced Traveller Information Systems (ATIS) shows that travellers make better travel decisions when they are well informed. In the dynamic setting of urban public transport systems, however, the ability to be informed is not enough: travellers need to be able to quickly access and assess the information that is relevant to their own mobility. Unfortunately, most public transport ATIS are not tailored or personalised to meet individual needs. To personalise transport information services, we advocate for a multi-layered approach, integrating (1) implicit preference elicitations, (2) personalised route planning and execution, (3) natural language processing and (4) context-aware mobile interfaces. In particular, city residents use modern-day smart phones ubiquitously. Following the trend of "people as sensor", these powerful devices can be used to sense how people travel (when, from where, to where, what mode, etc.), and, in doing so, thus elicit preferences (point 1). These preferences are more fine grained than what ATIS can now elicit from static web pages asking pre defined questions, allowing for more advanced route planning (point 2). Lastly, routes can now be requested and visualised on the go: smart interfaces, that free users from inputting requests via keyboard, and adapt based on what the user is

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currently doing, (e.g. if walking, running etc.) will ease user acceptance of the technology (points 3 and 4). In this paper, we discuss how state-of-the art ATIS systems can become personalised services by including one or more of the following: data mining and natural language processing can be used to learn travellers' implicit preferences, trip planning and routing that is computed based on explicit preferences, and how smart-phone mobile phones can dynamically adapt to travellers' surrounding environment and activities in order to maximise the relevance of the data they display.

Keywords: Mobile, Transport Information Systems, Routing, Personalization, Natural Language Processing, Adaptive Interfaces

1. **Introduction**

Interactive maps, route planners, and real-time service alerts have become essential components of public transport systems: they provide travellers with access to vital information that reduces barriers to using public transit. State-of-the-art Advanced Traveller Information Systems (ATIS) give passengers access to real-time data about the transport system as they navigate it. In doing so, they improve travellers' choices regarding whether to travel, route selections, and way finding abilities. However, the current approach to designing ATIS is a `one-size-fits-all' model; information is homogeneously accessible by all transit passengers, who must then manually identify or input what is relevant to their own needs. A notable feature lacking in these systems is the ability to *dynamically* and *automatically* tailor information to the individual needs of each traveller. Most online transit tools, for example, have yet to incorporate an understanding of travellers' preferences or their mobility-related requirements—factors that can greatly impact the overall transit experience. The differences between travellers' preferences are particularly critical in the context of public transport: encouraging the use of the public transport infrastructure in urban environments, which will invariably reduce congestion and pollution, relies on providing a service that each individual traveller feels will suit their own needs and goals. Personalisation systems offer a rich opportunity to both tailor information to the individual traveller and reduce the complexity and need for manually searching for relevant transit information.

A significant obstacle to personalising the public transport experience has been the lack of data about individual traveller preferences and routines. However, the introduction and widespread adoption of smart-phones offer a potential channel to this missing data, as well as collect data about passenger behaviour that has, to date, been inaccessible. Following the trend of “people as sensors”, these powerful devices can be used to sense how people travel (when, from where, to where, what mode, etc.) as well as allow them to dialog with route planning services dynamically via context-aware interfaces.

In this paper, we discuss how state-of-the art ATIS systems can become personalised services by including the following: data mining and natural language processing to learn travellers' implicit preferences, trip planning and routing that is computed based on explicit preferences, and how smart-phone mobile phones can dynamically adapt to travellers' surrounding environment and activities in order to maximise the relevance of the data they display. We describe a system currently being developed as part of the EC i-Tour project that integrates (1) implicit preference elicitations, (2) personalised route planning and execution, (3) natural language processing for local search and (4) context-aware mobile interfaces.

The rest of this paper is organised as follows. In Section 1.1, we introduce a travel scenario that will both motivate the need for dynamic, personalised ATIS, as well as demonstrate how the four components described above will operate together. In Section 2, we discuss related work, which places this system within the broader context of a variety of multi-disciplinary work. We then describe each component (Sections 3-6). We conclude in Section 7 by discussing future directions.

1.1. *Scenario*

This section briefly describes a basic travel scenario, in order to show how and why all the different components that are described in the following sections fit together:

Monday 7am. Alice wakes up and gets ready to go to work. She switches on her mobile app, which tells her all is fine in her route to work (bus and tube). She leaves home and gets on a bus. While going, the app alerts her that something has changed: because of a faulty train, the train station is congested and there are minor delays. She decides to avoid the station then and queries the routing system to get an alternative route, which suggests her to stay on the bus for 2 more stops, then take a tram for 3 stops and finally walk for 10 minutes. When she changes bus/tram, she uses the mobile app to get 3-dimensional navigation instructions of how to walk to the right stop, as she is not familiar with the route and does not know where to go. She is now walking towards the office and realises she also needs to find another place where to get lunch, as she won't pass in front of her usual shop. She starts the voice interface and asks for a sandwich shop that caters for gluten free diets and where she can pay by credit card, as she has no cash. The application recommends two places, and shows 3-dimensional walking directions of how to get there. She likes the place she chooses, very friendly staff and plenty of choices, so she leaves a positive review, but updates the system to clarify that credit cards are only accepted for payments of £10 or more.

This scenario highlights a number of challenges that are captured by different components of the system we describe in this paper:

1. **Multi-Modal Routing.** How does the system dynamically compute multi-modal routes?
2. **User Preferences.** How does the system know the user's *usual* route? How are crowdedness and delays measured in real-time? How are implicit preferences and ratings used for alerts and recommendations?
3. **Natural Language Search.** How does the system respond to the user's query (about gluten free restaurants) and produce destination recommendations?
4. **Activity Inference & Adaptive Interfaces.** How does the system know the user is on the bus? How are 3-dimensional interfaces leveraged to facilitate navigation?

In the following section, we describe the research that has been done to date on each of these facets. We will then review the unique approach we are adopting as part of the EC i-Tour project and the contributions, both to research as well as system implementation, to each of the above problems by looking at the components we are building.

2. **Related Work**

This section places the framework that we describe below within the context of existing systems and literature. There are four sections that we cover: advanced traveller information/routing systems, personalisation, natural language processing, and smart mobile interfaces.

1.2. *Routing, Journey Planning, and Traveller Information Systems*

A routing system generates routing advice for trips with a known origin and destination location and, possibly, one or more intermediate stops (waypoints). According to the transport modes supported, existing routing systems available on the web, mobile devices or in-vehicle board computers can be categorized as *road network routing* (e.g., foot, bike, car), *public transport routing* (e.g., bus, train) and *multi-modal routing*. The latter multi-modal routing systems also support trips that use combination of private and public transport (e.g., transfer from car to train to travel to the final destination). Traditionally, routing systems generate the fastest routes for a trip. Increasingly, however, systems are appearing on the market that consider a wider range of possible preference dimensions and allow travellers to choose a most economic (lowest cost), most environmental friendly (lowest emission) or a most scenic route. A further step in this direction concerns providing personalized routing advice, i.e. advice that is tailored to the preferences of the specific user in terms of the weights he or she assigns to criteria such as time, convenience, costs, safety, environment and so on. In the case of multi-modal routing systems, which enlarge choice opportunities to include also transport mode, the value of personalized route guidance becomes increasingly significant. As Chorus (2006) commented in his review of ATIS “the development of a next generation in ATISs potentially results in mobile, multimodal, dynamic and personal travel information”.

There is evidence of a growing interest in developing multimodal ATIS from both academia and industry. In Germany, Schultes [Sch08] and Pajor [Pa09] did extensive research to extend networks from single modal (mainly road network) to multimodal. Liu [Li09] proposed a switch point approach to model multimodal transport networks. The Mentz Company [Re07] developed a journey planner system and applied it to a regional scale with relatively high spatial resolution. Other applications include Bahn (German national railways timetable). In the United States, Zhang [Zh11], Li [Li10], Jariyasunant [Ja10] reported applications to support mobile multimodal ATIS in California for route planning. Peng [Pe08] proposed a distributed solution for planning of trips in a larger transport system. Companies like Trapeze, Jeppesen, Google also developed such products. In the United Kingdom, there are also many multimodal ATIS applications, such as Transport for London’s Journey planner. In the Netherlands, Van Nes [Ne02] conducted extensive research for designing multimodal transport networks. Beelen [Be04] developed a personal intelligent travel assistant for public transport. In other countries and regions, Houda [Mn10] proposed a public transportation ontology. Ayed [Ay08] proposed a transfer graph approach for multimodal transport problems. Zografos [Zo08] described an algorithm for itinerary planning based on dynamic programming. He also reported work on the design and value of online passenger information systems. Wang [Wa08] did a study on handling times and fares in a routing algorithm for public transport. Su [Su08] developed a multimodal trip planning system for intercity transportation in Taiwan. Kumar [Ku05] developed a multimodal transport system for Hyderabad, India.

As this brief review of existing work suggests, the integrated modelling of multi-modal transport networks is now well understood. Despite the fact that algorithms are available, however, an integrated, personalized travel information system, as foreseen for a next generation ATIS, currently does not exist.

Especially, on the part of personalized advice only limited work has been done to date. To the authors' knowledge, an advanced routing system taking personal preferences of users, multi-modal trips, time-dependent transport services and real-time information into account currently does not exist.

1.3. *Personalization*

Using technology to personalize people's experiences has, to date, been most visible on the web. The most prominent example is its use for recommendation in e-commerce, such as Amazon's recommender system [Am09]. Such systems often ask users to rate a variety of items (e.g., books), and rely on so-called collaborative filtering algorithms [Ad05] to automatically compute personalised rankings of e-commerce items based on the predicted interest a user will have for each one of them. For example, a user's interest in purchasing a book may be calculated based on the ratings that she/he has input for similar books, where similarity is itself computed by looking at how the entire population of web-customers has been browsing and rating books. The founding principle behind these systems is that each customer will have a unique experience with the online portal in terms of what content they are recommended: similar techniques have been used to recommend online news [Da07], music [Ce07], and movies [Pi09].

While these techniques have been wildly popular online, and have become cornerstones of many online businesses, they have yet to be applied to a transport setting.

1.4. *Natural Language Processing*

Natural Language Processing (NLP), in simplest terms, can be defined as a method of human-computer interaction. Natural language appears to be an optimal substitute for formal query languages in order to allow users to access databases using familiar concepts and requirements. Some of the key aspects of NLP are *natural language understanding* (converting text into a formal representation that the computer can manipulate), *optical character recognition*, and *question answering*. Current approaches point towards systems using one or more layers of some intermediate representation language; NLP may have an underlying ontology which represents knowledge as a set of concepts within a domain, and the relationships between those concepts. The relationships can be of different types and are used to describe both the domain and its concepts. The user's query is transformed into a set of clauses expressing high-level logical-semantic representations. The module generating the intermediate level may also encode a world model, typically consisting of an is-a, has-a hierarchy of concepts with some constraints to limit the predicate arguments that can appear in the logical form (Alshawi, 1992). NLP can be effectively used in almost every domain. For example, an NLP-based help-desk can improve the performance and efficiency of a company. Also, NLP is used in GIS technology, which has a great number of possible applications: resource management, marketing, logistics etc. The cost of training people in the use of a GIS system is currently estimated to have the same order of magnitude as the acquisition of the necessary hardware and software [Ma92]. NLP-GIS implies that the user must only have a minimal knowledge regarding a GIS system, hence reducing the training cost.

1.5. *Smart Mobile Interfaces*

The concept of smart interfaces stems from the ideas of contextual awareness, ambient intelligence and multimodal interaction: the goal is to tune user interaction paradigms to environmental conditions and user habits. Current research has focused on developing techniques to identify as much contextual information as possible. Relevant work includes the Context Managing Framework, developed by Korpipää et al. [Ko03] where a set of resources and context recognition servers are used to build a context manager to be eventually interfaced with an end user application. Other middleware include the Service-Oriented Context-Aware Middleware developed by [Gu04] to create context aware services for mobile applications. Context-Awareness Sub-Structure [Fa04] is a similar middleware to retrieve information from different distributed sensors, collect them and interpret them. Another system specialising in context awareness for mobile devices is Hydrogen [Ho02], which distinguishes between local and remote context, the former being the awareness available from the mobile device, the latter being the one available from other devices. A further framework is CORTEX system based on Sentient Object Model [Bi04] specifically designed to cater for mobile scenario requirements.

A very large corpus of research papers are available in the field of ambient intelligence, where behaviours of users have been monitored in closed, controlled “smart” environments. Increasing attention is being paid to monitoring movement behaviours of users, mainly for health monitoring and/or improving reasons. Examples include the work of Consolvo et al. [Co08], which make use of mobile phones connected to portable fitness sensing units connected to mobile phones via Bluetooth. Other similar applications make use of external sensing units [Ch08]. Several research works make use of information coming from sensors fitted on mobile (e.g., the Wireless Sensor Data Mining project [Kw10]) where Android phones are used to detect activities such as walking, jogging, ascending or descending stairs or stationary state (e.g. sitting or standing). Similar approaches have been developed by the scientific community to deal with multimodal interactions, where “multimodal” refers to the possibility of interacting with a computer interface through multiple interaction modalities (e.g. voice, gestures, gaze etc.), as opposed to “multimodal” transports, which refer to trips based on different types of transportation means (bus, train etc.). Several research works have explored how to “fuse” information coming from single uni-modal recognizers, into a more articulated multimodal action. A number of “fusion engines” have been developed as can be read in surveys such as in [La09]. In fact among the most famous to assess the best merging of information coming from the different recognizer we find semantic fusion [Wu99] [Jo97], the Members-Teams-Committee method [Ge03] as well as other relevant statistical techniques. The adoption of multimodal interfaces in the mobile devices brings improved ergonomics through adoption of more natural interactions and it allows greater naturalness in the way the user interface the machine through the adoption of flexible human communication patterns [Ov00]**.**

Given the review of related work above, the following sections will decompose the i-Tour system into 4 components that will describe what we are building and, more specifically, what problems these solve.

3. Multi-Modal Route Planning and Execution

In line with objectives for a new generation of ATIS, the routing system we propose here should have the following characteristics: multimodal, real-time information, multi-criteria evaluation (of link costs), personalized information/advice and environmental awareness. To achieve this, the multi-modal routing system uses two kinds of algorithms: a network compilation algorithm and a route search algorithm. Compilation of a network involves first compiling the private and public networks individually and next interconnecting the two networks by adding transfer links at nodes where the traveller can transfer between the two networks (e.g., park and ride facilities). The latter step is essential and results in a hyper (or super) network. To account for dynamic travel speeds, a time-dependent method is used for routing within private-vehicle networks. Public transport networks, instead, are characterized by predefined timetables and vehicle routes. The time-expanded method is used to incorporate timetable as well as route information in the public transport network. The pedestrian network is crucial for determining transfer links in the integration step. Walking is involved in any possible transfer between private and public modes. We add transfer links through searching nearest nodes in the pedestrian network. When a full multimodal transport network has been constructed in this way, we can use a standard routing algorithms, such as Dijkstra or A*, to search for optimal paths. The integrated networks can become very large depending on the availability of transport modes for a trip and the extent of the public transport network in the area under concern. To reduce computation time, strategies such as data pre-processing, bi-direction search, and making use of the hierarchical structure of road networks are considered.

The proposed routing system takes particular preferences of users into account by using extended link cost functions. The link costs functions do not only consider travel time and travel costs components but also include factors that relate to convenience and emission of pollutants. Especially, convenience is a rather complex factor that includes a number of dimensions such as possible preferences of a traveller for road type (e.g., highway over local roads), transport mode (e.g., car over train and train over bus), service quality (e.g., seat availability in a bus) and inconveniences related to transfers, waiting and physical effort (e.g., biking, walking). In the super network representation that we use the different modes and stages of a trip, such as waiting, boarding, alighting and transferring, are all identified by link type so that, in addition to attributes stored at links, all these preferences can be accommodated in link costs functions. On the other hand, emission is calculated at the link level as a function of distance travelled, travel speed, attributes of the vehicle (fuel type, vehicle technology) and number of passengers in the vehicle using emission factors from COPERT IV – the current European standard in emission modelling. In terms of travel costs, fuel use, fuel price and parking fee (if data supports) are main attributes for car, whereas ticket price is the main attribute for public transport. Fuel use is calculated at link level as a function of speed, distance and vehicle attributes (fuel type, technology) again using COPERT IV data about fuel consumption rates. Tariff structures for public transport can be quite complex. For multi-modal routing it is nevertheless an important factor. The routing system calculates approximations of ticket prices on a link level based on either one of two possible structures that applies: a system of tariff zones, on the one hand, and linear functions of distance, on the other hand, which may include a constant for using the service.

A key to providing personalized routing advice is the notion that ways to trade-off these various factors may differ between persons (e.g., income, inabilities) as well as depending on situational factors (e.g., weather, time, traveling alone or with a child, carrying luggage). The weights assigned to different criteria, such as inconvenience, travel costs, travel time and so on, as well as the ways a traveller evaluates inconvenience factors are stored as parameters in the system. For every given routing request, the values of the parameters appropriate for the case at hand are provided and loaded in the network before generating a route. Thus, the routing system can generate fastest, cheapest, most convenient and most environmental friendly routes as well as optimal routes based on the preferences of the user.

4. **Personalized Travel Alerts**

In the context of transport systems, we define the interest that a user has in public transport station as the proportion of times that the user starts or ends a journey at a particular station. In other words, if a user takes only 1 trip in a given period (and thus visits two stations, the origin and destination), the measured interest in the each station will be 0.5; interest values lie in the range [0, 1]. We assume that interest, defined in this way, is correlated to each user's actual station preferences. Note that, unlike above, in this section we restrict our test set to those users who have appeared at least once in the training period.

Given these *interest* scores that travellers are assigned as they move, we can design systems that automatically give travellers alerts about the routes that they take [La10]. In particular, we compare across users in order to identify potential interest in a station that a traveller has not been to. Just like online recommender systems say “people who liked the book X, also like book Y,” we can perform very similar computations to deduce “people who are interested in travel alerts for station X are likely to also be interested in travel alerts for station Y.”

One of the key aspects of successful recommender systems is that they tailor information in transparent way; users should be able to infer *why* they are being recommended what they receive. Our trip estimation proposals (detailed in [La10]) come with the same benefit: they not only allow for more accurate predictions, but also *reasons* why those predictions may be correct. Such transparency can also be used to inform travellers about how their data is being used, to cater for those who may be wary or have privacy concerns.

5. Natural Language Processing for Mobile Search

In our approach, natural language queries are mapped into a logical-semantic representation, generated from a level of linguistic representation of the query. These are then linked to the domain ontology, which acts as a formal interpretive model of predicative constants and expresses the conceptual restrictions constraining the compositional process of building logical forms out of the syntactically analysed natural language.

Below is an example of how a natural language questions is transformed into a set of clauses. “How can I get to X, by car, in less than two hours” is translated into a set of clauses: “I want to get to X” (and) “I travel by car” (and) “Journey time smaller or equal (<=) two hours,” expressing high level logical-semantic representations. Logical forms are then automatically mapped into SQL queries by post-processor and parser, a Fuzzy Engine to deal with treatment of lexical vagueness, an SQL translation

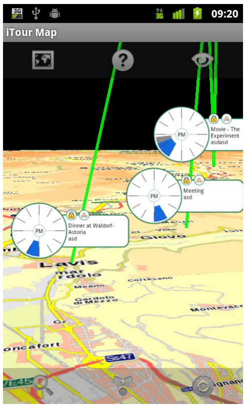

Fig 1:Contextual Recognition and selection, iconic interface

Engine and, where necessary, a Dialogue Manager. The application provides three types of access: web, SMS, voice. The NLP server, after a formal validation on the provided fields, enables the following blocks: orthographic verification, name recognition, place name recognition, syntactic engine and semantic engine. Each piece of data collected by the traveller's mobile or web app will be parsed and, if potentially useful to the NLP module, will be wrapped and transmitted as additional data array to system. NLP can thus learn the types of question selected, locations, system recommendations, and user preferences. The NLP module can be also used with a SMS/MMS interface. When the user chooses this system, the interaction is reduced: all dialog thresholds will be increased to reduce the number of SMS sent and received by the user. Only one or two results are directly sent to the user's mobile phone. The graphic interface is optimized to exploit all the features offered by rich applications. During question typing the user is helped by the system; it provides nearby place names (using geo-coding) and/or the frequently used ones in the recent queries and in recent searches. The system collects each typed query and saves the user's feedback. This represents global information that the NLP engine uses to provide accurate answers. The system will increase its performances from user interaction.

6. Context-Aware Mobile Interfaces

The definition of a system capable of recognizing different user behaviours such as walking, running, cycling or contextual situations like indoor and outdoor goes in parallel with a precise set of adaptive visual interfaces that change their configuration based on the inferred activity. This system, thanks to its internal context-aware recognizer based on the concept of human learning sets and Support Vector Machines is able to identify two main group of information: movement, and ambient conditions. As shown in Figure 1 (left and centre), representing the home screen of the application with a top left icon with the actual recognized status, or a grid of icon to select it when wrong, the amount of text is reduced to a minimum with an almost total adoption of icons. This can be seen also in Fig 1 (right) where the agenda events are located exactly on the corresponding location on the map, showing the subject but also the time slot, the delay, if it is private or public, the calendar type and the rating.

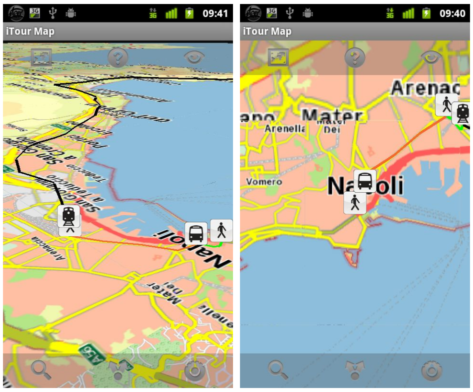

Figure 2: Left: Gesture Recognition. Right: Interface Example (2 and 3 dimensions)

These icons naturally imply the behaviour they trigger and are simpler to handle when user requirements change: they can be scaled, hidden, or rearranged with minimal effort. For instance, while walking, the number of icons can be reduced to the most useful ones like the one for the latest alerts and the map visualization, while when following the travel assistant the system can exploit built-in sensors to switch the map accordingly to the phone orientation as in Figure 2 (right images) where the map is visualised in two dimensions, three dimensions and augmented reality. The adoption of a gesture recognizer on all the available interfaces, as shown in Figure 2 (left images), simplifies the access to the most common operations such as confirm or cancel system suggestions, refresh the view or go back to the previous menu, without requiring a particular precision to select the corresponding option. The user needs only to draw a shape similar to one of those on a predefined set, regardless of its size.

7. Conclusion

In this paper, we have presented the on-going research and prototype development about personalized traveller information systems that is part of the EC i-Tour project. In the near future, we plan to improve the routing system with dedicated choice experiments involving representative samples of the population to collect data to feed into the system, as well as deploy the prototype to solicit feedback from a large sample of travellers.

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