Appendix A
Discussion

Discussed below are some related topics/issues this paper has not addressed fully.

A.1 Adaptation to Different Car-Types

Due to the harsh climate of the region we are residing in, special car-types, such as electric vehicles (EVs), hybrid EVs (HEVs), or plug-in HEVs (PHEVs), are less common and, therefore, DAPL's evaluation on them is difficult. Nevertheless, we discuss some adjustments need to be made on DAPL for different car types. For a gasoline-engine vehicle, the major magnetic field sources are alternators, batteries, relay switches, engines, tires (while spinning), etc [40]. EVs/HEVs/PHEVs introduce another major magnetic field source: batteries [40], [51]. The distribution of magnetic field thus depends highly on the location of their batteries. These components can emit both stable magnetic field in basic operations [41] and transient magnetic field variation (MFV) when certain controls take place. For example, when the car is accelerating/braking, the current drawn from batteries changes, and hence causes the magnetic field to change [52].

DAPL can already handle transient MFV or BT RSSI fluctuation by utilizing Trend Extractor as shown in Fig. 8c. To deal with the static magnetic field due to basic operations, we give an example of adapting the movement feature table to an HEV with batteries located under the right rear seat [53]. In this case, the strongest magnetic field exists in the right rear passenger seat while the driver seat has the weakest magnetic field [41]. In such a case, we can reverse the value assignment of (↗) and (↘) in the magnetic field column of Table 2 to apply DAPL in HEVs/PHEVs/EVs with a similar structure. To adapt itself to different car makes/models, DAPL can obtain the corresponding movement feature table by looking up the model information embedded in BT beacons.

While the current version of DAPL is designed for common four-seat vehicles (*i.e.*, sedans and SUVs), applying DAPL to other vehicle types is also part of the future work. Here we discuss some adjustments need to be made if an developer wants to apply DAPL to different car types. Suppose we now have a 2×3 (row×column) seat vehicle. If the two rightmost passenger seats exhibit similar magnetic field measurements, the developer can utilize DAPL's original 4-zone design as shown in Fig. 16a and update each entry in the feature table accordingly. Otherwise, each seat should be treated as an individual zone (Fig. 16b) and the feature table should be expanded to cover all the possible seat-level movements. The developer can also follow this principle to apply DAPL to other vehicle types (*e.g.*, a 3×2 seat vehicle).

A.2 Deployment of DAPL

DAPL is mainly designed to help those people who are aware of the danger of phone-distracted driving but sometimes forget to manually activate the driving mode or for those people who do not have enough incentives/interest to activate it manually. Note that distracted driving is illegal in most states in the US, but there are still distracted drivers [35]. Another potential user group/target of DAPL is teenage drivers (*i.e.*, the drivers who have tendency of texting while driving [4]). Parents will have incentives to buy phones with DAPL built-in, or install parental control apps[4],[5] with DAPL functionality on their teenagers' phones for their safety.

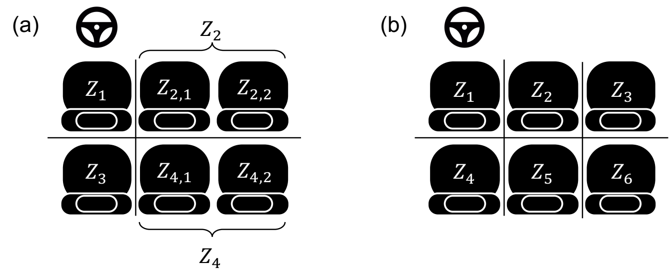

Fig. 16. This figure shows the potential zone partition scenarios.

There are three deployment options for DAPL. It can be implemented as a built-in OS function (by the phone manufacturer), as an API/library, or as a stand-alone app. As a built-in OS function, DAPL could be the future default driving mode that is embedded in phone OSes and cannot be deactivated by the driver, *i.e.*, built-in prevention of distracted driving. As an API/library, DAPL may provide other apps the ability to determine whether the phone is in the driver seat or not, to support their customized functions for the driver or the passenger. As a stand-alone app, DAPL will be a convenient and safer "upgrade" of the existing driving mode that helps the drivers automatically activate the driving mode to reduce the "unintended" distracted driving (*e.g.*, the distraction caused by notifications).

For insurance companies, they want to prevent car accidents to boost their profit. To make their customers drive more safely, the insurance companies will be willing to provide their customers premium discounts if their customers choose to use devices that have functions for prevention of distracted driving (*i.e.*, DAPL). Thus, users will have incentives to buy and use phones with DAPL. Consequently, phone manufacturers will also have incentives to produce phones with DAPL. Since carmakers just need to enable beacon broadcasting of built-in Bluetooth transceiver to install DAPL, they won't have any difficulty in deploying DAPL. Furthermore, their cars will have fewer accidents thanks to DAPL which can increase their sales. Last but not the least, the most obvious incentive for users to choose the phones with DAPL is to make them safer. The users who cannot resist the temptation of web browsing/texting while driving and/or forget or don't care to manually turn on driving mode, will be incentivized to use DAPL thanks to its automatic detection and the premium discounts provided by the insurance companies.

Appendix B
Supplemental Evaluation Results

B.1 Test Case Information

4. How to Use the Parental Controls on a Smartphone - Consumer Reports. https://www.consumerreports.org/smartphones/how-to-use-parental-controls-on-a-smartphone/
5. Teen Driving: Apps to Keep Your New Driver Safe. https://www.parentmap.com/article/teen-driving-apps-to-keep-your-new-driver-safe

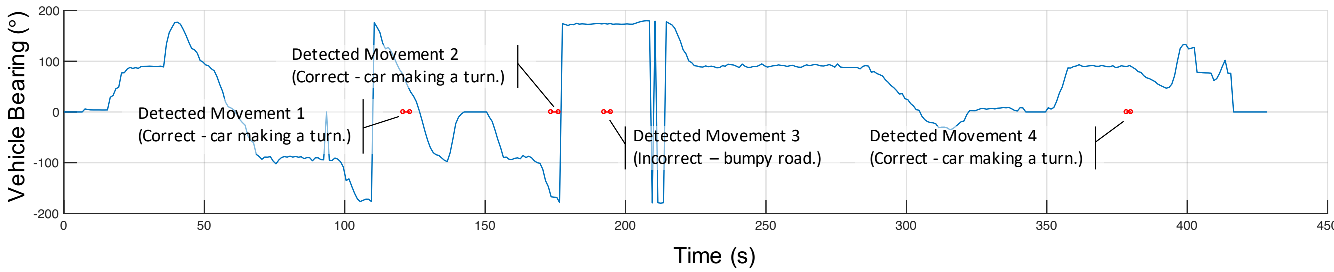

Fig. 17. This example shows the vehicle bearing during the experiment where the phone is kept in the right pocket of driver's pants.

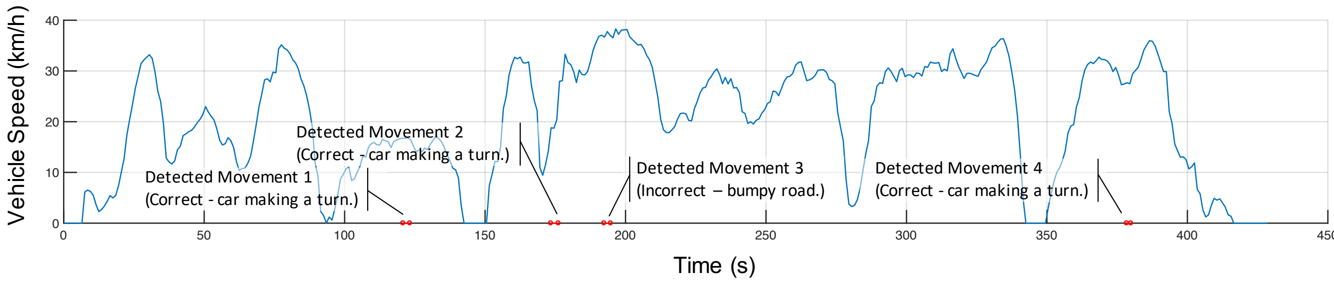

Fig. 18. This example shows the vehicle speed during the experiment where the phone is kept in the right pocket of driver's pants.

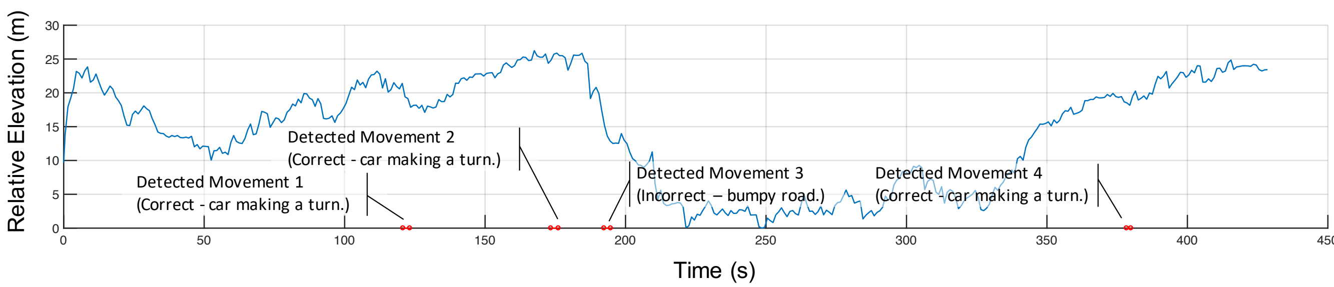

Fig. 19. This example shows the relative road elevation during the experiment where the phone is kept in the right pocket of driver's pants.

See Figs. 17, 18, and 19 for examples of vehicle bearing, vehicle speed and relative elevation during the experiments of phone movements in driver's clothing, respectively.

B.2 Reducing Sampling Rate for Energy Saving

Another way to reduce the energy consumption overhead further is reducing the sampling rate of the sensors. We use the same set of traces used in Section 4 and downsampling them for accuracy evaluation. The tested sampling periods are 5 (default), 10, and 20ms. We can observe that the localization accuracy drops to 86.17% (86.25%) when the sampling period increases to 20ms (10ms). Since Android API does not provide functions to directly control the sampling period of a sensor, the sampling period that we can set in *registerListener*[6] is just a hint/suggestion to the operating system. During our evaluation, we did not observe any difference when the sampling period is set to 5–20ms. Therefore, we do not provide the energy overhead measurements while varying the sampling period. Based on this observation, we suggest the sampling rate set to the highest rate to ensure the best detection accuracy while adjusting R_{act} is a better way to achieve the desired setting.

6. https://developer.android.com/reference/android/hardware/SensorManager.html