UnCrowdTPG: Assuring the Experience of Public Transportation Users

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Abstract*—Use of public transportation is on a rise, enabling greener cities and improvement of the quality of life of the city residents. The challenge for the public transportation system is that its demands are non linear and the passengers' experience depends on many human factors. UnCrowdTPG is a mobile service and a research platform that has been developed for understanding the mobility patterns of the users of public transportation services in Geneva (TPG), as well as their experience with respect to the crowds perceived aboard the vehicles. UnCrowdTPG models algorithmically this experience using crowdsourcing techniques and it provides to the individual estimations of the future expected experiences aboard, thus enabling them to better plan their journeys with respect to the crowds. In this paper we position the UnCrowdTPG service as a research platform. Additionally we discuss the research questions in areas like local governance and public healthcare supported by the data analysed collectively from all UnCrowdTPG users. We also discuss the challenges for implementing the truly smart transportation system in a small-sized European city like Geneva.

Keywords— Intelligent Transportation System, crowdsourcing, smart city, user experience, mobility patterns, crowd, public health

I. INTRODUCTION

Urban areas are expanding propelled by population and economic growth. Many authorities invest in infrastructures, as well as they incentivize the residents for particular actions towards "eco" cities [1]. These efforts include developments of public transport infrastructures and incentives for using it, instead of using a car [2]. Therefore, public transportation becomes an indispensable part of any city providing diversity of services aiming to be more reliable, faster and user–friendly, and a service accessible for all. However, during the rush hours, commuters can be greatly discouraged from using the public transportation services in general due to the late, overcrowded and noisy vehicles. Overall challenge is that we have a weak understanding of the experience of public transportation users and factors influencing it. The transportation company itself collects a cumulative data upon the vehicles usage and occupancy, as well as tickets sale. However, this data is not supported by the real users needs and feedback, neither is used back for the advantage of the individual users themselves.

In this paper we present UnCrowdTPG - a research initiative in which we have developed a mobile service. Users can plan their commute/trips based on the real-time information about the positioning of the vehicles in the city, as well as share their experience of using public transportation, specifically with respect to the crowd experienced at a given stop or aboard of a given vehicle. The assessment of the experience provided by users is solicited by the application itself, i.e., the application user is asked to rate the crowd volumes at the particular stop and in a particular vehicle. To do so, the application detects automatically when the user is at a relevant stop or in a vehicle. UnCrowdTPG predicts also the future experience for an individual person in a given vehicle, by leveraging probabilistic data analysis techniques. Based on the data provided by multiple users, the service predicts the (future) experience for an individual person, who in turn can contribute to their commuting plans and habits.

The main research questions that will be answered along our research on data collected via UnCrowdTPG relate to 1) understanding and modelling mobility patterns of commuters (including trajectories for public transportation and walking) in the city; 2) understanding and modelling the individual's experience of using public transportation and factors influencing it, related to crowds aboard; 3) proposing the most efficient ecosystem of mobility options for a given city given the concerns of local authorities and public healthcare needs. More technical research questions relate to deployment of UnCrowdTPG itself and include research on algorithms for a) an accurate and timely estimation for the individuals of their transportation stop and future vehicle (including direction of the service; b) detection of the individual being in a given vehicle travelling on a given line, in a given direction; c) crowd data analysis towards prediction of the crowd aboard.

The UnCrowdTPG service is deployed in Geneva (Switzerland), leveraging its public transportation services (*TPG*) open data initiative. Geneva has ~200'000 and Geneva canton has ~500'000 habitants (for areas of 15.93 km^2 and 282.48 km^2). The TPG network extends over 427 km, providing the service to 440'000 daily passengers using 426 vehicles (trams, buses and trolleybuses) [3]. The socio-demographics of commuters vary, but its majority is represented by young people (18-30) commuting from outside of the Geneva to the city centre for work or school [4]. In fact, there are almost 100'000 persons living in surrounding French villages and cities (connected with the TPG network) who pass the French-Swiss border every day for work/school purposes.

It is important to notice that in Switzerland the services are running mostly on schedule. To help users to gain time, TPG provides a basic trip-planner application that enables mobile/PC users to check in real-time the most convenient schedule. Given the relatively short time constraints for Geneva commuters, i.e., crossing the full city takes max 1h, it will be even more interesting to offer the possibility to plan a trip inside Geneva by ranking the proposed path and times by crowd. Additionally, it may be even possible to suggest to the users the time window in which it is better to perform a given trip. This will be very beneficial for people using the public transports without particular time constraints, for elderly, disabled or even for mothers with little child/children needing space and more comfort. The crowd assessment will also offer the possibility to shift working/school commuters' habits. Commuters with flexible working/school time will have the possibility to easily adapt their schedule to a more convenient trip time. From own experience we know that often just increasing the service frequency is not enough, as there is the need to help the users to discover its implications. If a person is used to taking a given crowded tram/bus at a given time, it may be difficult for them to know that there is another one empty just after. In addition, with the crowd information provided along the trip planner, for commuters with fixed hours it may be possible to negotiate with companies or schools a slight change of their schedule to better distribute people in the public transport. Geneva with its public transportation services and its challenges represent typical situation for a small-sized European city. Models developed for Geneva will enable further research and generalization for other cities of similar size and mobility patterns.

In this paper we position our research on UnCrowdTPG and therefore we first present the service development cycle and its results to date, as well as research directions enabled by an operational service and data collected through it.

II. UnCrowdTPG Service

A. Requirements

To understand the current experiences, as well as needs and expectations of the existing and potential TPG users we have conducted an online, semi-structured survey. In the survey we have aimed to understand, amongst the others, their attitude towards crowds aboard. We have surveyed 39 individuals; out of which 18 (46.2%) commute using TPG every day, while 15 (38.5%) - less than once a week. Three people commute by train and then TPG from Lausanne (60 km/40 min by train), one from Vevey (87 km/1h by train). All of the participants are ICT-literate and have a smartphone ranging from iPhone, Motorola, HTC, to the newest Samsung and LG devices. Out of 39 participants, 34 have mobile operator-based Internet access on their smartphone and the remaining 5 only WiFi-based Internet access. Furthermore, 24 (61.5%) participants use a mobile application to plan/execute their commute plans and trips; they mainly use the current TPG application. The second most popular application is the Swiss train trip planning ('CFF/FFS/SBB mobile') application.

When asked if they would change their trip, for example take a longer path or wait a bit more at the stop, to avoid crowded trams/buses, almost half of the participants (44.7%) responded positively ("definitely yes" or "yes, likely"). The same result was observed when they were asked to imagine a transportation application, which would let them plan their trip according to the crowd on trams/buses and at the stops. Again, more than a half of the participants (59%) responded that they would use it. For both questions, the answer "it depends" lead the participants to explain that they would be happy to do so only when they have enough time (majority of answers), and when the weather is enjoyable enough for waiting, or when they need to carry some things that are cumbersome in size. Additionally, the choice of taking a longer path or waiting a bit more may be influenced by their mood at a given point of time and location. When they are in a bad mood they prefer to be left alone and crowd would irritate them. They would thus definitely use and benefit from the UnCrowdTPG application.

We have also noted survey answers from five Geneva residents, who almost never use TPG services, due to the fact that they use car, bike, or walk every day. These people particularly indicated their need for understanding when the tram or bus is crowded. As infrequent TPG users, they are particularly critical to its services: once they find themselves in a crowded vehicle, they tend to generalize that such situation happens all the time and they promise themselves to "never again [*use*] TPG". Gaining the trust of such infrequent users would be a gain for TPG and, especially if they abstain from using a car in the city, for the city at large. UnCrowdTPG enables it. Additional participants' comments included request for the "electronic ticket" feature in the application.

Extrapolating the results from our sample, we anticipate that at least 50% of the current TPG users would be interested in the UnCrowdTPG services.

B. Geneva Public Transportation Services (TPG) API

The TPG company since late 2013 provides free real-time information for all TPG vehicles and their schedules, i.e., a list of all the stops (with locations and query by location), the waiting time at a given stop, the route of any operational vehicle (having unique ID, and in service at a given line and in a given direction) with arrival times at each stop (details at `http://data.tpg.ch`). As of 7th of July, there are 764 commercial stops and 1628 physical stops; a commercial one (e.g., train station) groups one to several of same physical ones together. This may vary from day to day depending on the road works conducted the city, special events and so on. The location conforms the WGS84 coordinate system. For any given GPS location, the TPG API returns the commercial stops located in a range of 500 meters from this location. The TPG API data originates in the TPG passenger information & operational support (SAEIV) system and is provided in the JSON and XML formats.

C. System Components

UnCrowdTPG contains 1) a mobile app component with a GUI, with which the user interacts, and 2) the UnCrowdTPG proxy-server component managed by our research lab. Every query for stops and next departures from the mobile app is sent to the proxy that a) interrogates the TPG API, b) computes the crowd estimation based on users contributions and c) aggregates the crowd data with the real-time transportation data.

D. UnCrowdTPG Mobile App

The UnCrowdTPG mobile app enables a user to choose a nearby (or distant) stop (Fig 1), see the next departures at this stop: TPG lines, directions and crowds (Fig 2) and how much time (in minutes) does it take to reach this stop when walking, and, once in the vehicle: see the next stops and their crowd information (Fig 3).

The crowd information ranges from 'not available', via 'low', 'medium', to a 'high' crowd. The crowd estimation is provided to the user with a confidence ranging from zero to five stars (corresponding to 0% to 100% probability) (Fig 4). Once the service assesses that the users reached the designated stop or they are inside the vehicle of interest, they are asked to contribute with a crowd rate to build an accurate crowd model at a stop (Fig 5) / and in a vehicle (Fig 6). To deploy these ratings, we leverage the context-aware Experience Sampling Method (ESM) [6], where the assessment of the phenomena of crowds is done only in a relevant context: at the stops and in vehicles. These are events automatically detected by the mobile application; they trigger ESMs and hence the data collection.

Each user rating entry for a stop includes the time-stamped crowd estimation from the user, and the physical stop code. Similarly, each vehicle crowd entry includes the time-stamped crowd estimation from the user, if the user is sitting or not, the vehicle ID, and the physical stop code for the stop at which the user entered the vehicle.

Each entry is anonymous; no information about the user is kept in the system. To avoid that data is sent to the server without an authorization, all interactions between the UnCrowdTPG mobile app and the UnCrowdTPG proxy server, are using https (SSL encryption) and a secret key associated to the server side assures the identity of the mobile application.

The major functions enabling the UnCrowdTPG services described above are detailed in the following sections.

III. UNCROWDTPG MAJOR FUNCTIONS

A. Detection of Location and the Stops Nearby

The aim of this function is a retrieval of stops nearby the user. Firstly, the user current location is determined, which can be done two-folds.

The first (default) method is provided by the mobile system, i.e., based on its built-in mobile network-based positioning method. If the accuracy of the user location is below 400m then the application will request continuously the location updates from the OS until it improves and only then proceed to retrieve the nearby stops. In the case when the user gets impatient while waiting, he/she is suggested to switch on either GPS or/and WiFi in order to improve the accuracy of positioning [7]. Neither GPS nor WiFi are specifically required by the UnCrowdTPG app, unless the user's location accuracy needs to be improved. This feature makes the application to be more energy efficient comparing to the systems, which by default require GPS/WiFi as sensors. The current user location is automatically updated while the user is interacting with the application (e.g., in a moving vehicle). Once the UnCrowdTPG application is closed, updates of the user location are 'suspended' until the next application usage.

The second method to define the user's location is the manual user input. A user is able to select a location on the map by a long press on the map and to get the stops near that position. This can be used in case the accuracy of the system location may not be good enough and the user does not want to switch on WiFi or GPS, or the user wishes to know nearby stops from a location that he is not currently in, e.g., when planning a trip ahead of time.

B. Detection of the Specific Stop

The aim of this function is detection of the stop the user is at. This algorithm is essential to associate the crowd data about the stop provided by the user, to the accurate sub-set of the transportation (stop and vehicles, directions).

As a commercial stop can be composed of many "physical stops" to which many lines can be associated in one or both directions. Once the commercial stop of the user is determined, all associated physical stops are presented to the users (in the main map view with the distance to reach them) and can be selected by the user.

The stop detection function aims at an accurate detection of the exact physical stop (vehicle line and direction) the user is interested in. This algorithm makes use of physical activity recognition service (i.e., build-in phone service based on the real-time analysis of the accelerometer data to classify recognizing if the user is 'walking', 'running', 'biking', being 'in a vehicle'), information about entering/exiting geofence [8], i.e., geo-referenced area around stops, as well as next vehicles' departures times at the stops nearby and the past user behaviour of being at this stop, in a given vehicle, in a given direction.

When the service assesses that the user approached ('walking') the selected commercial stop of interest, he is asked to rate the crowd at the suggested by the algorithm physical stop (vehicle line and direction, Fig 5). The user can easily correct this suggestion (by clicking the "Wrong connection" key and selecting the accurate one), if the algorithm is wrong. The algorithm learns from the user feedback.

C. Detection of the Specific Vehicle

The vehicle detection algorithm is the key point to associate the crowd data about the vehicle provided by the user to the accurate sub-set of the transportation network (vehicle line and direction). It follows directly the stop detection algorithm and it is triggered by the physical activity recognition service (i.e., by 'in a vehicle'). To make an accurate detection of the vehicle the user is in (like in Fig 6), this algorithm leverages information about entering/exiting geofence stop area, as well as next vehicles departures times and past user behaviour. Also here, the algorithm learns from the user feedback.

D. Crowd Estimation Model

The crowd estimation model is running at the UnCrowdTPG proxy-server and it provides the crowd estimates for specific TPG stop and for the specific vehicle of a specific line and direction. It leverages the crowd-sourced ratings [9] – as collected from users at the stops and inside the vehicles. The crowd estimation model is generated from historical data that reflect the crowd statistics for each line and all its stops for all times (hours of the day and all days of the week). The statistics collected are likelihood probabilities for each of the three levels of crowd ('low', 'medium', 'high'). These models are updated on a daily basis (i.e., every 24 hours) using the users' historical data.

The crowd estimation model is enriched with real-time data about the crowd at the stops and in vehicles acquired from the users in a current day, i.e., since the last update of the model. This real-time adjustment can be significant for the user in case of unusual crowd at a stop or in a vehicle. To account for the lack of complete knowledge about the crowd, a confidence measure has been devised to represent how likely it is for a given estimate to be true. This confidence measure depends on

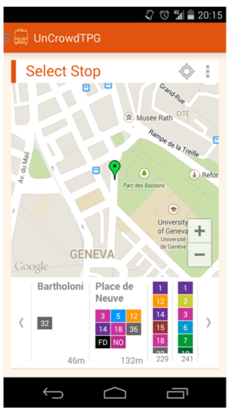

Fig. 1. Choice of stop(s) nearby

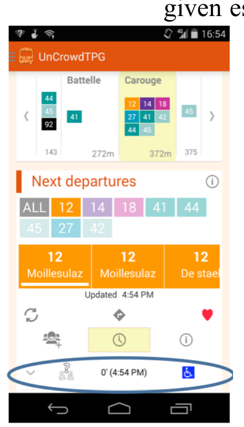

Fig. 2. Next departures at the stop

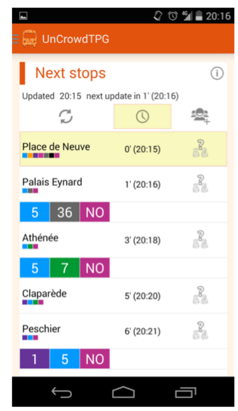

Fig. 3. Next stops, crowds and connections

Fig. 4. Crowd/confidence levels

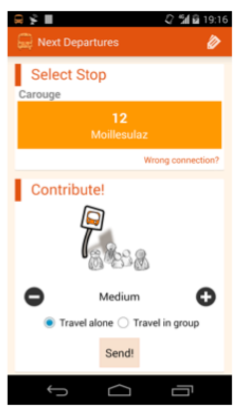

Fig. 5. Rating crowd at a stop

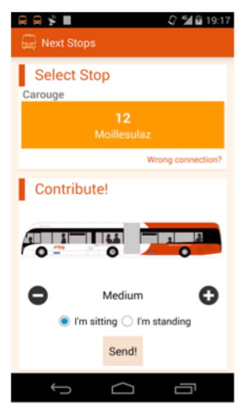

Fig. 6. Rating crowd in a vehicle

the total number of user inputs and the time since the latest input.

IV. UNCROWDTPG AS A RESEARCH PLATFORM

A. UnCrowdTPG Research

As university-based research lab we are interested in diverse research opportunities this project can enable us to conduct. Firstly, we are interested in understanding the dependencies between transportation option offered and crowds, the TPG user crowd requirements and their experiences for TPGs in different locations, times and personal circumstances (e.g., under stress, in a leisure time).

People giving their subjective opinion about the crowd will give a better view on their actual feeling of comfort. For example, each person in the vehicle may perceive 20 people in a vehicle differently. In the future developments of UnCrowdTPG we plan to incorporate more human-based subjective criteria of usage of the public transportation vehicles, e.g., cleanliness, noise level, temperature or feeling of security. The cumulative subjective data will capture the differences between different vehicles and could give indications on where adjustments in the infrastructure (vehicles/lines/frequency and so on) are needed. Subjective data will be also available to understand how the subjective feeling of the crowd changes over time at different stops and on different vehicles. This will contribute even more precisely to adjustments to the infrastructure as well as better planning.

B. UnCrowdTPG-Enabled Research

From a research perspective we are also interested in modelling of the mobility of TPG users and commute paths at large, which can be leveraged by: a) TPG itself to improve its services; b) public authorities (e.g., for security, safety, urban management); c) public health care system, e.g., for mental health or physical health (i.e., it is known from the literature that commuting relates to stress and risk of cardiovascular diseases [10]).

C. Further Service Deployment

We designed the current deployment of UnCrowdTPG to support users of the geographical area covered by TPG and their infrastructure (e.g., bus and tram). However, given the generic model of UnCrowdTPG the system can be applied to other public transportation systems to support their users, e.g., CFF/FFS/SBB train system in Switzerland, or bus/metro system in other cities of a comparable size (e.g., Grenoble, Malmo) assuming that transportation data is openly available in real time to be incorporated in the service). This can be highly beneficial for all involved parties, as it has a potential to increase revenues to public transportation companies, while improving the user's transportation experience.

D. Current Status

We followed an iterative design, rapid prototyping method to build an operational version of the UnCrowdTPG App. Along the past six months we have evaluated multiple iterations of UnCrowdTPG interface with our mQoL Living lab members [11] for its appeal, usability, speed and accuracy. We have evaluated the stop detection algorithm and vehicle detection algorithm as well, which is accurate in around 80% of the cases. The less physical stops are associated with the commercial stop, the more accurate the algorithm is. Additionally, the more user behaviour data from the past is collected (with respect to stops, vehicle lines and directions used), the more accurate the stop and vehicle detection algorithms.

The status of our crowd estimation algorithm is as follows. The algorithm has not yet been evaluated, as we are waiting for the TPG to provide us a set of objective data about their vehicles' occupancy, to which we will compare the outcomes of our algorithms. This objective data set if collected by each vehicle doors' sensors at each stop, as a number of persons entered and exited this door. This data is not available online at this moment; i.e., it is collected from vehicles' local storage once a week. Additionally, this data is not available publicly, i.e., via an API, and there is no future plans to release it. We will get an access to it via a University collaborative agreement with TPG.

If UnCrowdTPG users will not collaborate by providing their crowd experience data to us, our algorithm will be based on the objective data by TPG, which may be less accurate than the real perception of the users themselves.

From the basic research perspective, we conduct research on the correlation of type and size of the crowds the users find him/her-self in daily life (familiar people or strangers) on the user's perception of context intimacy. We attempt to deduct from the user interactions with his/phone if he/she feels intimate in a current context, based on which we may attempt to reason on the crowd size and type (familiar people or strangers). This basic research line is ongoing [12].

As of 1st of July 2014, the application is released to the public (`http://goo.gl/SEgusQ`) and we have 40 users. The application's Privacy Policy has been defined to match the current data protection laws in EU and ETFA. Users can always contact us via the app or over the post, email or a phone.

Given the UnCrowdTPG developments and current application release to the public, we will evaluate it further and report the results in our future scientific publications.

V. RELATED WORK

The related research and development activities are as follows. As there exist commercial positioning and navigation services like Google Transit, it does not consider detection of the current user's stop or vehicle. Additionally, from the perspective of research, none of the previous works on public transportation usage has taken the research to the level as ours, i.e., attempting to predict the user experience in real time.

Kalsson and Larsson [13] interviewed 58 passengers of local and regional buses in the city of Gothenburg (Sweden) about the importance of comfort factors when using the bus (temperature, seat availability, comfort of the seat, cleanliness, smell, noise, illumination, crowd, storage possibility and smooth driving style). Additionally, Costa *et al.* conducted a pilot study of a framework and a mobile app to assess a 'contextual mood' in public transportation of London [14], i.e., user affective state (if they are happy, relaxed, etc.) when using the public transportation. They have found out that the user's mood is difficult, but feasible to be assessed in context of public transportation and there is a need for an individual model for each user, i.e., some users indicated that mode of transport and condition of vehicles mostly influence their experience, while others indicated that it is the crowd and timeliness of the vehicles. Both works found out that crowd is an important factor influencing the commuter experience, but could not quantify it and predict it further, like our research does.

Zambonelli [15] has expressed the vision of urban crowdsourcing at large, supported by particular use cases, where data provided by citizens could be used for better city maintenance, safety and daily mobility. Artikis at al. [16], instantiates this vision by providing a concrete example of a traffic congestion modelling based on data collected from fixed sensors mounted throughout the city and mobile sensors mounted on public transport, as well as private vehicles. They demonstrate the effectiveness of the system in city of Dublin (Ireland). Estes [17] provides an example of UnCrowdTPG like application in Israel, which, based on the data crowd-sourced from its users' smartphones, recommends the best transportation option throughout the city: tackling the traffic and human mobility challenge at large. However, this initiative does not include any specific research activities.

VI. Conclusive Remarks and Future Work

The ultimate aim of our laboratory is to build and maintain a strong community of UnCrowdTPG users who use the application frequently and are motivated to contribute and collect the reliable information, which could be then used to provide accurate predictions of the experience of others. The community members collectively empower each other to make better transportation choices improving the overall community experience aboard. A short online survey, gives indicators supporting the uptake of the UnCrowdTPG app by the existing TPG customers and customers commuting between cities.

Additionally, from an academic research perspective we look forward to collaborate with Geneva residents via means of the UnCrowdTPG application and to enrich our modelling knowledge and skills by means of providing us with a real-life data. And results gathered along the usage of this service will be put back in practice to improve the life quality of Geneva residents – ranging from an improvement in the UnCrowdTPG application itself to a possible communication with local authorities – supported by an evidence grounded in the UnCrowdTPG data.

We are fully aware that an effective collaboration between the research, private investment and public sectors will be a critical determinant in the future development of cities. Citizens must be involved and need pathways through which they can contribute to the future evolution of their own city. The UnCrowdTPG application and framework is an example of such a pathway and provides benefits to all the stakeholders involved. Finally, a number of other partners involved in the future planning of Geneva's infrastructure will also benefit from the enhanced planning and mobility assessment capabilities such data will bring.

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