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Development of an Open Framework to Provide Intelligent Multi-modal Mobility Services

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1 ABSTRACT

The project i-Tour delivers a personal travel assistant, developed for smartphones, capable of routing users through a multimodal transport network. Additionally public transportation companies can interact with their customers through the access to ICT platforms. On top of multimodal routing features we have developed a system to deliver a full Web 2.0 communication tools that allows transportation providers and their partners to promote incentive schemes through the offer of ancillary services, when people are on the move and according to their location, in order to better serve them (providing a services that is useful to a given person, within a given place, at a given time) and to reduce CO_2 emissions. An incentives scheme would be also based on rewarding mechanisms and/or mileage-like campaigns, directly provided through the use of the such system as check-in check-out procedures for all the users.

The solution developed is a cross-technology platform (available for both fixed and mobile devices), which works as a gateway for all the information related to public transportation. This information can be updated also by the end-users that work as prosumers.

The actors of the system are: public transportation companies, public administrations, private partners that can offer services on the move, publishers, end-users. In this way all the stakeholders are interested to contribute and keep alive the community of users in order to get qualified leads. i-Tour becomes a communication system that can potentially serve million of users at the same time, and it is based over the most up-to-date internet technologies, such as web services and cloud computing networks.

2 INTRODUCTION

i-Tour has been thoughts as a native web 2.0 platform that allows all the counterparts of multi-modal transportation system, included the end-users, to interact among them easily and share information on the same environment in order to improve services and citizens awareness about a better use of public transportation against private one with getting environmental benefits in the urban areas.

The system has the follwong characteristics:

- Being a personal travel assistant, which gives all the alternatives to route destinations for the end-user, this information can be delivered onto mobile personal devices;
- i-Tour will help people to get always organized and in time with public transportation thanks to its technology, one can access the service on the move and find all the better routes to get in time at the work or for leisure meeting friends;
- All the routes will have voice directions as well as the 3D view on the screen and reaches the tram stop in time, the system will also alert about conditions of transport such as the upcoming metro to be too packed and if there are any other way possible to reach the place within an affordable timing;
- i-Tour will also give access to PC users through the internet asking route's indications in natural language: "get me to the closest shop that accepts my credit card where I can buy some food". 3D mapping will be available, while users accept, they leave the office carrying with their own Smartphone that meanwhile automatically starts providing directions on how to get to the desired location;
- The i-Tour community will help to maintain the system up to date with the latest information and/or changes in the routing thanks to the information provided by all the users. This service will also give in return the quantity of CO_2 reduction in the case of public transportation routing selected by the users.

- The amount of CO_2 saved will be commuted into points and an incentives scheme would be also based on rewarding mechanisms and/or mileage-like campaigns for public transportation, directly provided through the use of the such system as check-in check-out procedures for all the users.

3 TYPICAL SCENARIO OF I-TOUR

Within a typical scenario the user interacts with the i-Tour client to retrieve routing information across a multimodal transport network. Unlike other navigation systems, in i-Tour suggested trips can be based on a combination of different transport modes such as bus, train, metro or have the user walking or cycling to get to a station. Routing information are adjusted according to real-time traffic information, information on quality of services as provided by the community of other users, or based on other real-time information such as weather conditions (e.g. the system would not recommend walking if rain is forecast).

The scenario set by the project requires that the system should be considered essentially as a pedestrian routing system, in an enlarged sense, i.e. providing specific directions targeted for instance to a user walking home as well as a user cycling to a station to catch a train or walking at a station to get on a connecting underground line. In short the focus will be on all the routing situations wherever the user will not be driving private vehicles.

The interface has been designed to ensure ubiquitous use of travelling services, whereas the users should be able to switch, at any time, from web to mobile client, yet retaining the same features, look and feel, and machine state in terms of data and information being managed.

This scenario has required developing client applications which could store and retrieve all the necessary information from the network. In fact all state-relevant information is stored in the cloud, with the user accessing this information through the Internet. For this reason the two i-Tour clients can be regarded as two access points to the functionalities provided, as service, at the server side through the i-Tour middleware.

The mobile clients makes use of all the latest sensing technologies available on the latest mobile devices to provide a more natural and ambient-aware experience leveraging on technologies including satellite receiver (e.g. GPS) and electronic compass, to identify the position of the device in space, accelerometers and gyroscopes, to understand movements of the devices, ambient light sensors, multi-touch screens, microphones, cameras etc. This information is used to acquire awareness on the surrounding environment to ensure best possible adaptation.

The very nature of the system requires a scenario whereby the mobile device is always online, connected via 3D, UMTS or Wi-Fi in order to be able to access online information on routing, events of interests as well as other functionalities provided as a service to the i-Tour client (e.g. Natural Language Processing).

Additionally to the mobile client, i-Tour is developing a web client, as visible in Fig. 1 (right), from which the user can access the same set of functionalities available to the mobile client. The goal set, when designing the interface of the web-client, was to provide a ubiquitous experience whereby the user, at any time, can migrate from mobile to web client yet having access to the same set of information.

The overall user experience and graphical language is consistent with the mobile interface, to minimise cognitive effort required to switch between web-based and mobile client and reduce learning time.

4 RELATED WORKS

The importance of creating interfaces capable to promote greener transportation has been highlighted in previous studies such as those carried on by Froehlich et al. (2009). The study revealed the complexity behind perception and selection of various transportation means. Promotion of greener transport means, leveraging on benefits of often healthier transportation patterns (e.g. walking or cycling) can be extremely effective. As shown in the study described by Froehlich et al. (2009) in fact 52% of interviewed users declared that they "would have been more likely to select bicycling or walking had they thought of health benefits (e.g., caloric expenditure) when making the travel decision". If these options are automatically computed and suggested to the final user accordingly with its preferences, we could expect that the probability of more sustainable travel solution choices will be higher.

With regard to the development of personal assistant for pedestrian, it must be noted that little attention has been paid by commercial applications to deliver routing other than for private vehicle. In particular very little attention has been paid to true pedestrian routing, as in fact most of the systems which offer pedestrian routing they do so essentially as an adaptation of car navigation, simply by loosening constraints set by driving on roads (one way streets etc.). in fact the greatest majority of applications available for Smartphones or other portable devices essentially cater with car navigation and routing. The majority of them offer pedestrian routing only as an alternative without providing any support for routing through public transport network. Furthermore most portable car navigation system can be set to "pedestrian mode" however their interface does not change, neither does it take into account any specific requirement the new context may arise.

However it has been demonstrated that particular attention must be paid to cognitive aspects of the user when developing the routing and recommendation interface, particularly considering the so-called image schemata (Gaisbauer and Frank, 2008). This is a concept introduced in the late eighties, to define the conceptualization of the surrounding physical environment. Perceptive order is not just a rational and numerical problem, perception is not a picture of the outer world, it is the result of a selective mental process of organisation that involves the whole structure of the object.

If we steer away from car-based navigation systems, few dedicated cycling navigation systems are available from the market, either as adaptations of car navigation systems, such as TomTom Rider (http://www.tomtom.com/en_gb/products/bike-navigation/) or evolution of bike trip computers, essentially targeted to amateurs with a clear sport-oriented twist, such as Garmin Edge series (www.garmin.com). Their adaptation to specific requirements of bikers merely resides in an extended road network database which includes bike lanes and paths suitable for riding a bike, in the use of a larger buttons (e.g. to allow for easier interaction when wearing gloves), in the possibility to plot information on altimetry profiles or racing information. Instead little or no attention has been paid to providing different types of routing, for instance based on landmarks met along the street, on real-time information regarding availability of bikes at designated bike-sharing facilities, or least of all, integration with other transportation means.

With specific regard to multimodal routing interfaces, if we exclude web-based systems such as Google Transit (www.google.com/transit), which is practically an extension of a standard web-based routing system, and we focus on interfaces available for portable devices such as smartphones, very little is available from the market as well as from the research community.

A notable exception is CityAdvisor (http://www.cityadvisor.net/) an application for Windows Mobile 6.0 powered phones that provides routing over public transport network. The system allows routing over the public transport network based on indications and symbols of different network lines. The indications provided are essentially the ordered list of unimodal journeys that the user has to take to reach destination, without providing any navigation on how to reach them nor on how to transit among different journey segments. Furthermore no advanced recommendation is available based on specific user preferences neither a mechanism based on updates is set in place.

When dealing with pedestrian routing several studies have proved the benefits of so-called landmark-based navigation if compared to turn-by-turn instructions as it provides a simpler navigation mechanism with constant contact with the surrounding scene. Landmark-based routing relies on directions given according to key points (landmarks) along the route. Rather than instructing the user based on distance from roads or junctions, the routing provides a "natural" set of instructions based on the key points which will be met enroute, such as "after reaching the church on your left, then turn right and proceed until you get to the station". Usually routing by landmark is accompanied to use of images of the landmark, to help the user keep contact with the surrounding space. Additional graphics can be also used to superimpose arrows on top of images to better illustrate directions to take. One of the most relevant examples is described in (Hile et al., 2008) and (Hile et al., 2009). In this case, routing is ensured through use of geo-tagged images. The system renders on top of them directions (coloured arrow) identified around the path.

Especially for pedestrian routing, it has been demonstrated that traditional navigation based on distance and names of the streets is not effective whilst guiding a person through landmarks provides a much more effective navigation that improves confidence and trust (May et al., 2008).

5 THE UBIQUITOUS PERSONAL TRAVEL ASSISTANT

The mobile travel information system represents the heart of the i-Tour mobile client. Within standard personal navigation systems, routing is traditionally accessed through an interface where the user can type in an address of a place, or the name of a point of interest, and the system calculates the optimal route to reach the given location.

i-Tour instead starts from a completely different perspective. Although traditional navigation is still possible the system has been designed to ensure that routing is tightly integrated with the calendar(s) of the users. Calendars in fact are repositories of events and their corresponding locations that can be used, if properly described, to identify the daily activity of the user and the corresponding trips.

The user typically schedules events within their calendar at different times of the day, specifying the location. The system then uses this information to calculate the best route across the various locations where events are scheduled.

Most notably through the i-Tour interface the user can also define a list of activities by scheduling a time range to perform them without precisely defining neither their time nor their duration. This becomes particularly useful when the user has a certain degree of flexibility and does not require getting to a place by a given time. A typical example is the user willing to go shopping for 4 hours. In this case, the user can define a list of places (most probably shops) that he/she would like to visit without defining neither a precise time nor a precise order. These events, which are all defined within a single macro-activity called “shopping”, scheduled from 12:00 to 16.00, can be then used by the system to calculate the optimal route, according to the user’s travel preferences.

Fig. 1: (left) the home page of the mobile client and (right) an overview of the web-client interface

5.1 Overall requirements

The i-Tour clients are both shown in Fig. 1. The mobile client has been specifically designed for mobile Android-powered smartphones and tablets such as the recently released Galaxy Tab by Samsung. The requirements set by the project scenario imply that the client application must be capable to:

- Manage events stored within one or more calendars.
- Events can be created by learning from user’s behaviours based on specific travel patterns by the users or other members of the social network.
- The system is constantly tracking the user’s position.
- The system is online for most of the time.
- The smartphone is fitted with a number of sensors, including accelerometers, gyroscopes, GPS, compass, light sensor, which are used to retrieve information on the user’s movement as well as on the surrounding environment.

5.2 The mobile client interface

As illustrated in Fig. 1 (left) the home page of the mobile client provides access to high-level functionalities as well as to messages coming from the i-Tour service infrastructure. The interface, which graphically mimics a roundabout, is composed of a several areas. The central section is used as a dashboard for relevant alerts or messages. A set of icons, used to access the main functionalities, have been placed obliquely to improve selection when the device is being held with one hand only and the user interacts through their thumb. The interface can be mirrored for left-handed users. These icons are used to activate the main functions of the client, namely the calendar and scheduling of events and the map-based environment, the messages from the community of users, the recommendation system functionalities and finally the system settings and preference interface. The lower right corner of the screen is filled with the icon of an avatar which can be pressed, with a finger (e.g. the thumb), to activate speech recognition of natural language commands, whose interpreted message is shown in the balloon on top of the avatar's icon. The grey area at the bottom right of the screen is used to contain messages and alerts by the network services.

If we move to the top half of the screen we find an information button, marked with an icon bearing an "i", can be used to access detailed information on the current trip as visible Fig. 2

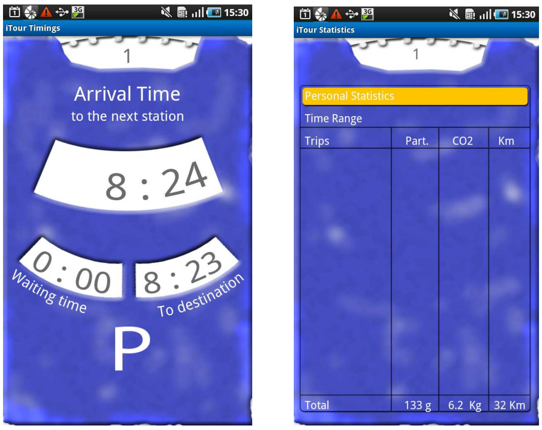

Fig. 2: various components of interface used to access connection information

Moving upwards to the top of Fig. 1 (left), a bar with several keypoints, which mark the various segments of the current trip, shows an overview of the current trip, including position of the user and transport means planned for all the trip segments. A colour coding, is used to help the user appreciate immediately the conditions of the remainder of the trip, including quality of services of the various journey segments and possible delays. If a delay is expected, with regard to the initial expected time of arrival, this is highlighted by the system. The circle corresponding to the travel option becomes either red (in case of delay) or green (if arrival is expected ahead of schedule), while the position of each node of the bar is adjusted accordingly (if delay is expected the position will be moved away when set to the visualization of time of arrival).

Last but not least the top section of the screen is used to provide contextualised information on weather conditions enroute (start, end and midpoints).

5.3 High-level map-based interaction

With i-Tour the user can check the forthcoming events, as scheduled in their agendas, based on their position over a map. This is accessible as a standard map-based environment (2D), as a 2.5 scene represented by a 2D map projected within a 3D space, as a 3D scene and last, but not least, as Augmented Reality scene. When the user is looking at the 2.5 or 3D visualization modes the system then adjusts the overall point of view so that the user can appreciate the relevant portion from a birds eye perspective. The map shows the portion of territory scaled to fit the locations of the forthcoming events.

If run on the mobile device, the system will automatically adjust the point of view of the scene, rendered as perspective image, to be aligned with the current position of the user and direction the device is being pointed at. In other words the image is aligned to make sure that the user can see on the screen the portion of the scene in front of them. This way when the user physically rotates around their position while holding the device, the system will ensure that the heading (the forward direction) of the virtual point of view of the scene on the screen is aligned with the user's heading direction in the real world.

The interface can also show 3D buildings of the surrounding scene, whose extent is scaled according to the graphical performance of the mobile device. This strategy is essential to ensure a smooth experience to avoid that the presence of a high number of high-detail buildings could cause the system to slow down unacceptably.

By pressing the relevant icon the user can eventually switch to a full 3D view where the height of the terrain is rendered realistic manner. A smooth transition, showing the terrain deforming to reach the real orography, ensures a smooth interaction and pleasant user experience. During the transition all point of interests, as well as any other graphical element rendered on top of the map, including buildings, are moved upwards to the proper position in space, according to the 3D terrain information available.

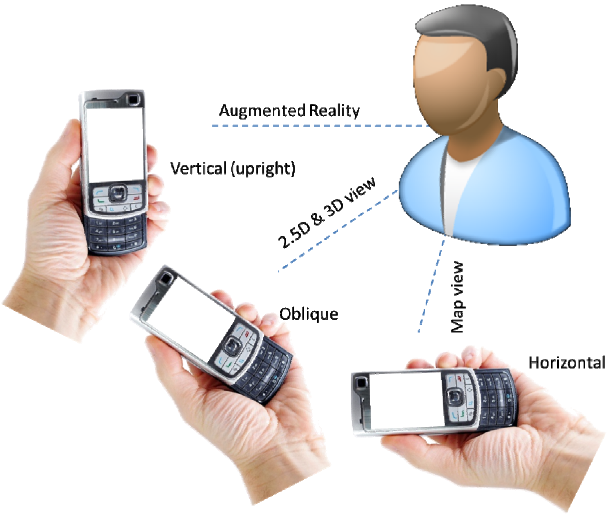

Fig. 3: the different position triggers different visualisation modes

Eventually the user can also turn on the Augmented Reality mode, where virtual information are projected on top of images captured by the camera fitted on the mobile device. This interface is particularly beneficial when the users need to explore information available in the nearby (for instance location corresponding to a number of close-by meeting in a given area) by simply pointing the device at the relevant position in space.

The user can switch between different views in a very simple manner, by simply holding the device at different angles (see Fig. 3). If the device is held flat horizontal the system automatically moves the point of view to an azimuth map-like view (2D). A smooth transition ensures a user-friendly experience.

The system can also switch to Augmented Reality mode by holding it straight in front of the user. As soon as the system detects from the sensors that the device is nearly vertical it changes to Augmented Reality (AR) visualization mode. All the geometries representing the terrain and buildings fade away to leave room for the augmented scene, where information on events etc. are rendered on top of images from the surrounding scene as captured by the camera.

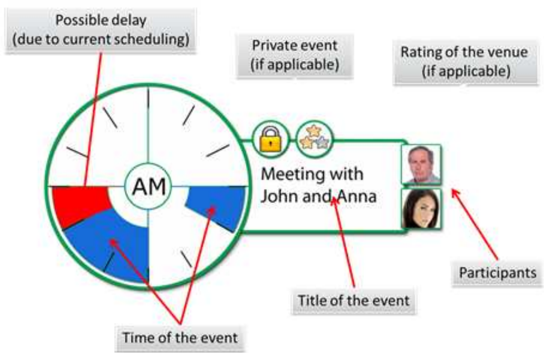

Fig. 4: an overview of the interface showing various events in agenda and (right) a detailed view of the widget

5.4 Event graphical component

In all the various visualisation modes, based on geographical information, each calendar item is shown, within the software interface, next to the corresponding geographical location. Each event in the agenda is represented within the map by a widget summarizing the most relevant information (see Fig. 4).

As visible from Fig. 4, a dial shows approximately the time of the day and duration of the event. This is useful to get a quick overview of the time and duration of each event. Possible delays due to current scheduling (e.g. due to traffic) are also highlighted (in red) within the various sectors of the dial. The widget additionally includes a brief description of the event, as provided by the user when the event was created. Additional information on each event is shown within a widget which provides essential information on the event, include:

- Status of the event (confirmed or guessed by the system).
- The calendar the event belongs to (marked by the color of the widget's edge).
- The period of the day/night the event has been scheduled, through a colored dial that shows at glance if the event is scheduled in the morning, afternoon, evening or at night. This information can also be the result of a compound event, for instance a user being in office from 10:00-12:00 then from 14:00-16:00 and from 17:00-19:00.
- An icon that further qualifies the event (e.g. office, home, event in agenda etc.).
- Brief description of the event.
- Images of other persons invited to the event.
- An icon that displays if the event is private (details are not available when seen within shared calendars by other users).
- Rating of the venue, as available from the recommender system.

The location of the event is shown next to the location of the widget within the scene corresponding to the venue of the event. If the event has not been given a location, then the corresponding icon is rendered in overview in screen space. The edge of each of the widgets is colored according to the calendar it belongs to. This way the user can easily appreciate if a scheduled event is for instance a personal or business-related event.

Some graphical components may contain information on those events whose occurrence has been automatically guessed by the system (and therefore not confirmed by the user) according to specific behavioral patterns. These components, which have not been explicitly defined by the user, appear as partially transparent with a dashed pattern. This is for instance the case of automatically scheduled trip to get to the office in the morning or to return back home at night during working days. The user can select one of those events by clicking on the widget and confirm or reject the event.

The various widgets are connected by arcs which simply show the sequence of events as currently scheduled. Next to each arc there is an icon which informs on the type of transport mode currently recommended by the system to get to those locations. The user can select the icon on each arc to change the transportation means for that segment. When the user does so the system automatically sends a request to the server which will return –as result- the various transport means available and routes available to the user to reach the destination as graph, as visible in Fig. 5.

5.5 Graph-based route selection

The route selection process relies on an interaction paradigm based on a graph-like structure. The graph has been developed to provide the user with an essential set of information required for the user to appreciate the best travel options as well as the state of the current trip.

The graph, as visible in Fig. 5, has a circular topology and it is dynamically adjusted as soon as updates are received from the server routing component. The graph is meant as user-centric representation, in that the center of the graph represents the current position of the user.

The various travel options available, resulting from the routing system, are represented as a branch of the graph. Each branch is divided in sub-branches according to the number of connections required to get to destination. Names of connecting stations are also shown. An icon informs the user of the various travelling pattern planned within each travel solution.

There are various visualization modes that can be selected to identify the best route, specifically the graph can represent:

- Time to reach the final destination.
- Distance to reach the final destination.
- Emission (In terms of CO2 or PM) generated to reach the final destination.
- Cost to destination.

The distance from the center of the graph can represent either the time required to get to the destination, the distance, the emission or the cost. When user switches within the different views, the graph adjusts automatically to account for the new configuration. When the user is interacting with the mobile i-Tour client he/she can switch between the various visualization modes by simply bending the device on the side.

Regardless of the visualization mode, the graph always shows the various alternatives available to reach the same destination. In other words all the leaf nodes (the terminating nodes) of the graph all represent the same destination. The various branches represent instead the different routes available to reach the final destination.

Depending on the selected visualization modes, the various nodes are placed located, following a radial approach, at a distance which is function of the time, distance, emission, cost required to reach a given place.

This way it becomes very easy for the user to identify the best option according to the given visualization mode. For instance, when in time mode, the user can immediately identify the best solution (i.e. that bringing the user to destination in the shortest possible time) as the solution identified by the shortest path. Similarly, when in emission mode, the user can identify the most sustainable option, by selecting the shortest route, i.e. with the lowest emission in terms of CO^2 or PM (Particulate Matter).

As soon as the user selects a segment, this is highlighted and when the user selects the segment additional information on that part of the travel is shown (e.g. bus number, expected delay etc.).

Each node of the graph reports the name of the corresponding station. The various graphical features of the graph are used to inform the user about relevant information on each travel option. The recommended travel option, i.e. the option providing fastest, most sustainable, shortest or cheapest solution (depending on the visualization mode), is highlighted by the corresponding branch of the graph being rendered with a thicker line. The recommended option is also highlighted with high contrast, will less favourable options are rendered with lower contrast.

Circles in the background highlight the top three options, providing the means to appreciate immediately the most interesting travel options for the users. An icon next to the three different routes clearly identify the first three choices. A label next to the circle informs of the arrival time of the tree best options.

It should be noted that to improve readability the graph is not linear.

Each segment of each branch, which represents an independent unimodal journey, is additionally associated to an icon that shows the corresponding transport mode (e.g. train, bus etc.). Additionally coloring is consistently employed to inform the user about quality of service. In particular the color of the arc inform the user weather the very journey leg will or will not be comfortable for instance due to the amount of passengers onboard that very vehicle or due to other factors that may influence the judgment of the user.

This information in fact summarizes the overall concept of quality of service resulting both from the information gathered by the system (e.g. information coming from sensors onboard a bus informing of the amount of passengers on a given vehicle), as well as information coming from the community of users through the recommender system (e.g. a bus may be badly rated because unclean). Similar color code is used to inform the user on quality of service at exchange stations (e.g. platform packed with people).

The user can prune away undesired travelling options, by clicking on a read (delete) button next to each leaf node. The graph then automatically readjusts to maximize the readability. Since clicking on a relatively small icon on a small screen (as in the case of Smartphone) is not user friendly, especially when in a mobile context (e.g. while walking), the user can remove undelivered option by simply placing a finger onto the corresponding icon and by shaking the mobile device. Since this information is based on measurements provided by the sensors fitted onboard the mobile device we have introduced a safeguard to avoid accidental deletion of travel options based for instance of sudden accelerations detected by the accelerometers, e.g. detected when the user is walking downstairs holding the device in their hands. The deletion process, when performed through a movement of the device, is to be confirmed through a finger gesture by dragging it downwards, as if nodding, or on sideward, to cancel the operation.

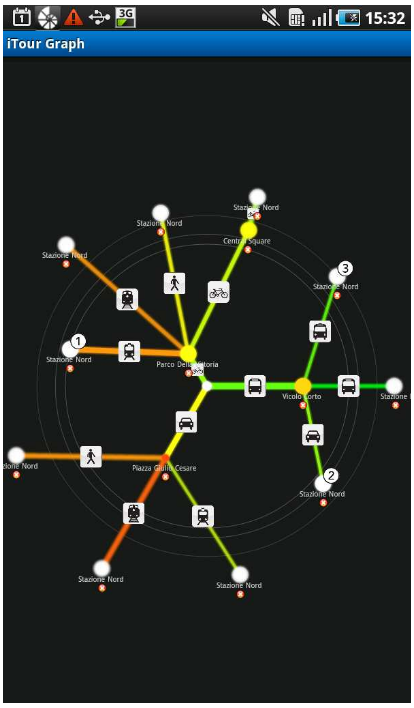

Fig. 5: screenshot of the graph-based interface

All the described graphical interfaces and interaction paradigms are the results of several sessions of internal development and expriments on a restricted number of users and are the most effective achieved so far. In the future, as soon as the first prototype of the system will be available, we have planned to extend and inspect more in depth the usability quality tests of our interfaces based on feedbacks provided by a wider set of daily users.

6 CONCLUSIONS AND FURTHER DEVELOPMENTS

It has been demonstrated that standard turn-by-turn directions, traditionally effective to provide driving directions, are not best suited to pedestrian navigation, which is essentially the case of i-Tour where the user walks or uses public transport facilities. The use of landmarks to augment recommendations and navigation, which has been subject of extensive research, can be instead very beneficial to pedestrian routing as presented within section 4 “related works”.

At the same time improving readability of routes within indoor environment can be fundamental in the context of routing the user across a complex system of indoor environments such as large underground stations. However it should be noted that the main issue, when dealing with indoor routing, is precise indoor localization. The poor precision or no coverage typical of GPS localization (even if A-GPS is available) within indoor environments is crucial since precision, when providing walking directions, should be even higher than when driving, due to the low speed of the user which requires instructions in the range of few meters.

Since providing precise localization is often extremely complex, from the technical point of view, further works will explore the development of interface-based strategies to minimise the limitations of the lack of location information to deliver alternative strategies to routing, which do not require precise localization. One of the possible strategies which will be explored is to implement a properly balanced combination of traditional and landmark based routing.

As illustrated in Fig. 6, in fact the system could provide standard directions based on localization when outdoor, while it could switch to full landmark-based routing when localisation precision drops below a certain threshold.

At that point instructions could be formulated as a sequence of images (with direction) that the user should move across as soon as they walk along the route. Given the fact that the system would be unaware of the actual position of the user speciall attention will have to be paid on how to ensure basic forms of localization in case a re-route request when satellite-based location is not available, for instance through automatic (trying to extract relevant features of the surrounding scene from images captured by the device) or by manually pointing their position within a map.

Fig. 6: a viable hybrid routing strategy for i-Tour based on full map based (in outdoor contexts) and landmark-based guiding (in indoor context with no localisation)

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