Presentation

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Leveraging Controller Area Network Data for Predicting Vehicle Position during GPS Outage

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***Abstract*—The Connected Car is part of a rapidly growing number of Internet of Things devices. Access to data from within the vehicle enables a range of services, from traffic monitoring to warning drivers of upcoming hazardous conditions. Many of these online services are reliant upon vehicles transmitting accurate and real-time positional data. Unfortunately, this information is not always available in areas of low Global Positioning System (GPS) coverage, resulting in a need for the vehicle's position to be estimated. In this paper we present experimental results of an approach which combines values collected from a vehicle's Controller Area Network (CAN Bus), with previous GPS position data from a Smart Phone, to predict a vehicle's position in simulated areas of GPS outage.**

I. Introduction

With the rise of the Connected Car and autonomous driving there is increasing demand for continuous vehicle location data, allowing more accurate Internet of Things services to be provided. An example is detecting icy road conditions, if a vehicle detects that current road conditions are poor then it can warn other vehicles in the surrounding area to be cautious. GPS is typically used to provide precise location information of vehicles to an accuracy of several meters [1]. However, GPS can suffer from low reliability [2], for example in urban areas and locations with poor satellite signal, such as tunnels.

Existing research exists on the topic of predicting vehicle trajectory and location in situations of GPS outage. Skog *et al.* [3] provide a survey of in-car positioning and navigation technologies, and outline techniques to incorporate data that would be found on the vehicle's internal systems. However, as many vehicles lack in-built navigation systems Almazan *et al.* [4] use the inertial measurement unit (IMU) of a mounted Smart Phone to predict GPS position in areas without GPS coverage. Tin Leung *et al.* [5] make use of sensor fusion algorithms for combining GPS data with an IMU. Kumar *et al.* [6] extended this further by making use of On-board Diagnostics (OBD) speed data and an external IMU to predict vehicle location during GPS outage.

This paper explores whether we can leverage data on the internal system of a vehicle, which lacks an in-built navigation system, and combine this with Smart Phone GPS data. Data is collected from the CAN Bus of the vehicle to predict the location based on previous GPS positional data from a Smart Phone, without the need for an supplementary IMU. Additionally, this means that the Smart Phone can be unmounted and free to be used during travel as its IMU is not utilised.

II. Materials and Methods

System Setup

The CAN Bus of an Opel Astra was accessed using a Bluetooth Dongle connected via the OBD port. An Android Smart Phone was then connected to the Dongle via Bluetooth connection to receive and transmit CAN messages from the vehicle. The Smart Phone collected a variety of CAN messages from the vehicle and streamed these to a server via GSM in real-time.

A variety of internal data is available on a vehicle's CAN Bus, for this experiment we accessed the Yaw Rate Accelerometer, and the Front Left and Right Wheel Speed. These three variables are detected and transmitted to the Smart Phone approximately once every 100 milliseconds. GPS data of the vehicle was provided by the Smart Phone, in particular we required the vehicle's Bearing (or Heading), Longitude and Latitude. This data was gathered by the phone approximately once per second.

The process for predicting a vehicle's new position using CAN Bus data is outlined in Algorithm 1, and uses simple linear formulas to estimate the change in trajectory and location using the internal variables from the vehicle. Upon loss of GPS signal the Bearing delta is estimated using the Yaw Rate of the vehicle and combined with last known Bearing provided by GPS. This estimated Bearing is then taken with the average of the Front Left and Right Wheel Speed to estimate the change in Longitude and Latitude, which is then combined with the last known GPS position of the vehicle. These estimated values are then used as the next set of 'last known' values until GPS signal is recovered.

Algorithm 1 Vehicle Trajectory Prediction during GPS Outage

Require: Upon losing GPS signal, take the last known GPS data and predict once every 100 milliseconds

1: New Bearing of the vehicle, using last known Bearing and Yaw Rate
2: New Longitude of the vehicle, using last known Longitude, predicted Bearing and Average Wheel Speed
3: New Latitude of the vehicle, using last known Latitude, predicted Bearing and Average Wheel Speed
4: **return** These predicted values are used as 'last known' values until GPS signal is recovered.

Simulated Experiment

Journey data was taken during a 12 minute trip around St. Gallen, Switzerland, with a total distance travelled of approximately 4km (3991m). This resulted in 720 GPS readings, and approximately 7,200 CAN Bus messages for each variable measured. The journey was typical of city driving, consisting of sharp turns and straight roads, and included periods of stop and start traffic.

For the purpose of evaluation, we simulated periods of GPS outage for five lengths of time, 10 seconds, 30 seconds, 1 minute, 2 minutes and 5 minutes. This was achieved by taking each measured GPS coordinate and then predicting the values which followed for the desired length of outage time. The error was calculated from the distance between the predicted GPS and the measured GPS coordinates and averaged over the length of the outage. The 'final error' was also captured, calculated from the distance between the final predicted GPS coordinate and the first GPS coordinate after the simulated period of GPS outage (as the error increases over time). A total of 3,080 situations were ran on this data.

III. Results

The preliminary results collected are outlined in table I. As expected, the accuracy of the system decreases as the length of the GPS outage period increases, this was due to an aggregated increase in bearing error when turning. However, the approach performs significantly better than a naive approach of simply using 'last known GPS Bearing and Speed' before the outage, as turning actions are captured and incorporated into the predicted bearing.

The average final error after 5 minutes of GPS outage was 71.20m, given that the average distance travelled in this time was approximately 1.7km (1,663m) we feel that this is an acceptable margin of error. At the other end of the scale, prediction was significantly more accurate for shorter time periods, during 10 seconds of GPS outage the system predicted a vehicle's location within an average final distance of 4.14m after approximately 55m travelled. As the accuracy of GPS is estimated to be between 10 and 15m [1], we feel that this is a particularly good result.

TABLE I: Average distance error (meters) during simulated GPS outage

Time Period	Mean Error	Mean Final Error
10 seconds	2.30	4.14
30 seconds	5.96	11.30
1 minute	10.96	20.09
2 minutes	18.91	32.01
5 minutes	38.64	71.20

Fig. 1 additionally shows the complete route taken and 5 minutes of simulated GPS outage. The example period of outage shown included stop and start traffic, sharp turns and sections of straight road.

IV. Discussion and Conclusion

Although the results presented were not compared to the other approaches mentioned in this paper, we see a clear

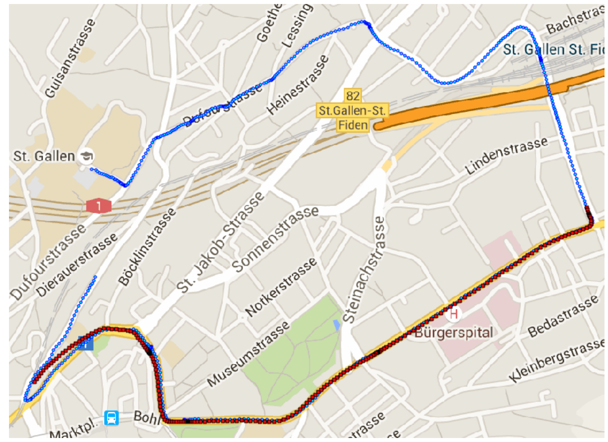

Fig. 1: Complete trip GPS coordinates (blue) and predicted coordinates during 5 minutes of simulated outage (red)

ability to predict a vehicle's position during periods of GPS outage using data found on the vehicle's CAN bus. The system outlined was able to provide accurate prediction on location during simulated GPS outages in a vehicle without an in-built navigation system, and does not limit the Smart Phone to be mounted during the journey. However, there is room for improvement, as the system uses raw sensor values in a linear fashion. Skog *et al.* [3] outline a variety of signal processing techniques, such as the Kalman Filter, and other internal vehicle measurements commonly used in this domain, which would likely improve the system accuracy. We encourage future research into the added benefit of accessing real-time CAN Bus data for vehicle's in the Internet of Things, in order to further explore the value that this data can provide in terms of driver safety and detecting hazardous road conditions.

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