ENHANCED AUTOMOTIVE PASSIVE ENTRY

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. Non-Provisional application Ser. No. 15/894,774, entitled "Enhanced Automotive Passive Entry" filed Feb. 12, 2018, which claims priority to Provisional Application No. 62/457,747, entitled "Enhanced Automotive Passive Entry" filed Feb. 10, 2017, the entire contents of which are herein incorporated by reference for all purposes.

BACKGROUND

[0002] Modern cars allow entry using a key fob, and some cars allow starting by a button when the key fob is inside the car. Such operation is called passive entry and passive start, which use a position of the key fob to unlock the car, allow starting the car, and provide other functionality. The location of the key fob is determined using magnetic signals emitted from magnetic antennas in the car. The magnetic signals are measured by the key fob and sent to the car for determining a location of the key fob.

[0003] The key fob can be bulky and be an additional item that a user must carry. Further, the magnetic fields are short range, and current techniques are susceptible to hackers, which can allow a thief to access the car and potentially steal it.

[0004] Therefore, it is desirable to provide new methods and devices that overcome any one of these problems.

BRIEF SUMMARY

[0005] Some embodiments can provide methods and devices for allowing a mobile device (e.g., a key fob or a consumer electronic device, such as a mobile phone, watch, or other wearable device) to interact with a vehicle such that a location of the mobile device can be determined by the vehicle, thereby enabling certain functionality of the vehicle.

[0006] According to one embodiment, the mobile device and the vehicle can include radiofrequency (RF) antenna(s) and magnetic antenna(s). The mobile device can measure signal properties of the RF signals and the magnetic signals from the vehicle that relate to a distance of the device's antenna from a vehicle antenna. Examples of signal properties include a received signal strength indicator (RSSI) and a time-of-flight value (e.g., a round trip time, RTT). In some implementations, the magnetic antenna(s) can measure an RSSI of the magnetic signals, and the RF antenna(s) can measure a time-of-flight value. The various types of antennas can be used in combination or separately. For example, the RF antenna(s) can be used to determine changes in location of the mobile device far from the vehicle (e.g., to determine a user is approaching the vehicle), while the magnetic antenna(s) can be used to determine a location of the mobile device when the mobile device is near or inside the vehicle. Either the mobile device or the vehicle can determine the location. The location can be provided to a control unit of the vehicle, thereby enabling the control unit to perform a prescribed operation of the vehicle, such as unlocking one or more doors or allowing use of a start button.

[0007] In some embodiments, magnetic charging coils can be reused as a magnetic antenna. In other embodiments, a near-field communications (NFC) antenna can be reused as a magnetic antenna for use in determining a location of the device. Such a reuse of one or both can avoid a need for dedicated magnetic antennas and providing for a smaller and less expensive mobile device. In other implementations, a vehicle can have three-dimensional magnetic antennas, thereby allowing the mobile device to have only one magnetic antenna.

[0008] According to another embodiment, signal values measured from one or more antennas (e.g., RF or magnetic) can be used with a machine learning model to classify a location of the mobile device as being within one of a set of regions. The set of regions can include a first subset of one or more regions outside the vehicle and a second subset of one or more regions outside the vehicle. The machine learning model can be trained using various sets of signal values measured at locations across the plurality of regions. The particular region can be provided to a control unit of the vehicle, thereby enabling the control unit to perform a prescribed operation of the vehicle.

[0009] A better understanding of the nature and advantages of embodiments of the present invention may be gained with reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** shows a vehicle with an LF location system.

[0011] FIG. **2** shows the internals of a key fob.

[0012] FIG. **3** shows the high-level system design for an LF passive entry/passive start automotive system.

[0013] FIG. **4** shows an alternative high-level system design for an RF ranging passive entry/passive start automotive system according to embodiments of the present invention.

[0014] FIG. **5** shows a sequence diagram of a ranging operation involving a mobile device and three antennas of a vehicle according to embodiments of the present invention.

[0015] FIG. **6** shows a proposed high-level system design for a hybrid LF magnetic+RF ranging system for passive entry/passive start automotive system according to embodiments of the present invention.

[0016] FIG. **7** shows a mobile device having components for data collection, processing, and transfer of measurements and ancillary data according to embodiments of the present invention.

[0017] FIG. **8** is a flowchart of method of enabling an operation by a vehicle involving a mobile device according to embodiments of the present invention.

[0018] FIG. **9** shows a region-based passive entry/passive start automotive system according to embodiments of the present invention.

[0019] FIG. **10** shows a proposed machine learning training processing diagram according to embodiments of the present invention.

[0020] FIG. **11** shows an implementation of the machine-learning model for identifying which region a mobile device is located relative to a vehicle according to embodiments of the present invention.

[0021] FIG. **12** is a flowchart of a method for enabling an operation by a vehicle involving a mobile device.

[0022] FIG. **13** is a block diagram of an example device, which may be a mobile device, in accordance with some embodiments.