

SENSOR, SYSTEM AND METHOD FOR VEHICLE DETECTION

FIELD OF INVENTION

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The present invention broadly relates to a sensor module for detecting a vehicle at a spot, to a sensor network, and to a system and method for vehicle detection.

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BACKGROUND

Various vehicle detection techniques have been developed for applications in e.g. traffic management, car park management, etc. In some of these techniques, magnetic sensors such as anisotropic magneto-resistive (AMR) sensors are used as they have relatively low cost and compact size, and are adaptable to a wireless sensor network domain.

Figure 1 shows a prior art schematic diagram illustrating vehicle detection using a conventional stand-alone AMR sensor 102, similar to one shown in "Application Note - AN218 Vehicle Detection Using AMR Sensors" from Honeywell and available on the Internet at http://www51.honeywell.com/aero/common/documents/myaerospacecatalog-documents/Defense_Brochures-documents/Magnetic__Literature_Application_notes-documents/AN218_Vehicle_Detection_Using_AMR_Sensors.pdf. As can be seen in Figure 1, a high sensitivity AMR magnetometer in the form of the AMR sensor 102 is placed on the ground. In a uniform magnetic field, the AMR sensor 102 has a static (i.e. steady) level/reading. The reading may gradually change or be perturbed due to the environment. For example, the metallic composition of a vehicle 104 may perturb the earth's magnetic field, as represented by lines 106. In the technique shown in Figure 1, local magnetic field distortion is detected by the AMR sensor 102. Generally, a threshold detection technique is used to detect the vehicle from the

AMR sensor data. However, such threshold-based detection techniques can lead to false detections due to the drifting/shifting of the static level/reading of the AMR sensor data.

5 Figure 2a-2b shows schematic diagrams illustrating a possible detection error when using the set-up of Figure 1 in adjacent parking spots 210, 220. In Figure 2a, a vehicle 204a enters the first parking spot 210, while no vehicle enters the second parking spot 220. AMR sensors 202, 212 are placed on the ground of the parking spots 210, 220 respectively. As shown in Figure 2a, magnetic field lines 206a in the
10 first parking spot 210 are distorted, while the magnetic field lines 216a in the second parking spot 220 are substantially uniform. Thus, using the conventional threshold-based detection technique, the AMR sensors 202, 212 can confirm the status of the parking spots 210, 220, i.e. "occupied" and "unoccupied" respectively, at a very good level of confidence. However, as shown in Figure 2b, when a large vehicle, such as
15 a truck 214, enters the second parking spot 220, not only the magnetic field lines 216b in the second parking spot 220 are distorted, the distortion pattern of magnetic field lines 206b in the first parking spot 210 is also not the same as that in Figure 2a. This may be due to the much larger metallic body of the truck 214. Thus, using the conventional threshold-based detection technique, the AMR sensor 212 can confirm
20 the status of the second parking spot 220 as "occupied" at a very good level of confidence, but the sensor 202 cannot continuously confirm the occupancy status of the first parking spot 210 (i.e. presence of vehicle 204b) at the same confidence level, resulting in a possible false detection.

25 New vehicle detection technologies are constantly being developed and existing technologies improved. There also have been attempts at developing multi-sensor vehicle detection systems. However, there are challenges and drawbacks to such prior art approaches. For example, a system with AMR and infrared sensors may have poor environmental protection (e.g. against dust, oil, etc.) in an outdoor
30 environment. The sensitivity of the sensors may be highly degraded if contaminants collect on the sensor surfaces. In another prior art approach, United States Patent Publication No. 2011/0221624 A1 discloses an apparatus that includes a radar communicatively coupled to a processor to verify the detection result of a primary magnetic sensor that is also communicatively coupled to the processor. The final

result is communicated to a central site via a radio. However, such apparatus may have significant interference issues, especially when deployed in a car park environment. Resolving the interference issues may require complicated multiplexing, which typically allows only one sensor node to operate at a time, which
5 may reduce vehicle detection rate.

A need therefore exists to provide a system and method for vehicle detection that seeks to address at least one of the above problems.

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SUMMARY

In accordance with a first aspect of the present invention, there is provided a sensor module for detecting a vehicle at a spot, the sensor module comprising:

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an active detector configured to generate an active detection signal based on earth's magnetic field strength at the spot; and

a passive detector configured to generate a passive detection signal based on an energy level of a radio-frequency (RF) signal at the spot;

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wherein a presence of the vehicle at the spot is determined based on at least the active detection signal.

The presence of the vehicle at the spot may be determined based on both the active detection signal and the passive detection signal.

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The sensor module may further comprise an RF transceiver for communicating with a base, and the passive detector may be configured to measure the energy level of the RF signals transmitted by the RF transceiver and reflected from the vehicle, for generating the passive detection signal.

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The sensor module may further comprise a processor communicatively coupled to each of the active detector, the passive detector and the RF transceiver for processing the respective signals.

The sensor module may further comprise a power source configured to supply power to each of the active detector, the passive detector, the RF transceiver and the processor.

5 In accordance with a second aspect of the present invention, there is provided a sensor network comprising a plurality of sensor modules as defined in the first aspect.

10 In accordance with a third aspect of the present invention, there is provided a system for vehicle detection, comprising a plurality of sensor modules as defined in the first aspect each disposed at a respective one of a plurality of spots for detecting respective vehicles at said spots.

15 The presence of the vehicle at a first spot may be affirmed if a magnitude of the active detection signal of the first sensor module at said first spot is greater than a first detection threshold.

20 The second and third sensor modules at respective second and third spots adjacent to the first spot may be interrogated if the magnitude of the active detection signal of the first sensor module is lower than the first detection threshold and greater than a second detection threshold.

25 The passive detection signal of the first sensor module, and the active detection signals of the second and third sensor modules may be used for interrogating the modules.

 The presence of the vehicle at the first spot may be affirmed if:
 the passive detection signal of the first sensor module is greater than a third detection threshold;
30 the active detection signal of the second sensor module is lower than a predetermined multiple of the active detection signal of the first sensor module; and
 the active detection signal of the third sensor module is lower than the predetermined multiple of the active detection signal of the first sensor module.

The first spot may be disposed between the second and third spots.

In accordance with a fourth aspect of the present invention, there is provided a method for vehicle detection, the method comprising the steps of:

- 5 generating, using an active detector, an active detection signal based on earth's magnetic field strength at a spot;
 generating, using a passive detector, a passive detection signal based on an energy level of a radio-frequency (RF) signal at the spot; and
 determining a presence of a vehicle at the spot based on at least the active
10 detection signal.

Determining the presence of the vehicle at the spot based on at least the active detection signal may comprise using both the active detection signal and the passive detection signal.

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 Generating the passive detection signal may comprise:
 providing an RF transceiver for communicating with a base; and
 measuring, using the passive detector, the energy level of the RF signals transmitted by the RF transceiver and reflected from the vehicle.

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The method may further comprise processing the respective signals using a processor communicatively coupled to each of the active detector, the passive detector and the RF transceiver.

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The method may further comprise:
 assembling the active detector and passive detector into a sensor module;
 and
 disposing each of a plurality of said sensor modules at a respective one of a plurality of spots for detecting respective vehicles at said spots.

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Determining the presence of the vehicle may comprise:
 determining whether a magnitude of the active detection signal of the first sensor module at a first spot is greater than a first detection threshold; and

affirming the presence of the vehicle at the first spot if the result of the above step is positive.

5 The method may further comprise interrogating the second and third sensor modules at respective second and third spots adjacent to the first spot if the magnitude of the active detection signal of the first sensor module is lower than the first detection threshold and greater than a second detection threshold.

10 Interrogating the modules may comprise using the passive detection signal of the first sensor module, and the active detection signals of the second and third sensor modules.

Determining the presence of the vehicle may comprise:

15 determining whether the magnitude of the passive detection signal of the first sensor module is greater than a third detection threshold;

determining whether the magnitude of the active detection signal of the second sensor module is lower than a predetermined multiple of the active detection signal of the first sensor module;

20 determining whether the magnitude of the active detection signal of the third sensor module is lower than the predetermined multiple of the active detection signal of the first sensor module; and

affirming the presence of the vehicle at the first spot if the results of the above steps are positive.

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BRIEF DESCRIPTION OF THE DRAWINGS

30 Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1 shows a prior art schematic diagram illustrating vehicle detection using a conventional AMR sensor.

Figure 2a shows a prior art schematic diagram illustrating a correct detection using the set-up of Figure 1 in adjacent parking spots.

Figure 2b shows a prior art schematic diagram illustrating a possible false
5 detection using the set-up of Figure 1 in adjacent parking spots.

Figure 3 shows block diagram illustrating a sensor module for detecting a vehicle at a spot according to an example embodiment.

10 Figure 4a shows a schematic diagram illustrating the passive detector of Figure 3 according to an example embodiment.

Figure 4b shows a pair of graphs illustrating synchronisation of the enable signal of the passive detector with the signal from the RF transceiver according to an
15 example embodiment.

Figure 5 shows a schematic diagram illustrating an interrogation of sensor modules in adjacent parking spots according to an example embodiment.

20 Figure 6 shows a detailed flow chart illustrating the interrogation of sensor modules in Figure 5 according to an example embodiment.

Figure 7 shows a flow chart illustrating a method for detecting a vehicle according to an example embodiment.

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Figure 8 shows a schematic diagram illustrating a computing device that can implement the method and system of the example embodiments.

30 DETAILED DESCRIPTION

Figure 3 shows a block diagram illustrating a sensor module 300 for detecting a vehicle at a spot according to an example embodiment. The sensor module 300 includes an active detector 302, a passive detector 304 and an RF transceiver 306.

A control and signal processor 310 is communicatively coupled to each of the active detector 302, the passive detector 304 and the RF transceiver 306. In addition, a power source or controller 308 is connected to each of the active detector 302, the passive detector 304, the RF transceiver 306 and the processor 310 for supplying power required by each of these devices. It should be understood that the individual components may have separate power sources. In some implementations, the active detector 302 is an AMR sensor similar to one used in the set-up of Figure 1. As described, the active detector 302 generates an active detection signal based on a magnetic field strength at the spot, e.g. by detecting a distortion of the earth's magnetic field as the vehicle enters the spot.

In some implementations, the passive detector 304 is an RF power detector capable of detecting energy levels of an RF signal at the spot for generating a passive detection signal. For example, the passive detector 304 includes an antenna 305 that is operable within the RF range, or more generally, an RF receiver. In other words, the passive detector 304 does not actively emit signals, but rather, passively receives RF signals. The transceiver 306 also includes an antenna 307 that is operable two-way within the RF range, for communicating with a wireless sensor network (WSN) controller 317. In a preferred embodiment, the antenna 305 may detect the RF signal transmitted from the antenna 307 and reflected off a vehicle, as will be described in detail with respect to Figure 4a. The frequency of the RF signals is typically in the 800/900 MHz ISM band. Typically, sensor module 300 comprising the active detector 302, passive detector 304, RF transceiver 306, power source 308 and processor 310 can be assembled as a single package that can be mounted on different surfaces.

Figure 4a shows a schematic diagram illustrating the passive detector 304 of Figure 3 according to an example embodiment. Here, the spot is in a parking lot of a car park, and the sensor module 300 (Figure 3) may be disposed on the floor of the parking lot below a position where a vehicle 410 is parked. However, it will be appreciated that the sensor module 300 may be disposed at other positions in the parking lot, or at other locations, e.g. traffic junctions, entrance/exit points, etc. in alternate embodiments. Typically, the sensor module 300 is a node of a WSN that includes a plurality of such sensor modules, and the transceiver 306 (Figure 3)

transmits data to the WSN controller 317 (Figure 3) periodically, as per the WSN update rate e.g. every 2 seconds, or on demand. The transmitted RF signals 402 that are emitted from the antenna 307 (Figure 3) can be multi-directional such that some of the energy eventually reaches the WSN controller 317 for transferring data to the controller, while some of the energy is scattered in the car park space.

In the example embodiments, the passive detector 304 (Figure 3) may undergo several processes controlled by the processor 310, including calibrating and self-learning of the environmental conditions, and validation of the reflected RF signal. During the calibration and self learning of the environmental conditions, both the active detector 302 (i.e. AMR sensor) and the passive detector 304 are periodically calibrated in a NO CAR condition (i.e. the parking lot is "unoccupied") to ensure the stability of the bias values of the detectors 302, 304. In addition, the signal received by the passive detector 304 is continuously processed and compared with previous signal values to provide an estimate on the environmental noise levels. The instantaneous estimated bias values of the detector 304 can thus be updated based on current and the previous signal values. In some embodiments, the calibration and updating may take place in parallel with the detection steps.

For example, as shown in Figure 4a, when the vehicle 410 is present, some of the transmitted RF signals 402 are reflected from a frame of the vehicle 410 during transmission such that the reflected signals 404 may be detected by the antenna 305 of the passive detector 304 (Figure 3). The passive detector 304 measurement is enabled and controlled in time synchronous with the transmitted RF signal by the control processor 310 (Figure 3), and it measures the energy level of the time synchronised reflected RF signal. The change in the energy level of the time synchronised reflected RF signal is used for vehicle detection. In example embodiments, the passive detection signal may be used in addition to the active detection signal generated by the active AMR sensor 302 (Figure 3) to detect the vehicle 410. Similarly, in alternate embodiments, the passive detection signal can be used with the active detection signal to detect an absence of a vehicle, e.g. as the status of the parking spot changes from "occupied" to "unoccupied".

As described, the data from the passive detector 304 may be used for detection processing as secondary data and in conjunction with the data from the active detector 302 (e.g. AMR sensor). Typically, the strength of the RF signal reflected from the vehicle in the parking lot is supposed to be higher than signals reflected from other objects, as the parked vehicle is in close proximity with the RF transceiver 306 of the sensor module 300 (Figure 3). In some embodiments, the detecting range limit of the passive detector 304 may be less than 1m. In the example embodiments, the passive detector 304 is configured to validate the reflected RF signal for vehicle detection.

Figure 4b shows a pair of graphs illustrating synchronisation of an enable signal of the passive detector 304 (Figure 3) with an emitted signal from the RF transceiver 302 (Figure 3) according to an example embodiment. As can be seen in Figure 4b, the enable signal (line 420) of the passive detector 304 is synchronised with the emitted signal (line 430) of the RF transceiver 302, such that the passive detector 304 receives only reflected pulses of the respective emitted pulses, and not noise signals 440. For example, at an AMR sensor data detection instance, the corresponding time synchronized passive detector data and its nearby data are put together and the passive detector data is validated, and then used for vehicle detection processing.

In some implementations such as in a car park application, a plurality of sensor modules 300 are used as nodes of a wireless sensor network (WSN). Such WSN may have a multi-hop network topology for data transmission which may enable each sensor node to receive adjacent sensor nodes' information, e.g. the occupancy status, the AMR sensor processed data, and the passive detector processed data of the adjacent sensor nodes. In addition, the detection method of the example embodiments may use the adjacent sensor nodes' information to eliminate interference. The processor receives the adjacent sensor information, calculates the respective sensor data ratio, which is then compared with the respective thresholds, and confirms the occupancy status with a better confidence level.

Figure 5 shows a schematic diagram illustrating an interrogation of sensor modules in adjacent parking spots according to an example embodiment. In the implementation shown in Figure 5, sensor modules 502, 504, 506, which are nodes of a WSN, are disposed on the floor of adjacent parking spots 510, 520, 530 respectively. Vehicles 512, 516 are parked at the side parking spots 510, 530 respectively, while the central parking spot 520 is empty. Other arrangements of vehicles may exist, as will be readily appreciated. As illustrated in Figure 5, using a multi-hop topology the sensor modules 504 can read the information, i.e. the detection signals, from the neighbouring sensor modules 502, 506 to verify its detection result. Moreover, the sensor module 504 can communicate with a WSN controller 540 via the sensor module 502 and optionally, an intermediate node 508 which may be mounted on a structure of the car park space, e.g. a lamp post, a wall, etc.

Figure 6 shows a detailed flow chart 600 illustrating the interrogation of sensor modules in Figure 5 according to an example embodiment. In Figure 6, sensor 1 (the first sensor module) may correspond to the sensor module 504 at the central parking spot 520 in Figure 5, while sensor 2 and sensor 3 (the second and third sensor modules) may correspond to sensor modules 502 and 506 at the side parking spots 510 and 530 respectively. In this example implementation, the occupancy status of the central parking spot 520 is being determined by using the sensor module 504, and optionally interrogating the adjacent sensor modules 502 and 506.

With reference to Figure 6, at step 602, absolute values of the active and passive detectors of each sensor are read. For example, the absolute active and passive detector readings of sensor 2 are **ad2** and **pd2**, while those of sensor 1 are **ad1** and **pd1**, and those of sensor 3 are **ad3** and **pd3**. This step may be carried out periodically as per the WSN update rate, e.g. every 2 seconds, or on demand. Also, in some implementations, the passive detector readings are taken at the time the active detector readings are being transmitted to the WSN controller 540 (Figure 5).

At step 604, data from the active and passive detectors may be filtered and processed at each of the sensors 1, 2 and 3, e.g. by the respective processors in

these sensors. This step may help to filter unwanted data to reduce or eliminate noise and interference.

At step 606, the active and passive detection signals are computed in each of the sensors 1, 2 and 3. For example, the computation of a detection signal may be made by subtracting an absolute detector reading taken in step 602 with the absolute detector reading of the same detector in the immediately prior cycle. The active and passive detection signals of sensor 2 are calculated as $\Delta ad2$ and $\Delta pd2$, while those of sensor 1 are $\Delta ad1$ and $\Delta pd1$, and those of sensor 3 are $\Delta ad3$ and $\Delta pd3$ respectively.

As described above, steps 602, 604 and 606 are carried out at the sensor level. After the detection signals are computed in step 606, the detection signals may be processed further in the sensor module itself or may be communicated to the WSN controller 540 (Figure 5) for central processing depending upon e.g. the application usage. In an implementation, at step 608, the magnitude of the active detection signal $\Delta ad1$ of sensor 1 is compared against a first detection threshold **THD1**. If the magnitude of $\Delta ad1$ is greater than **THD1**, it may mean that the active detector has detected a high distortion of the magnetic field at the parking spot 520. Thus, the occupancy status of the parking spot 520 can be determined as "occupied" (as illustrated by Yes in Figure 6) using the active detection signal alone.

If the magnitude of $\Delta ad1$ is lower than **THD1**, at step 610, the magnitude of $\Delta ad1$ is compared against a lower second detection threshold **THD2** to check whether it is between the first and second detection thresholds **THD1**, **THD2**. If the result is No, it may mean that the active detector has not detected any significant distortion of the magnetic field at the parking spot 520. Thus, the occupancy status of the parking spot 520 can be determined as "unoccupied", and the detection process refreshes to step 602.

However, if result is Yes, i.e. the magnitude of $\Delta ad1$ is between the first and second thresholds **THD1**, **THD2**, at step 612, data from multiple data sources are combined, e.g. by using the passive detection signal and interrogating sensors 2 and 3, for confirming the occupancy status of the parking spot 520. In an implementation,

a number of comparisons are made. For example, if the magnitude of the passive detection signal $\Delta pd1$ of sensor 1 is greater than a third detection threshold **THD3**, if the magnitude of the active detection signal $\Delta ad2$ of sensor 2 is less than a predetermined multiple k of the magnitude of $\Delta ad1$, and if the magnitude of the active detection signal $\Delta ad3$ of sensor 3 is less than the predetermined multiple k of the magnitude of $\Delta ad1$, the occupancy status of the parking spot 520 can be determined as "occupied" (as illustrated by Yes in Figure 6). Otherwise, the occupancy status of the parking spot 520 is determined as "unoccupied", and the detection process refreshes to step 602. In some implementations, the occupancy status of the parking spot 520 may be further processed at step 614, e.g. to activate an indicator, to show on a display, to change a counter value, to start/stop a timer, etc.

In an example sensor configuration, the values of **THD1**, **THD2** and **THD3** are 200 counts, 100 counts and 40 counts respectively, while the value of k as a normalized scaled ratio is 0.33. Thus, if $\Delta ad1 > 200$, a vehicle is detected and the status of the parking spot is affirmed as "occupied". On the other hand, if $100 < \Delta ad1 < 200$, the passive detection signal is used, and the adjacent sensor modules are interrogated, as described above with respect to step 612. For example, the system check whether $\Delta pd1 > 40$, whether $\Delta ad2 < 0.33\Delta ad1$ and whether $\Delta ad3 < 0.33\Delta ad1$. If the result is Yes, a vehicle is detected and the status of the parking spot is affirmed as "occupied". It will be appreciated that the comparisons may be different, and the values of **THD1**, **THD2**, **THD3** and k may be changed in alternate embodiments.

The system according to the example embodiments can improve vehicle detection reliability through use of the Wireless Sensor Network (WSN) features already in-built into the respective sensor modules. As described, the improvement may be achieved by the use of a passive RF power detector to detect the WSN's transmitted RF energy as reflected back by a vehicle, and the interrogation of adjacent sensor modules through the WSN for confirming the detection result through the combination of multi-source sensor data. Such a multi-source sensor system can increase detection accuracy, reduce uncertainty and be more robust to changes in the environment. The detection rate may also be improved.

Advantageously, the system of the example embodiments may be adapted for use in either a standard lot in a car park or a heavy-traffic and dynamic roadside parking spot.

5 Figure 7 shows a flow chart 700 illustrating a method for vehicle detection according to an example embodiment. At step 702, an active detection signal may be generated based on earth's magnetic field strength at a spot using an active detector. At step 704, a passive detection signal may be generated based on an energy level of a radio-frequency (RF) signal at the spot using a passive detector. At
10 step 706, a presence of a vehicle at the spot may be determined based on at least the active detection signal.

 Some portions of the description which follows are explicitly or implicitly presented in terms of algorithms and functional or symbolic representations of
15 operations on data within a computer memory. These algorithmic descriptions and functional or symbolic representations are the means used by those skilled in the data processing arts to convey most effectively the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence
20 of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities, such as electrical, magnetic or optical signals capable of being stored, transferred, combined, compared, and otherwise manipulated.

 Unless specifically stated otherwise, and as apparent from the following, it will be appreciated that throughout the present specification, discussions utilizing terms such as
25 "processing", "calculating", "determining", "computing", "generating", "initializing", "outputting", or the like, refer to the action and processes of a computer system, or similar electronic device, that manipulates and transforms data represented as physical quantities within the computer system into other data similarly represented as physical quantities within the computer system or other information storage, transmission or
30 display devices.

 The present specification also discloses apparatus for performing the operations of the methods. Such apparatus may be specially constructed for the required purposes, or may comprise a general purpose computer or other device selectively activated or

reconfigured by a computer program stored in the computer. The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose machines may be used with programs in accordance with the teachings herein. Alternatively, the construction of more specialized
5 apparatus to perform the required method steps may be appropriate. The structure of a conventional general purpose computer will appear from the description below.

In addition, the present specification also implicitly discloses a computer program, in that it would be apparent to the person skilled in the art that the individual
10 steps of the method described herein may be put into effect by computer code. The computer program is not intended to be limited to any particular programming language and implementation thereof. It will be appreciated that a variety of programming languages and coding thereof may be used to implement the teachings of the disclosure contained herein. Moreover, the computer program is not intended to be limited to any
15 particular control flow. There are many other variants of the computer program, which can use different control flows without departing from the spirit or scope of the invention.

Furthermore, one or more of the steps of the computer program may be performed in parallel rather than sequentially. Such a computer program may be stored
20 on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a general purpose computer. The computer readable medium may also include a hard-wired medium such as exemplified in the Internet system, or wireless medium such as exemplified in the GSM mobile telephone system.
25 The computer program when loaded and executed on such a general-purpose computer effectively results in an apparatus that implements the steps of the preferred method.

The method and system of the example embodiment can be implemented on a computer system 800, schematically shown in Figure 8. It may be implemented as
30 software, such as a computer program being executed within the computer system 800, and instructing the computer system 800 to conduct the method of the example embodiment.

The computer system 800 comprises a computer module 802, input modules such as a keyboard 804 and mouse 806 and a plurality of output devices such as a display 808, and printer 810.

5 The computer module 802 is connected to a computer network 812 via a suitable transceiver device 814, to enable access to e.g. the Internet or other network systems such as Local Area Network (LAN) or Wide Area Network (WAN).

10 The computer module 802 in the example includes a processor 818, a Random Access Memory (RAM) 820 and a Read Only Memory (ROM) 822. The computer module 802 also includes a number of Input/Output (I/O) interfaces, for example I/O interface 824 to the display 808, and I/O interface 826 to the keyboard 804.

15 The components of the computer module 802 typically communicate via an interconnected bus 828 and in a manner known to the person skilled in the relevant art.

20 The application program is typically supplied to the user of the computer system 800 encoded on a data storage medium such as a CD-ROM or flash memory carrier and read utilising a corresponding data storage medium drive of a data storage device 830. The application program is read and controlled in its execution by the processor 818. Intermediate storage of program data maybe accomplished using RAM 820.

25 It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. For example, the method and system of the example embodiments can be
30 applied to detect whether a vehicle has left a parking spot to affirm the occupancy status of the parking spot as it changes from "occupied" to "unoccupied". The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A sensor module for detecting a vehicle at a spot, the sensor module comprising:

5 an active detector configured to generate an active detection signal based on earth's magnetic field strength at the spot; and

a passive detector configured to generate a passive detection signal based on an energy level of a radio-frequency (RF) signal at the spot;

10 wherein a presence of the vehicle at the spot is determined based on at least the active detection signal.

2. The sensor module as claimed in claim 1, wherein the presence of the vehicle at the spot is determined based on both the active detection signal and the passive detection signal.

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3. The sensor module as claimed in claim 1 or 2, further comprising an RF transceiver for communicating with a base, wherein the passive detector is configured to measure the energy level of the RF signals transmitted by the RF transceiver and reflected from the vehicle, for generating the passive detection signal.

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4. The sensor module as claimed in claim 3, further comprising a processor communicatively coupled to each of the active detector, the passive detector and the RF transceiver for processing the respective signals.

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5. The sensor module as claimed in claim 4, further comprising a power source configured to supply power to each of the active detector, the passive detector, the RF transceiver and the processor.

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6. A sensor network comprising a plurality of sensor modules as claimed in any one of claims 1 to 5.

7. A system for vehicle detection, comprising a plurality of sensor modules as claimed in any one of claims 1 to 5 each disposed at a respective one of a plurality of spots for detecting respective vehicles at said spots.

5 8. The system as claimed in claim 7, wherein the presence of the vehicle at a first spot is affirmed if a magnitude of the active detection signal of the first sensor module at said first spot is greater than a first detection threshold.

10 9. The system as claimed in claim 8, wherein the second and third sensor modules at respective second and third spots adjacent to the first spot are interrogated if the magnitude of the active detection signal of the first sensor module is lower than the first detection threshold and greater than a second detection threshold.

15 10. The system as claimed in claim 9, wherein the passive detection signal of the first sensor module, and the active detection signals of the second and third sensor modules are used for interrogating the modules.

20 11. The system as claimed in claim 10, wherein the presence of the vehicle at the first spot is affirmed if:

the passive detection signal of the first sensor module is greater than a third detection threshold;

the active detection signal of the second sensor module is lower than a predetermined multiple of the active detection signal of the first sensor module; and

25 the active detection signal of the third sensor module is lower than the predetermined multiple of the active detection signal of the first sensor module.

12. The system as claimed in any one of claims 9 to 11, wherein the first spot is disposed between the second and third spots.

30 13. A method for vehicle detection, the method comprising the steps of:
generating, using an active detector, an active detection signal based on earth's magnetic field strength at a spot;

generating, using a passive detector, a passive detection signal based on an energy level of a radio-frequency (RF) signal at the spot; and

determining a presence of a vehicle at the spot based on at least the active detection signal.

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14. The method as claimed in claim 13, wherein determining the presence of the vehicle at the spot based on at least the active detection signal comprises using both the active detection signal and the passive detection signal.

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15. The method as claimed in claim 13 or 14, wherein generating the passive detection signal comprises:

providing an RF transceiver for communicating with a base; and

measuring, using the passive detector, the energy level of the RF signals transmitted by the RF transceiver and reflected from the vehicle.

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16. The method as claimed in claim 15, further comprising processing the respective signals using a processor communicatively coupled to each of the active detector, the passive detector and the RF transceiver.

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17. The method as claimed in any one of claims 13 to 16, further comprising:

assembling the active detector and passive detector into a sensor module;

and

disposing each of a plurality of said sensor modules at a respective one of a plurality of spots for detecting respective vehicles at said spots.

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18. The method as claimed in claim 17, wherein determining the presence of the vehicle comprises:

determining whether a magnitude of the active detection signal of the first sensor module at a first spot is greater than a first detection threshold; and

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affirming the presence of the vehicle at the first spot if the result of the above step is positive.

19. The method as claimed in claim 18, further comprising interrogating the second and third sensor modules at respective second and third spots adjacent to the first spot if the magnitude of the active detection signal of the first sensor module is lower than the first detection threshold and greater than a second
5 detection threshold.

20. The method as claimed in claim 19, wherein interrogating the modules comprises using the passive detection signal of the first sensor module, and the active detection signals of the second and third sensor modules.
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21. The method as claimed in claim 20, wherein determining the presence of the vehicle comprises:

determining whether the magnitude of the passive detection signal of the first sensor module is greater than a third detection threshold;

15 determining whether the magnitude of the active detection signal of the second sensor module is lower than a predetermined multiple of the active detection signal of the first sensor module;

determining whether the magnitude of the active detection signal of the third sensor module is lower than the predetermined multiple of the active detection signal
20 of the first sensor module; and

affirming the presence of the vehicle at the first spot if the results of the above steps are positive.