Telemetric Transport Mode Validation

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Abstract

This paper introduces a model for the validation of transportation modes by processing sequences of geospatial data in a telemetric fashion. This deals with a validation problem, if a customer is in an specific transportation mode or not. In order to derive a model that is capable of such a task, we set up a web-based architecture, which has a central HTTP server and a SQLite database at its heart. Several mobile clients (we are mostly targeting smartphones) will gather geospatial positioning data via GPS satellite, connect to the central server and upload the recorded data sets. The server will hold a stack of the recorded geospatial data and analyse it in order to make an attempt in validating the used transportation modes. The validation process is based on comparing the plan data from the superordinate traveller information system, which the customer used before, with the recorded data from the smartphones. For the purpose of distinguishing between public and individual transportation and to increase the validation accuracy, it is vital to consider data sets from other travellers (as in from other sensors/smartphones). The results from the published work will be implemented in a next-generation traveling information system (nTIS), which is embedded in the *Schaufenster Elektromobilität* project *IKT-Services* in *AP 7000 – Kundenorientierte Mobilität*. The implementation will be tested and evaluated in the context of said project. The GPS recording capability will be implemented within the guidance and assistance functionality of the mobile application. The validation method will be part of the nTIS server application.

1. Motivation and objective

The mobility of the future has a lot of demands and challenges. Through the continuously growing population and wealth we suppose that more and more people become travellers [1]. To satisfy the growing demand for mobility it is critical to design a sustainable mobility infrastructure, which is able to satisfy the needs of the many.

Mobility management is understood as the concept of providing travellers with information and incentives to converge towards a sustainable infrastructure for mobility. The main methods are prevention, reduction and improvement of traffic to create an efficient and more environmentally and socially acceptable mobility for everyone [2]. This is generally achievable by raising the share of public transportation and lowering individual, motorized mobility through the provision of incentives or customer-oriented information on the (especially environmental) sustainability of each individual's mobility. These methods can be delivered by complex next-generation traveling information systems (nTIS), which will be capable of planning trips, providing assistance during a trip and raising sustainability awareness by analysing mobility behaviour on a personal scale individually for each traveller [3].

Kramers [4] conducted an empirical analysis and evaluated modern traveling information systems. The evaluation states that all of the compared systems are absent of critical features or only equipped with a limited extent of said features. This conclusion substantiates when looking at sustainable aspects of mobility. State of the art traveling information systems are not able to provide their users with enough information on the extent of the environmental impacts of their personal mobility. In order to raise the sustainable awareness of travellers, it is vital to inform the

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travellers on the effects and consequences of their personal mobility and especially their choices of transportation modes.

The project IKT-Services aims to develop a nTIS, which meets the requirements specified by Kramers [4] to overcome this lack of sustainability awareness. The system will provide functionality to track modal choices of a traveller, analyse and summarize his mobility behaviour and deliver reports on the ecological, environmental and social impacts of his travels. The customer access and guidance is enabled through a mobile application. In order to realize this concept, it is indispensable to come up with a model to use sequences of transmitted geospatial data to extract certain meta-characteristic features from it and hence enable telemetric transportation mode validation.

The objective of this work is to generate a system for the validation of a transportation mode by using information from the nTIS, the smartphones GPS sensor and additional data from open information services such as OSM.

2. Related work

Generally, a lot of work is done in detecting the transportation mode (subfield of activity recognition), which is usually based on the use of a smartphone's GPS or accelerometer sensor or a combination of them. The accelerometers have the advantage of a low power consumption and a high density of measures per second, in which the GPS sensor provides the context of a person. Most studies use smartphones as sensor, because they have a large market penetration, are easily programmable and most of the time they are held on the person (cf. [5]). In the past, special sensing platforms were used. One relevant part of the validation is the detection of a transportation mode. In this case we analysed the work done on detection to derive the approaches for the work on validation. The table below list some of the relevant work in transportation mode detection, which focuses on the application of the previously introduced smartphone sensors.

Author	Information base	Objective
Hemminki et al., 2013 [5]	Accelerometer, conjunction of sensors possible	Tracks the acceleration during travel time and records an acceleration pattern, which is typically unique to a certain type of vehicle
Kjaergaard et al. 2011 [6]	Accelerometer and GPS sensor	Separate motorised transportation from stationary mode
Stenneth et al., 2011 [7]	GPS pings from smartphone and vehicle	Combined the GPS sensor data provided from the user with GPS data provided from the vehicles of the public transport
Reddy et al. 2010 [8]	Accelerometer and GPS sensor	Use of decision tree and first order HMM classifier based mainly on GPS speed for detecting motorised transportation
Kim et al. 2010 [9]	Accelerometer	Detect stationary mode trough the variance of the accelerometer sensor

Table 1 Relevant work for transportation mode detection

The detection of a transportation mode is not part of this work. The transportation mode is pre-defined by the traveler, because the traveler selected a specific route in the nTIS before. Hemminki [5] evaluated the approach in an android application to motivate people to reduce their CO2 footprint. They also mentioned that different smartphones could influence the precision through different sensors of different quality.

3. Use case

The telemetric transportation mode validation will be implemented in a next-generation traveling information system (nTIS). This system is currently under heavy development and part of the German national project landscape Schaufenster Elektromobilität. It is located in the project IKT-

Services (IKTS) under AP7000 Kundenorientierte Mobilität [10]. The goal of this work package is to create a web-based traveller-oriented application, which will not only enable the traveller to plan multi-modal mobility (pre-trip), but also provide context-sensitive support along the actual travel (on-trip) as well as reporting summaries after completed trips (post-trip). The system will feature various techniques to implicitly enhance (environmental and social) sustainability of its user's mobility. A key requirement to enable context-sensitive assistance and attractive incentives on the way to a more sustainable mobility is an accurate estimate of the utilized transportation modes. A concrete use case is to observe and validate, whether the traveling person is taking the bus as planned or not. This can be abstractly seen as a navigation system for public transport. Furthermore it is possible to calculate exact values for the end-user reporting. The work introduced in this paper attempts to meet the requirements of the travel assistance for transport mode validation needed in the work package AP7000.

4. Design decisions

4.1. Design

In the context of the previously described use case, the validation of a used transportation mode (based on a sequence of geospatial data) deals with a validation problem. This problem consists of different likelihoods and probabilities on whether or not a certain transportation mode has been used to record the analysed data. In consideration of the superordinate research project (IKTS) we have an assumption of the used transportation modes in a journey. The assumption is based on a chosen traveling option of a customer, who has explicitly started the route. We divided a route in connections, each connection is separated by a switchover of a transportation mode. The connections consist of several transportations, each switchover of a transportation is a stop. The transportation contains scheduled arrival and departure times and actual (real time) arrival and departure times.

The main use case is to observe if a traveller is in the proposed transportation mode and vehicle. Through the nTIS we know the departure and destination of the travellers. This is basically separated in two dimensions, time and position. So we are able to validate these two dimensions. In consideration of the classification of a journey we can validate different positions and timestamps. In principal, we have to validate if the person is really "on-trip". Through incoming GPS signals from the smartphone, it is possible to detect a general movement and to determine an "on-trip" state. If no GPS signals are arriving, the customer doesn't want to be assisted or the smartphone is offline, then no validation will take place. For our test application we imply, that a customer is on-trip and sending GPS signals to our backend.

The GPS signals from the customer are aligned with the data from the nTIS on a central system. First we compare the dimension of time. The first GPS signal should arrive at our backend in a time period close to the departure time. The position should also be in a specific range, since the latitude, longitude and accuracy values have a specific calculated distance to the departure stop of the journey. In relation to nearby signals with a relative minimum distance and time, the GPS signal is selected and compared to the transport stop. In this approach we selected the GPS points, which are in a 15 second range to the departure time. In the distance dimension we include points, which are in a radius of 15 meters plus the average GPS accuracy (15 + average accuracy). On every transport stop it is possible to validate the transportation mode, especially in public transportation, where there are a lot of validation points. Walking and biking are much harder to validate, since it is necessary to validate the trip via a public router. Even so the customer can take another route to the destination. In this case the minimum limitation of the distance and time period for validation should be extended, although it cannot be granted to be adequate. In locations the customers knows well, there might be a preferred route, which could differ from the recommended

one. The validation of a car trip is possible when observing the changes of street types. At these points we divided the connection in transports with “stops” (departure and destination). Therefore, the time range for validation should be extended, because each person is driving at a different velocity and the times of changes are fixed in the nTIS.

As mentioned above, the guidance through the application must be activated. Relying on that, there are two possible cases, which can occur. The users are following the selected route or not. In case the customer is not following the route, the guidance application has to intervene. The detection of an aberration is done by detecting the distance of the last GPS point and the next stop. If the distance between the next stop and the latest GPS signal does not decrease or even grow, the user is on a wrong way. This distance is not simply the air-line, since it has to be calculated by a router like Google Maps for any specific location. Also, there has to be a threshold in which the GPS signals can diversify. Nevertheless, the calculation of the distance between GPS point and location of the next stop for every incoming GPS point is very time consuming.

Additional to the above comparison, some rudimentary checks are implemented. One part is the validation of the GPS signal gathered from the smartphone with an online map service like OpenStreetmap (OSM). A comparison of the route way with the street type from OSM is done, e.g. if the user is on a highway or railroad.

In one of our first attempts we recognized that there is an inaccuracy in the GPS data between high-end and low-budget GPS sensors in smartphones (cf. [5]). This was manifesting as we recorded identical routes with different types of smartphones. Cross-checking the smartphone GPS sensor data from several people can increase the validation statement of the transportation mode. Especially public transportation modes with a lot of passengers (and a lot of GPS signal data) promise to return valuable results, which can also aid in the positioning of the vehicle.

4.2. Implementation

For development and testing we set up a relational database based on SQLite and a web-based backend developed with Ruby on Rails. The recorded data from a smartphone GPS sensor features a unique identifier (integer) for every measured point and a consistent device identifier and route title to group these points (varchar 255). The actual data consists of latitude and longitude values with an estimated accuracy guess (decimal), a sensor timestamp at which the data has been recorded and an insertion timestamp at which the data set has been saved on the telemetric server side (datetime). Also included are speed and bearing (decimal).

As second step we developed a rudimentary mobile Android application. The purpose of this application is to globally position the mobile host device via the built-in GPS sensor and to transmit the observed position via HTTP to the web-based backend server (described before). The mobile application is able to start and stop the GPS observation in consideration of the trip context. In addition it is possible to set the observation interval in steps of 5 seconds up to 30 seconds. The Android SDK utilizes an easy way to use the data from the GPS sensor and is automatically initiating the data transfer to the backend server. Later this rudimentary application should be replaced by the application from the IKTS research project. The positioning is necessary for the traveller guidance and assistance, but it is not obligatory.

First we tracked basic some routes to check the functionality of the prototype. Next we travelled via various modes of transportation and recorded the generated geospatial data. These journeys were simultaneously planned in the nTIS, giving us the stops and switchovers of the trip. Afterwards the relevant data sets from the nTIS were selected and exported for developing and testing of the validation process.

4.3. Visualization and evaluation

The processing in R is done with the support of the following libraries "RSQLite, rgl, ggmap". First we visualized a cube with the dimensions latitude, longitude and travel time in seconds (Figure 1). Most of the trips started at the same point, the University of Oldenburg. The lines in pink indicating, because of the greater distance between the points, that these were routes with higher speed (motorized). The blue line in the centre of the cube, which is almost parallel to the travel time axis, contains some green points. This route was recorded from two separate smartphones, which were in the same transport medium. The points are very close and feature a low speed, which indicates that this route was travelled on foot.

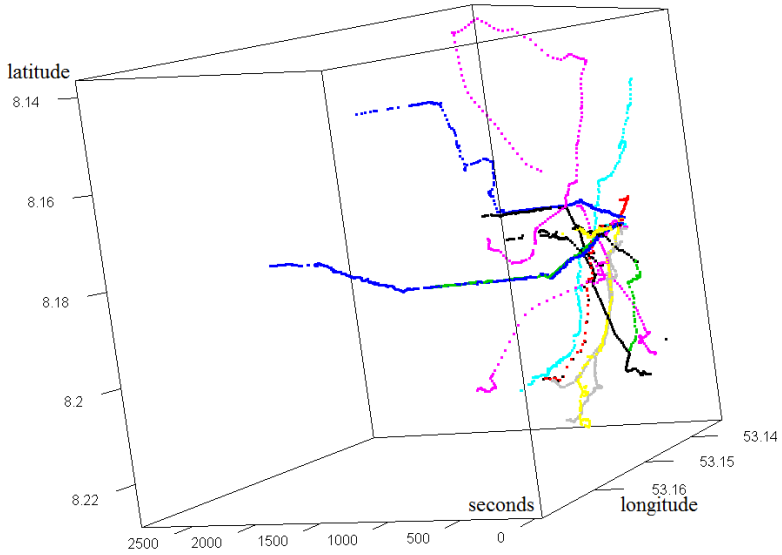

Figure 1: Sample visualization of different routes

In Figure 2, a sample route was taken and exemplarily visualized. The red dots are the stops (and switchovers) of the trip. The blue squares are GPS pings from the smartphone sensor in a radius of 15 meters. The green triangles are GPS pings, which are in a 15 seconds time range of the departure time. Multi-modal trips with bus sub-connections as shown below, indicate that the time dimension is not the best attribute to measure. The distance is much more meaningful, but the combination of both, the distance and time dimension is the key to validate the transportation mode.

The trip contains 17 stops or switchovers and 482 sensor pings from the test user. The average accuracy is 18.88 meters. 79 of these points are in range to a stop of 15 meters + the average accuracy (around 34 meters). In a 15 second time period 172 points are relevant for validation. 34 of these points conform in the dimensions of time and distance. On 17 stops there are 34 pings, which meet the requirements of the validation process. This leads to a validation rate of 2. It is significant that the test user is in the pre-selected transportation mode for this section of the route.

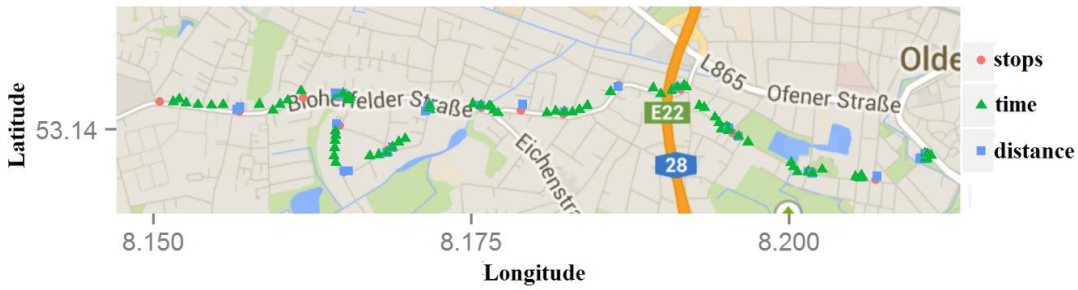

Figure 2: Validation of stops

5. Privacy

In terms of the validation of transportation modes it is not necessary to save the GPS points. It is sufficient to process the data stream as it comes in. Nonetheless, the design of a privacy concept is not part of this paper nor the superordinate research project (AP7000). A possible solution is the use of a disclaimer to increase transparency, in line of “Which data is collected and what is done with the data?”.

6. Conclusion

The validation is very important in terms of the proposed superordinate research project, but any real-world deployment of continuous transportation mode validation on smartphones requires that the detection has minimal impact on the operational time of the smartphone. A possible solution is to activate the GPS signal recognition only in specified intervals (near to upcoming stops/in a specific time range). The transmission could be done as batch job, which would be capable of transmitting whole sets of pings. Statistical methods such as interpolation could be applied additionally.

In the next steps, the system can be extended to a transportation mode detection system. Therefore it is necessary to save the data temporarily for the use (and training) of artificial intelligence methods. Also it is not required to have personalized data sets. A possible approach could be the adaptive boosting, as described by Hemminki [5].

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