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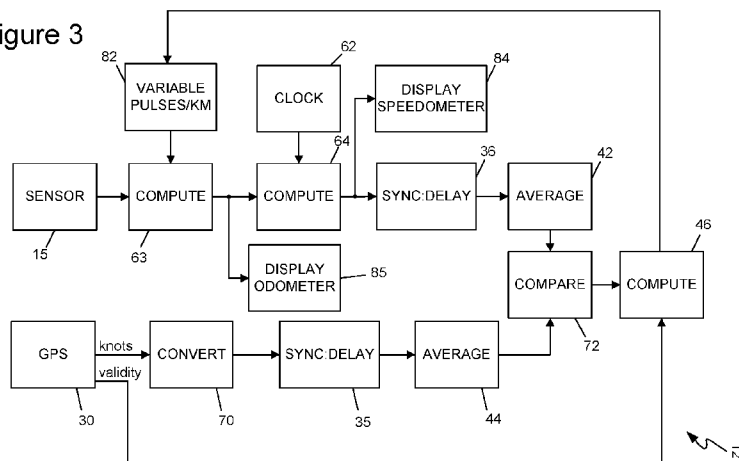
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Figure 3



(57) Abstract: A vehicle speedometer, including: a first component to generate first speed data representing speeds of a vehicle from rotation data representing rotations of a vehicle part, the rotational speed of which is proportional to the vehicle speed, and a conversion factor for converting the rotations of the vehicle part to corresponding speeds of the vehicle; a second component to generate second speed data representing speeds of the vehicle from GPS signals; and a speed correction component to process delay data, the second speed data, and the rotation data or the first speed data to update the conversion factor so that the first component can generate further first speed data representing speeds of the vehicle with improved accuracy; wherein the delay data represents at least a relative delay between a speed of the vehicle represented by the first speed data and a corresponding speed of the vehicle represented by the second speed data; and wherein the speed correction component is configured to process the second speed data and the rotation data or the first speed data in accordance with the delay data over accumulation intervals and respective GPS intervals, with a relative delay between the accumulation intervals and respective ones of the GPS intervals to synchronise the second speed data and the rotation data or the first speed data even when any of the following apply: (i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval; (ii) the heading of the vehicle varies over the accumulation interval and the GPS interval; and (iii) the net variation in the heading of the vehicle is non-zero over the accumulation interval and the GPS interval, the conversion factor being updated on the basis of the synchronised second speed data and rotation data or first speed data.

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VEHICLE METER

TECHNICAL FIELD

- 5 This invention relates to a vehicle meter, and in particular to a vehicle speedometer, a method of determining vehicle speed, a vehicle odometer, and a method of determining vehicle travel distance.

BACKGROUND

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Commonly, vehicle speedometers operate by determining the rotational speed of a component of the vehicle which rotates at an angular velocity or rotational speed that is generally proportional to both the speed of the vehicle and the angular velocity or rotational speed of a vehicle wheel. Historically, speedometers usually operated by
15 generating an eddy current proportional to a rotational speed, and using the generated eddy current to drive a meter able to display speed dependent on the magnitude of the eddy current. More commonly, in modern vehicles, optical or magnetic sensing means are provided and are able to directly produce a pulse train whose frequency is dependent on the rotation speed of a vehicle component. This
20 pulse train is then digitally processed to provide a visual display of the vehicle speed.

Because vehicle speedometers generally rely on the rotational speed of a rotating component of the vehicle, the accuracy of speed determination is dependent on the accuracy of the relationship between the rotational speed of that component and the
25 actual velocity or speed of the vehicle. For example, if the angular velocity of a vehicle drive shaft is measured, then the vehicle differential gear ratios need to be taken into account. However, the relationship may vary significantly, depending on circumstance. In particular, the effective radius of the vehicle wheel, including the tyre, needs to be taken into account when calibrating the speedometer for a particular
30 vehicle wheel/tyre as used by the vehicle, and that radius is dependent on both the tyre used and its condition. Tyre radii/diameters vary depending on tyre type and inflation pressure, and also to some extent the extent of wear. If the outer diameter of the vehicle wheel and tyre combination is changed, then unless the speedometer is re-

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calibrated to take account of those changes, then significant errors in speedometer readings will generally result.

In view of the recognised practical impossibility of accurately determining vehicle speed for at least the reasons discussed above, standards authorities may only require that speedometers be accurate to a limited extent. For example, in the state of Victoria, Australia, the requirement was previously that the reading of a vehicle speedometer be accurate to only $\pm 10\%$, but more recently this requirement was changed to a range from -0% to $+(10\% + 4\text{km/hr})$. By this newer requirement, a speedometer reading of 100 km/hr might reflect an actual speed of only 87 km/hr. Vehicle manufacturers seeking to limit as much as possible any opportunity for drivers of its vehicles to seek redress in case of attracting penalties such as fines or licence suspension for speeding when the vehicle speedometer under-estimated the vehicle speed, might therefore calibrate their speedometers to indicate close to $+(10\% + 4\text{km/hr})$ or at least towards the high end of the allowed range.

Of course, while vehicle speeding is recognised as a major contributing factor in road accidents, serious overestimation of speed may itself also contribute to unintentional breaches of road rules, and possibly contribute to accidents. For example, highways may have traffic lanes in respect of which there is a minimum speed limit as well as a maximum limit. Also, driver fatigue is a significant cause of road accidents, particularly during long distance driving where increased trip times due to slow driving may increase accident risk. Further, drivers following a vehicle travelling at 87 km/hr, the speedometer of which displays 100km/hr, might become frustrated if their speedometers show something closer to true speed, if they are unable to pass the leading vehicle, resulting in tailgating and road rage or other dangerous behaviours.

Customarily, vehicles are also fitted with odometers for deriving and displaying information about distance travelled by the vehicle. Usually, these derive the distance information in a similar way to that described by which speedometers derive speed information, and corresponding and possibly serious errors in displayed distance travelled may therefore similarly arise. The errors may have significant adverse consequences. For example, taxi meters generally at least in part compute fares based on distance travelled. If, for example, the error in a speedometer reading is the mentioned $+(10\% + 4\text{km/hr})$, then the distance travelled by the vehicle may be very

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significantly over-estimated by the meter, leading to passengers being charged significantly more than what the charge would have been in the absence of that error.

Aside from these considerations, fraudulent "winding back" of vehicle odometer readings may be more difficult with modern electronic odometers. For example, these may record rearwards movement of vehicle wheels as positively incrementing the odometer. Also, these generally do not have easily accessible mechanical couplings capable of being tampered with, such as a rotating cable. However, it is not impossible to tamper with an electronic speedometer to cause incorrect display and/or to record travelled distances that are greater than the distances actually travelled. While direct tampering of taxi meters may be difficult without leaving obvious signs of tampering, due to mechanical sealing of the meters by regulatory authorities, an electronic device might still be installed in a relatively inaccessible location in the taxi, wired to insert additional pulses in the pulse train from the meter rotation sensor to processing circuitry of the taxi-meter, so as to cause the meter to compute and display an inflated taxi fare based on a travel distance measurement that is significantly greater than the distance actually travelled. The same effect can be achieved by the mentioned substitution of smaller wheels. Also, although taxi meters may be sealed by authorities so as to deter tampering with the meter, it may easily be possible to substitute the meter in a taxi by one from a taxi having larger wheels, so that the meter over-estimates distance travelled, again resulting in fraudulent overcharging of passengers.

Finally, as concerns taxi meters, taxi meter fare structures decided by the relevant regulatory authority may not be implemented by physically accessing the meters. Rather, a wireless signal may be transmitted, which is received more or less simultaneously by each registered taxi to automatically and electronically update the taxi meters to cause them to operate in accordance with a new fare structure. In the past, taxis were recalled to the regulatory authority for this purpose, and at that time the authority could physically check the calibration of the taxi meters. When updated wirelessly, this opportunity for systematic checking calibration of meters is lost. Leaving aside the consequent loss of this recurring opportunity to check for fraudulent tampering of taxi meters, even unintentional errors in the operation of taxi meters may accumulate over long periods of time, and cause significant drifts in accuracy, without detection.

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It is desired, therefore, to provide a vehicle meter that alleviates one or more difficulties of the prior art, or to at least provide a useful alternative.

SUMMARY

5 In accordance with some embodiments of the present invention, there is provided a vehicle speedometer, including:

a first component to generate first speed data representing speeds of a vehicle from rotation data representing rotations of a vehicle part, the rotational speed of which is proportional to the vehicle speed, and a conversion factor for converting the
10 rotations of the vehicle part to corresponding speeds of the vehicle;

a second component to generate second speed data representing speeds of the vehicle from GPS signals; and

a speed correction component to process delay data, the second speed data, and the rotation data or the first speed data to update the conversion factor so that
15 the first component can generate further first speed data representing speeds of the vehicle with improved accuracy,

wherein the delay data represents at least a relative delay between a speed of the vehicle represented by the first speed data and a corresponding speed of the vehicle represented by the second speed data, and

20 wherein the speed correction component is configured to process the second speed data and the rotation data or the first speed data in accordance with the delay data over accumulation intervals and respective GPS intervals, with a relative delay between the accumulation intervals and respective ones of the GPS intervals to synchronise the second speed data and the rotation data or the first speed data even
25 when any of the following apply:

- i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval;
- ii) the heading of the vehicle varies over the accumulation interval and the GPS interval; and
- 30 iii) the net variation in the heading of the vehicle is non-zero over the accumulation interval and the GPS interval,

the conversion factor being updated on the basis of the synchronised second speed data and rotation data or first speed data.

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In some embodiments, at least one of the second component and the speed correction component is configured to process the GPS signals to generate usability data such that the speed correction component only updates the conversion factor if the usability data indicates that the GPS signals are usable to update the conversion factor.

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In some embodiments, the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of at least one sudden change of direction.

- 10 In some embodiments, the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of any combination of:
- i) a change in altitude of the vehicle over a corresponding time period exceeding a corresponding threshold value; and
 - ii) a change in the heading of the vehicle over a corresponding time period
- 15 exceeding a corresponding threshold value.

In some embodiments, the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals appear to be unreliable.

- 20 In some embodiments, the delay data represents a first delay of a speed of the vehicle determined from the first speed data and a second delay of the corresponding speed of the vehicle determined from the second speed data.

- In some embodiments, the synchronisation of the second speed data and the rotation
- 25 data or the first speed data includes:
- generating data defining the duration of the accumulation interval;
 - selecting at least one of: the start time; and the end time, of the accumulation interval according to the delay data; and
 - processing a subset of the rotation data or first speed data corresponding to the
- 30 accumulation interval and the second speed data corresponding to the corresponding GPS interval.

- In some embodiments, the accumulation interval is defined over a number of timeslots, where each timeslot is of a predetermined duration which determines the
- 35 precision of the time delay that may be associated with the accumulation interval, such that the processing of the first speed data over the accumulation interval

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involves accumulating information relating to the rotation of a vehicle part collected within each of the timeslots of the interval.

In accordance with some embodiments of the invention, there is provided a method
5 for determining vehicle speed, including:

generating first speed data representing speeds of a vehicle from rotation data representing rotations of a vehicle part, the rotational speed of which is proportional to the vehicle speed, and a conversion factor for converting the rotations of the vehicle part to corresponding speeds of the vehicle;

10 generating second speed data representing speeds of the vehicle from GPS signals; and

processing delay data, the second speed data, and the rotation data or the first speed data to update the conversion factor so that the first component can generate further first speed data representing speeds of the vehicle with improved accuracy,

15 wherein the delay data represents at least a relative delay between a speed of the vehicle represented by the first speed data and a corresponding speed of the vehicle represented by the second speed data, and

wherein the processing of the second speed data and the rotation data or the first speed data in accordance with the delay data over accumulation intervals and
20 respective GPS intervals, with a relative delay between the accumulation intervals and respective ones of the GPS intervals to synchronise the second speed data and the rotation data or the first speed data even when any of the following apply:

- i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval;
- 25 ii) the heading of the vehicle varies over the accumulation interval and the GPS interval; and
- iii) the net variation in the heading of the vehicle is non-zero over the accumulation interval and the GPS interval,

the conversion factor being updated on the basis of the synchronised second speed
30 data and rotation data or first speed data.

In some embodiments, the GPS signals are processed to generate usability data such that the conversion factor is only updated if the usability data indicates that the GPS signals are usable to update the conversion factor.

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In some embodiments, the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of any combination of:

- i) a change in altitude of the vehicle over a corresponding time period exceeding a corresponding threshold value; and
- 5 ii) a change in the heading of the vehicle over a corresponding time period exceeding a corresponding threshold value.

10 In some embodiments, the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of travel along a steep incline.

In some embodiments, the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals appear to be unreliable.

15 In some embodiments, the delay data represents a first delay of a speed of the vehicle determined from the first speed data and a second delay of the corresponding speed of the vehicle determined from the second speed data.

In some embodiments, the synchronisation of the second speed data and the rotation data or the first speed data includes:

- 20 generating data defining the duration of the accumulation interval;
- selecting at least one of: the start time; and the end time, of the accumulation interval according to the delay data; and
- processing a subset of the rotation data or first speed data corresponding to the accumulation interval and the second speed data corresponding to the corresponding
- 25 GPS interval.

30 In some embodiments, the accumulation interval is defined over a number of timeslots, where each timeslot is of a predetermined duration which determines the precision of the time delay that may be associated with the accumulation interval, such that the processing of the first speed data over the accumulation interval involves accumulating information relating to the rotation of a vehicle part collected within each of the timeslots of the interval.

35 In accordance with some embodiments of the invention, there is provided a method for determining vehicle travel distance, including:

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generating first speed data representing speeds of a vehicle from rotation data representing rotations of a vehicle part, the rotational speed of which is proportional to the vehicle speed, and a conversion factor for converting the rotations of the vehicle part to corresponding speeds of the vehicle;

5 generating second speed data representing speeds of the vehicle from GPS signals; and

 processing the delay data, the second speed data, and the rotation data or the first speed data to update the conversion factor so that the first component can generate further first speed data representing speeds of the vehicle with improved
10 accuracy,

 wherein the delay data represents at least a relative delay between a speed of the vehicle represented by the first speed data and a corresponding speed of the vehicle represented by the second speed data, and

 wherein the speed correction component is configured to process the second
15 speed data and the rotation data or the first speed data in accordance with the delay data over accumulation intervals and respective GPS intervals, with a relative delay between the accumulation intervals and respective ones of the GPS intervals to synchronise the second speed data and the rotation data or the first speed data even when any of the following apply:

20 i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval;

 ii) the heading of the vehicle varies over the accumulation interval and the GPS interval; and

 iii) the net variation in the heading of the vehicle is non-zero over the
25 accumulation interval and the GPS interval,

the conversion factor being updated on the basis of the synchronised second speed data and rotation data or first speed data.

In some embodiments, the GPS signals are processed to generate usability data such
30 that the conversion factor is only updated if the usability data indicates that the GPS signals are usable to update the conversion factor.

In some embodiments, the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of any combination of:

35 i) a change in altitude of the vehicle over a corresponding time period exceeding a corresponding threshold value; and

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ii) a change in the heading of the vehicle over a corresponding time period exceeding a corresponding threshold value.

In some embodiments, the usability data indicates that the GPS signals are not usable
5 to update the conversion factor if the GPS signals are indicative of travel along a steep incline.

In some embodiments, the usability data indicates that the GPS signals are not usable
10 to update the conversion factor if the GPS signals appear to be unreliable.

In some embodiments, the delay data represents a first delay of a speed of the vehicle determined from the first speed data and a second delay of the corresponding speed of the vehicle determined from the second speed data.

15 In some embodiments, the synchronisation of the second speed data and the rotation data or the first speed data includes:
generating data defining the duration of the accumulation interval;
selecting at least one of: the start time; and the end time, of the accumulation interval according to the delay data; and
20 processing a subset of the rotation data or first speed data corresponding to the accumulation interval and the second speed data corresponding to the corresponding GPS interval.

In some embodiments, the accumulation interval is defined over a number of
25 timeslots, where each timeslot is of a predetermined duration which determines the precision of the time delay that may be associated with the accumulation interval, such that the processing of the first speed data over the accumulation interval involves accumulating information relating to the rotation of a vehicle part collected within each of the timeslots of the interval.

30 In accordance with some embodiments of the invention, there is provided a taxi meter having any one of the above vehicle speedometers.

In accordance with some embodiments of the invention, there is provided a method of
35 determining a taxi charge in which the charge is based at least in part on vehicle travel distance determined by any one of the above methods.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the present invention are hereinafter described, by way of example only, with reference to the accompanying drawings in which:

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Figure 1 is a schematic diagram of a vehicle fitted with a taxi meter having a speedometer and odometer in accordance with an embodiment of the present invention;

10

Figure 2 is a block diagram of the taxi meter of Figure 1;

Figure 3 is a block diagram of the speedometer and the odometer of the taxi meter;

15

Figure 4a is a flow chart of an initialisation process performed by the taxi meter;

Figure 4b is a flow chart of a looping process performed by the taxi meter;

20

Figure 4c is a flow chart of a timer routine process performed by the taxi meter;

25

Figures 5a and 5b are schematic diagrams illustrating the synchronisation of data derived from rotation of a vehicle part with corresponding data derived from GPS signals; and

Figures 6a and 6b are schematic diagrams illustrating the path of a vehicle travelling through a series of hills and valleys, and along tracks where heading changes cancel out respectively.

30

DETAILED DESCRIPTION

OVERVIEW

In addition to the traditional mechanical methods for determining vehicle speed and travel distance information, this information can alternatively be determined from the global positioning system ("GPS"). Generally, where suitable conditions prevail, such GPS-derived information is significantly more accurate than that obtainable by use of conventional speedometers as described above, and it is likewise possible to derive more accurate distance measurements this way. In particular, GPS-based speed and distance measurements are generally free of errors due to the causes described above. However, a satisfactory GPS signal is not always available. The GPS signal may for some reason be blocked and not received at all, or if received may be of insufficient quality to be useful. For example, the signal will not generally be receivable at all in tunnels, and the local terrain or other obstacles may otherwise cause loss or degradation of the signal. As to the latter, generally, GPS receivers rely on information from several GPS satellites, and the signal from some or many satellites may be blocked or may be of poor quality due to obstructing mountains or tall structures, for example. Obstruction may also occur in deep valleys. For at least these reasons, total reliance on the GPS system is considered to be impracticable.

Accordingly, embodiments of the present invention combine the advantages of both methodologies by deriving vehicle speed and/or distance information using mechanical means, but also correcting this information based on speed and/or distance information derived from a GPS device.

THE VEHICLE METER

Referring to Figure 1, a vehicle 10 is shown having a taxi meter 100 incorporating a speedometer and an odometer. A rotation sensor 15 is provided in this case arranged to detect rotation of the vehicle drive shaft 16, which is rotated by the vehicle engine 18 via vehicle gearbox 20 to rotationally drive rear wheels 22 of the vehicle 10 through a vehicle differential 24.

Rotation sensor 15 produces an electronic pulse train of frequency proportional to the speed of rotation of the drive shaft 16 and hence also proportional to the rotational speed of the vehicle wheels 22, and thus the vehicle speed.

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The pulse train from sensor 15 is transmitted to taxi meter 100 via an electrical lead 26, and the taxi meter 100 computes and displays taxi fares dependent in part on the signal from sensor 15.

5

The vehicle 10 also has a GPS device 30 for determining positional data from radio signals received from artificial earth satellites 40. Output from the GPS device 30 is directed to the taxi meter 100 via an electrical cable 32.

10 Figure 2 shows components of taxi meter 100.

A distance computing module 63 of the taxi meter 100 receives the pulse train from the sensor 15 and produces at its output a signal indicative of the distance travelled, e.g. in kilometres. The distance travelled, d , is related to the count of the received
15 pulses as:

$$d = k_1(n);$$

where n is the number of pulses counted, and k_1 is a conversion or scale factor
20 determined from the physical characteristics of the vehicle 10 and sensor 15. Conversion factor k_1 may for example be calculated taking account of the number of pulses per revolution of vehicle drive shaft 16, the differential gear ratio of the vehicle differential 24 and the effective radius of the drive wheels 22 and its tyres at the point of contact of the tires with the road over which the vehicle travels, and/or k_1 may be
25 experimentally determined. The conversion factor k_1 is stored in an updatable memory 82 in communication with the distance computing module 63.

The distance travelled, as computed by computing module 63 is displayed at an odometer display 85.

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Vehicle odometers generally provide information as to the total distance travelled by the vehicle since manufacture, as well as at least one distance travelled since a reset of the odometer occurred. In the case of taxis, the taxi meter 100 will generally be so reset at commencement of hire of the taxi. In the present instance, provision can be
35 made for such resetting by application of a reset signal to the computing module 63 produced by e.g. pressing a reset button 200 explained later. The signal indicating

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the distance travelled since the most recent meter reset, as produced from the computing module 63, is passed to a speed computing module 64 which also receives a clock signal from a clock 62. The speed computing module 64 computes, from the distance signal and clock signal, an output representing the prevailing vehicle speed.

5 Thus, the output from the distance computing module 63 may be in the form of a pulse train the frequency of which is proportional to distance travelled in kilometres. Then, the speed computing module 64 may cyclically and repetitively count the number of received pulses within intervals of equal time length, determined from clock 62, to produce speed information that is periodically updated at the output of
10 computing module 64. The prevailing speed, so determined, is displayed at a speedometer display 84.

The output signal from the speed computing module 64 is applied to a visual display 84 of the speedometer so that the display 84 displays the prevailing vehicle speed.

15

The output from the speed computing module 64 is passed via a first delay module 36 to a first averaging module 42 which produces, at the output thereof, a signal representative of the average of the vehicle's speed over a predetermined period of time. That is, the speed information from speed computing module 64 is, as
20 explained, periodically updated. The first averaging module generates a signal representing a periodically updated "rolling" or "moving" average of so derived speed information, each such update representing the average of a predetermined number of updates of speed information received by the first averaging module 42.

25 The GPS device 30 generates a signal representing vehicle speed as determined from GPS satellite data. This signal may represent speed in units different to the units in which vehicle speed is computed by the speed computing module 64. In that case, as shown in Figure 2, the output from the GPS device 30 is converted by a GPS units converter 70 to represent speed in the same units as computed by the speed
30 computing module 64. For example, in Figure 2, it is presumed that, as is common, the GPS output represents vehicle speed in knots, whereas the speed represented by the output from module 64 is typically in km/hr. So, the GPS units converter 70 produces from the input signal from the GPS device 30 an output representative of vehicle speed in km/hr.

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Output from the GPS units converter 70 is passed to a GPS delay module 35. The output from the GPS delay module 35 is of similar form to the signal output from the converter 70, being still indicative of speed output from the GPS units converter 70, but of that speed at a slightly delayed time, for a purpose described below.

5

The output from the GPS delay module 35 is passed to a GPS averaging module 44 which produces, at the output thereof, a signal representative of the average of the GPS-derived vehicle speed represented by the output from the GPS units converter 70 over a predetermined period of time. That is, the speed information from the GPS units converter 70 is, as explained, periodically updated. The GPS averaging module 44 produces a signal representing a periodically updated "rolling" or "moving" average of so derived speed information, each such update representing the average of a predetermined number of updates of GPS-derived speed information presented to the GPS averaging module 44.

15

Outputs from both averaging modules 42, 44 are applied to a comparator 72 which computes an offset output signal representative of the difference in speeds as represented by the two inputs to the comparator 72. The offset signal is applied to a conversion computing module 46 which computes an updated value of the conversion factor k_1 which in turn updates the memory 82 with this updated value of the conversion factor k_1 . By this, the output from the distance computing module 63 is corrected in accordance with the updated conversion factor k_1 to bring the speed as represented by that output to reflect the speed as represented by the converted speed value received from the GPS units converter 70, that is to cause the speed as displayed by speedometer display 84 into conformity with the speed derived from the GPS device 30.

The signals from the GPS device 30 include information as to the viability of the speed information it provides. That information, is provided as a viability signal which is passed from GPS device 30 to the conversion computing module 46. When this viability signal is indicative of a usable vehicle GPS signal, the conversion computing module 46 operates as described to provide the updated conversion factor k_1 as described above. However, when the viability signal is not so indicative, the conversion computing module 46 does not update the conversion factor k_1 . That is, no adjustment of the conversion factor k_1 is made at the memory 82. This situation prevails until the viability signal output of the GPS device 30 indicates that a

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satisfactory GPS signal is received, whereupon the updating operation as described resumes, pursuant to the viability signal being so indicative.

The purpose of delay modules 35 and 36 is to synchronise the signals from the GPS units converter 70 with the signals from the speed computing module 64 by introducing delays so that the signals received by the comparator 72 always represent the average speed of the vehicle over a common time interval, regardless of whether they are derived from GPS signals or from the sensor 15. This is required because internal delays in processing signals would otherwise result in temporal mismatching between GPS-derived speed values and speed values derived from the sensor 15, leading to substantial errors if the GPS speed values were used to correct the sensor 15-derived speed values when the speed is changing. In cases where the vehicle is travelling at constant speed, this will not generally matter, but the difference can be sufficient to cause significant errors in circumstances where the vehicle speed is changing at an appreciable rate.

The delays introduced by the delay modules 35 and 36 are determined based on the mechanical components and the GPS device 30 of the specific vehicle in which the meter is implemented. In the embodiments described herein, the determination of the delays is typically performed once during an initialisation process, and the resulting delay values are fixed thereafter. In other embodiments, the meter may be configured to perform adjustment of the delays introduced by delay modules 35 and 36 dynamically at additional times after the initialisation process.

In the described embodiments, the delays provided by the delay modules 35, 36 are determined by "offline" analysis of the undelayed sensor data and GPS data to find the delay values that give the best temporal alignment or match. Specifically, the delays are determined by selecting a set of consecutive speed values from stored sensor-derived speed data and GPS-derived speed data acquired over a time period where the vehicle speed varied substantially and preferably did so multiple times in order to provide multiple features in the data sets to facilitate alignment (e.g, several peaks and troughs of different magnitudes in a graph of vehicle speed vs time over the acquisition period).

The granularity of each determined delay corresponds to the corresponding data sampling period. For example, the GPS data is sampled once per second, and

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consequently the GPS delay is determined in increments of one second, whereas the sensor 15 data can be sampled significantly faster, resulting in smaller increments of the sensor delay. In combination, the "perfect" delay values (i.e., perfect temporal alignment) can be closely approximated. To achieve the best time alignment (i.e.,
5 synchronisation) in the general case, it may be required to delay one data stream (of speed values) by a relative large sample time, and the other data stream by multiple smaller sample times whose sum is less than one of the longer sample times, thereby effectively providing a delay of the first data stream by less than its full sample time relative to the second data stream. However, in cases where the sensing system with
10 the smallest overall delay also has the finest granularity (as is the case with the described embodiment where the sensor 15 has both the finest granularity and the smallest overall delay in comparison with the GPS data), the delay module may be omitted from the data path of the larger delay, coarser temporal granularity sensing system (in this example, being the GPS data path and thus the delay module 35).

15 In any case, each relative alignment is assessed by quantifying the overall difference between the two sets of speed values. In the described embodiment, the difference is quantified as a sum of the squares of the differences between speed (or equivalent) values at each sampling time over the acquisition period. However, other methods for
20 quantifying the differences between the two datasets may be used in other embodiments. The relative delays are determined by minimising the resulting sum as the GPS delay and the sensor delay are varied.

25 In the described embodiment, the delay is implemented by selecting vehicle speed data acquired at earlier times, as described below.

A taxi meter fare computing module 80 receives input pulses from clock 62 as well as signal from the distance computing module 63, and generates a fare signal representing a taxi fare accumulating in accordance with a pre-programmed fare
30 schedule stored in associated rate schedule or tables 92. The fare signal may, for example, represent the fare accumulating on a time basis when the vehicle 10 is stationary, and on a distance travelled basis when the vehicle is moving, and the transition between time-based and distance-based fare calculation may occur at a predetermined vehicle speed. A fare display 90 is provided in communication with the
35 fare computing module 80, and displaying a fare in accordance with the signal from the fare computing module 80.

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While reset button 200 may be used to reset a trip meter which may be displayed on odometer display 85, it should in no way affect the fare computation by the taxi meter.

5

In the case of a taxi meter as generally described below, it is generally convenient that the vehicle odometer and speedometer computation and displays be effected generally as described herein and as shown in Figure 2. However, other embodiments may incorporate existing vehicle speedometers and/or odometers, in which case one or both of the displays 84 and 85 may be omitted.

While as embodiments of the invention has been described in the particular context of a taxi meter 100, other embodiments may be provided in the form of a speedometer including sensor 15 and module 63, 64 and display 84, and/or odometer including sensor 15, module 63 and display 85, in each case also including converter 70, comparator 72, module 46 and memory 82, see Figure 3.

It is anticipated that embodiments of the invention may revolutionize speedometer accuracy and operational standards worldwide. That is, in embodiments of the invention, one or more of the following advantages may be achieved:

1. Road safety may be improved due to improved speedometers accuracy. For example, an accuracy of $\pm 0.5\%$ may be achieved.
2. Vehicle manufacturers may be able to provide new vehicles with high speedometer accuracy, with the expectation that such accuracy will be maintained for the whole vehicle life.
3. Road authorities may be able to reduce the legally allowed tolerance of speedometers to e. g. $\pm 0.5\%$.
4. It may be possible for road authorities to cease or greatly reduce the installation and maintenance of costly speed checking equipment.
5. The need for road authorities to routinely check vehicle speedometer accuracy checks may be removed or reduced.

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6. The invention may be applied to the great majority of vehicles, and particularly to taxis.
- 5 7. Implementation of future taxi fare schedule adjustments may be simplified, since the need for post-adjustment checks may be reduced or eliminated.
8. Detection of fraudulent practices by taxi drivers and operators may be facilitated.
- 10 9. The invention may be adapted to record and report to authorities attempted taxi fraud.

15 It will be apparent to those skilled in the art that embodiments of the invention can be implemented in hardware, or may be at least partly implemented using a programmable device such as an FPGA and/or a microprocessor. Some embodiments of the invention may be software implemented. The GPS information required can be extracted by the GPS device 30 from the received GPS signal using standard methods
20 known to those skilled in the art. For example, the GPS signal may, conventionally, be transmitted as an ASCII coded signal with periodically transmitted data blocks including coded sentences having delimited fields. Typically, one such field conveys the current speed in knots. Fields representing horizontal and vertical dilution of precision of location determination may be included in each data block, and these can
25 be extracted to become part of the mentioned validity signal received at the conversion computing module 46.

For example, if the Horizontal Dilution of Precision (HDOP) value is greater than a configured threshold value, for example '4', the data is marked as invalid or unusable
30 due to the large error possible in the data values. Larger HDOP values indicate a larger probability that the data is erroneous. Alternatively, or additionally, the validity of the GPS data may be represented directly in a transmitted field, and extracted for presentation to the conversion computing module 46. The form of the validity indicator varies based on the particular sentence of GPS data processed by the
35 computing module 46 during the validity determination process. For example, in \$GPRMC the validity indicator is in the form of a letter, with "A" and "V" indicating

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valid and invalid data respectively. However, in other data sentences a number is used to indicate the type of fix (e.g. 2D, 3D, dead reckoning, etc.). In the embodiments described herein, the \$GPRMC sentence is considered during the GPS data validity determination process, where the received data is marked as invalid if labelled as such
5 by the validity indicator of the \$GPRMC sentence.

VEHICLE SPEED DETERMINATION

Parameters

The taxi meter 100 performs a vehicle speed determination process based on several
10 parameters, including:

- i) the number of pulses generated by the sensor 15 per kilometre of distance travelled by the vehicle (P_{KM});
- ii) the accuracy required for the determined speed values (a); and
- 15 iii) the period of time over which information received from the sensor 15 and from the GPS device 30 is processed to determine the vehicle speed.

The number of pulses generated per kilometre (P_{KM}) is determined by the mechanical components of the vehicle, including the vehicle drive shaft 16, the differential gear ratio of the vehicle differential 24 and the effective radius of the drive wheels 22, as
20 described herein in relation to the conversion factor k_1 . The number of pulses generated per kilometre is related to the factor k_1 , which dynamically changes during the speed determination process. Initially, such as when a vehicle is first manufactured, the system can be configured to store a 'nominal' or 'base' value of P_{KM} in memory 82, which represents the expected value of the parameter given the
25 vehicle's mechanical components.

The vehicle speed accuracy a is a real valued parameter representing the maximum acceptable uncertainty in the vehicle speed determined by the taxi meter 100 from the number of pulses counted over a corresponding time period and that would result
30 from an error of one pulse in the number of pulses counted in that period.

In the described embodiment, the vehicle speed uncertainty for a given speed determination is determined by the change in the determined vehicle speed (as calculated by the speed computing module 64) that would result from a difference of a
35 single pulse in the train of pulses obtained from the sensor 15 (as counted by the

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distance computing module 63) that were used to calculate the vehicle speed. To facilitate ensuring that the accuracy of the speed estimates produced are within the tolerance specified by the speed accuracy value, this α value is converted to a minimum number of pulses ($P_{\min}$) to be counted to determine each corresponding vehicle speed value. For example, a speed accuracy value of $\alpha = 0.5$ indicates a tolerance of $\pm 0.5\%$ in vehicle speed, which for a particular hypothetical vehicle might correspond to a minimum number of pulses of $P_{\min} = 200$. The speed accuracy value α can be set arbitrarily, but in practice is based on the legal and/or operational requirements that the vehicle is subject to.

10

To produce accurate speed estimates, the system counts the pulses generated by the sensor 15 over a time interval of fixed duration, referred to as the "accumulation interval". The minimum vehicle speed for the GPS data to be considered valid is determined by the accumulation interval, the PKM value, and the α value. The size of the accumulation interval can be customised based on the specific vehicle and its operation. For example, considering speed information over a larger time period decreases the minimum vehicle speed required for GPS data validity at the cost of increasing the processing needed to store and retrieve a larger number of pulse count values. This allows for flexibility in the configuration of the system, where short time intervals may be beneficial in applications where the vehicle primarily travels at high speeds (such as, for example, when the system is deployed on a motorcycle).

20

Speed Determination Processes

The flow charts of Figures 4a, 4b and 4c illustrate the steps of speed determination processes in accordance with some embodiments of the invention. In the described embodiment, the processes are implemented in the form of a computer program, although this need not be the case in other embodiments, where the processes may be implemented in hardware, either in part or in their entirety. The speed determination processes include three sub-programs: an INITIALISE sub-program 210, as shown in Figure 4a; a LOOP sub-program 240, as shown in Figure 4b; and a TIMER ROUTINE sub-program 270, as shown in Figure 4c. Sub-program 210 is run to initialise the operation of the taxi meter 100, after which sub-programs 240 and 270 run continuously.

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Execution of sub-program 210 begins at an entry step 212, executed for example automatically on start up of vehicle 10. Pursuant to execution of this step, an initialisation step 214 is executed, at which communication with the GPS device 30 is initialised. After initialisation, at step 216 signal validity markers are set to INVALID.

- 5 After that, at step 218, initialisation of arrays and/or variables used in the sub-programs 210, 240, 270 is effected. Subsequent to this, sub-program 210 terminates at an exit step 220.

- Execution of sub-program 240 begins at an entry step 242. Pursuant to entry, at step 10 244 a determination is made as to whether GPS data is available from the GPS device 30. If GPS data is available, data concerning validity and usability of the GPS signal is extracted from the GPS signal, at step 246. Then, at step 248 a determination is made as to whether the available GPS data is usable based on the data extracted at step 246 (as described below). The GPS data is, at step 254 or 250, associated with a 15 validity marker. The GPS data is stored in an array of speed or distance values (depending on which is being used), as calculated from the GPS data as each sample is received, and respective validity markers or indicators for those values. If, at step 246, data is determined not to be usable, at step 250 the validity marker for this slot in the GPS data array is set to INVALID. Otherwise, usable data, as received from the 20 GPS device 30, is saved at step 252, and at step 254 the validity marker is set to VALID. At step 256, a GPS received flag is set to a RECEIVED state. The GPS received flag is used in sub-program 270 at step 274 to further flag the validity of the data in the GPS data array. Following step 256, a new cycle of operation of sub-program 240 is initiated.

25

- The GPS data saved at step 252 is in the form of an array of a predetermined number of speed values. In the described embodiments, the predetermined number includes the currently computed value together with a set number of preceding calculated values. For example, values for a preceding time period of about 32 seconds may be 30 included in the array.

- Sub-routine 270 is executed periodically, such as at one second intervals. Operation is initiated at an entry step 272. At step 274 determination is made as to whether GPS data from GPS device 30 has been received within a predetermined time interval, 35 such as an interval twice that between successive executions of sub-program 270, i.e. two seconds where the latter interval is one second. If no signal has been received in

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this predetermined time interval, at step 276 a validity marker is set to INVALID. Otherwise this marker is left as set by sub-program 240.

At step 278, the prevailing value of speed as derived from pulses generated by sensor 15 and processed the distance and speed computing modules 63, 64 is saved to an array. That array includes a predetermined number of values of speed as so saved. In the described embodiments, the predetermined number includes the currently computed value, together with a set number of preceding calculated values. For example, in the described embodiment, values for the preceding time period of about 32 seconds are included in the array. At step 280, a predetermined number of values in the array are averaged to generate an average speed value derived from sensor 15.

The number of values used in the averaging process is determined from the properties of the vehicle and the GPS device 30, such that the total number of pulses counted over the values selected for averaging is at least equal to a minimum number of pulses ($P_{\min}$, described below) required to achieve a given accuracy value α . For example, to perform averaging with $P_{\min} = 200$ for a vehicle having a pulses generated per kilometre $P_{\text{KM}} = 1000$, an accuracy value $\alpha = 0.5$ and a minimum valid speed of 20 kph (described below), a sample time of 36 seconds is required in order for the vehicle to travel the 200m necessary such that at least 200 pulses are counted by the sensor 15. Therefore, in this example, the averaging process is performed with array values corresponding to data collected from the sensor 15 over a 36 second time period. The values so selected include consecutively stored values for a subset of all stored values, the subset being selected so that it represents speed values at times synchronised with corresponding values of speed derived from GPS device 30, as described below.

At step 282, a predetermined number of values in the array stored at step 252 are averaged to produce an average speed value derived from GPS device 30. The values so selected may include consecutively stored values for a subset of all stored values, the subset being selected so that it represents speed values at times synchronised with values of speed derived from the signal of the sensor 15. That is, the delay 35 is implemented so that the set of GPS-derived values selected for averaging at step 282 and the set of mechanically derived speed values selected for averaging at step 280 both correspond to the vehicle speed(s) during the same time period.

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At step 284, a determination is made as to whether all validity markers, as saved at step 250 or 254 with respect to saved values of GPS speed determinations, used for averaging at step 282 are VALID. If not, the sub-program exits at step 298. Otherwise, at step 290 a new value of pulses/km is calculated. Then, at step 292, the value so calculated is compared with the corresponding value stored in memory 82. The difference between the new and existing pulses per kilometre values is determined as a percentage difference value Δ (i.e. $\Delta = |\text{new value} - \text{existing value}| * 100 / \text{existing value}$). The Δ value is compared against an acceptance threshold value, which is typically between 0.5%, and a 'proportional update threshold' value, which is typically 5%. If Δ is less than the acceptance threshold (i.e. if the new value differs from the existing value by a percentage less than the threshold) then the existing value is maintained. Conversely, if the difference exceeds the acceptance threshold but is less than the proportional update threshold, then the existing value is updated by direct replacement with the new value (and this value is logged or reported if logging is enabled). Finally, if the difference exceeds the proportional update threshold value, then the existing value is updated proportionally based on the new value, and not by direct replacement with this new value.

For example, the proportional update process may involve the update of the existing pulses per kilometre value with the average of the existing and new values. This proportional update process is performed to reduce the effect of any gross errors that could maliciously be introduced into the system, while still allowing prompt adaptation of the pulses per kilometre parameter in situations where, for example, the meter is moved between vehicles with different pulses/Km values. At step 294 the value derived at step 290 is saved and loaded into memory 82 to become the new prevailing value used to determine the vehicle speed by computing module 63. The GPS speed values used to calculate a measure of average GPS based vehicle speed in step 282 are set to INVALID in step 296, such that these values are excluded from use for the calculation of subsequent GPS based speed estimates. After that, the sub-program exits at step 300. Otherwise, if the determined Δ value is smaller than the acceptance threshold, the sub-program exits at step 298 without updating the existing pulses per kilometre value. The updating of the calibration value in memory 82 using the data synchronisation and subsequent usability and validity checking steps described above eliminates the need for methods that rely on continually correcting the pulse stream. Specifically, by storing and dynamically updating the value of the pulses per kilometre in the meter there is no need to perform correction techniques, such as dead

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reckoning, to produce adjusted pulse data external to the meter, when the received GPS data is invalid.

Validity and Usability of the GPS Signal

- 5 A multi-part process is implemented to determine the validity and usability of the GPS signal at step 248. The GPS device 30 receives accuracy and validity information in a form referred to in the art as "sentences" in relation to received GPS speed data. For example, a "\$GPRMC sentence", includes several "fields", the third of which indicates the validity of the corresponding GPS speed data, wherein the symbol 'A' indicates
- 10 that the GPS speed data is 'active' or valid, and the symbol "V" indicates that the corresponding GPS speed data is Void or invalid. In a "\$PGGSA" sentence, the third field indicates '1' for no fix, '2' for a 2 dimensional fix and '3' for a 3 dimensional fix, while fields 4 to 15 indicate the "PRNs" (identifiers) of the satellites used for the fix, field 15 indicates the overall dilution of precision, whereby a smaller number indicates
- 15 a more reliable reading, field 16 indicates the horizontal dilution of precision, and field 17 the vertical dilution of precision. The GGA sentence has different indicators, in field 5 there is a fix quality indicator, field 6 indicates the number of satellites available for the fix, and field 7 indicates the horizontal dilution of precision (as described above).
- 20 In addition to these standard indicators, the usability of the received GPS speed data is assessed based on the current calibration value k_1 . To be considered usable, the speed indicated by the GPS data must be greater than the minimum vehicle speed that, based on the current calibration value k_1 , corresponds to a number of pulses such that a difference of a single pulse results in a change of speed of less than the
- 25 predetermined but configurable speed accuracy, where this required precision level can be set as desired, typically based on the specific application of the system. This ensures that the vehicle speed calculations are of a minimum level of precision, as described below.
- 30 Usability is also calculated based on the direction or bearing indicated by the GPS data. Variation in the direction (also referred to as the "heading" or "bearing") data values indicates that either the GPS data is inconsistent or "jumpy", as happens when the vehicle is stopped or the vehicle has turned a sharp corner (as the distance travelled around a sharp corner is significantly larger than the distance measured
- 35 between the start point and the end point along a straight line). If the direction or

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bearing values vary by more than a set limit, then the GPS data is considered unusable due to the inaccuracies in the speed calculations that would result if such GPS data were used.

- 5 The system can also determine the usability of the GPS data in relation to steep inclines. This usability criterion can be considered conditionally, such as in situations where the system has been configured to use only the horizontal location data in the GPS speed calculations. For example, for meters implemented on trains, where all inclines are less than approximately 1 in 100, the difference between the horizontal
10 component of the GPS data vector and the actual distance travelled by the vehicle is small enough to be disregarded. However, for a car on roads with an incline grade that is typically 1 in 10, the difference will be more significant. This is advantageous since, in this case, the difference between the horizontal component of the displacement vector derived from the GPS data can be significantly different to the
15 actual (i.e. three dimensional) displacement experienced by the vehicle when travelling along such inclines.

- However, the system can alternatively be configured to use three dimensional location information to generate accurate speed estimates even when the vertical location of
20 the vehicle varies substantially over the relevant calibration periods. Conventional dead reckoning based GPS speed correction systems are unable to accurately determine vehicle speed from GPS data under such circumstances, because they depend on the calculation of calibration parameters via a process that requires either travel in a straight line, or a period of travel over which there is zero net variation in
25 the heading of the vehicle.

- Specifically, in many dead reckoning based systems the correction of errors in the speed of the vehicle assumes that the vehicle is traveling in a straight line (i.e. that there has been no change in heading of the vehicle since the most recent GPS location
30 information was received), and is therefore generally incapable of generating accurate speed estimates when that assumption is incorrect. This is particularly problematic in situations where vehicle speed estimates are produced using only horizontal GPS location data to determine the vehicle position (as described above) but the altitude of the vehicle (i.e., its height above sea level) changes significantly over relevant time
35 periods.

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For example, Figure 6a illustrates a hypothetical situation where a vehicle is travelling through a series of valleys (points A, B and C) and hills (points D, E and F), and the vertical component of the vehicle's velocity changes in a generally oscillatory manner while the vehicle travels with a constant velocity with respect to a horizontal plane. In this case, vehicle speedometer systems utilising only horizontal location data will infer a straight line of travel and a constant velocity for the vehicle. This occurs when GPS information is used to calculate vehicle location data in the form of latitude and longitude coordinates only (as in the case of the system described in US 5,828,585), or when vehicle location data is produced or modified by "map matching" techniques that resolve the vehicle's position to a point on a two dimensional road path (as in the case of the systems described in EP 0806632 and EP 2541203). Under such circumstances, dead reckoning and other speed correction methods that perform calibration based on heading and/or horizontal range parameters only, will produce inaccurate speed estimates by ignoring changes in the vehicle's altitude and vertical speed during its travel from A to F.

By contrast, the system described herein is configured to accommodate for changes in altitude experienced by the vehicle. For example, the system can be configured to selectively update the calibration value k_1 as described above using the received GPS data only if the variation in the vehicle's altitude over the relevant period is less than a threshold altitude change value. For example, in the case presented in Figure 6a, the system can be configured to utilise GPS location data during periods of travel where the vertical displacement of the vehicle is small (such as when travelling from 'Start' to 'A', and 'F' to 'End'), while ignoring the GPS data received during periods where the vertical displacement is large (such as when travelling from 'D' to 'E') in order to avoid inaccurately updating the k_1 value.

Furthermore, the system described herein can produce accurate speed estimates in the presence of changes in the heading of the vehicle over the accumulation interval and the corresponding GPS interval (such as for the example shown in Figure 6a). The received GPS data is determined as usable for the purpose of updating the calibration value k_1 if the variation in the vehicle's heading over the relevant period is less than a non-zero heading threshold value. This is advantageous in comparison to previously proposed systems, such as that described in EP 2541203, which require a period of travel in which the net variation in the heading of the vehicle is zero (such as, for example, when the vehicle travels along a circular or figure-eight type track, as shown

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in Figure 6b) in order to perform the parameter calibration steps necessary for accurate vehicle speed error correction.

5 A GPS data value is also flagged as unusable if the change in the GPS speed is greater than a set limit. Unrealistically large changes occurring between successive GPS speed values typically indicates the existence of an error in the GPS data. Such errors can result from interference, such as that caused, for example, by aircraft reflecting GPS signals.

10 DATA SYNCHRONISATION

The averaging of the vehicle speed and GPS speed values in steps 280 and 282 is performed on synchronised data streams. Synchronisation is performed such that the vehicle and GPS speed data values each correspond to the same time period. Data received from the GPS receiver is typically delayed with respect to the data generated from the pulses generated from a rotating part that is proportional to the speed of the vehicle. Additionally, depending on how the pulses are generated, a delay may exist between the instant when the vehicle changes speed and the time when the pulses required to detect the speed change are counted. For example, depending on the method of gathering the data from the vehicle, the vehicle speed data values could represent the vehicle speed during the immediate previous second, while the GPS data value may represent the speed information for the second prior to that. As described below, this absolute delay can be accommodated in circumstances where it is desired to accurately know the absolute vehicle speed at some specified (past) time or times.

25 Synchronisation of GPS and Odometer Calculated Speeds

To achieve synchronisation, the vehicle speed data is delayed to match the GPS data. Synchronisation of the mechanically-derived and GPS-derived speed values, using the delay components 35 and 36, allows the system to account for differences in the times at which the respective vehicle and GPS speeds become available, while maintaining independence between the determination of these speed values. For example, without synchronisation a vehicle starting from rest may, according to the vehicle data, have travelled a distance in the first second, whereas the GPS data may report a zero distance travelled at that time if its update occurs a second later. The mismatched relative timing of these values would lead to large inaccuracies in the calculation of the vehicle speed at step 290.

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In the described embodiment, the synchronisation applied at steps 280 and 282 is performed in response to receipt by the GPS receiver 30 of each set of valid GPS signals representing the vehicle coordinates, and involves, for each corresponding

5 update of the k_1 value:

- 1) determining a corresponding duration of an accumulation interval over which the pulses generated by the sensor 15 are to be counted, where this interval extends over a number of timeslots (N_s), with each timeslot having a predetermined length (T_s) for which pulses obtained from the sensor 15 are counted;
- 10 2) selecting the specific start time (t_s) and end time (t_e) of the corresponding accumulation interval according to a delay, as described below, such that the accumulation interval is delayed relative to the corresponding GPS data interval; and
- 15 3) accumulating the pulse counts for each timeslot within the accumulation interval and, based on the current value of k_1 and the time duration of the accumulation interval, generating a vehicle speed estimate that is synchronised with a corresponding vehicle speed estimate generated from the GPS data.

- 20 The meter 100 receives GPS data substantially periodically, with a period that is typically significantly longer than that of the odometer pulse signal. If the GPS period T_{GPS} is known, then the T_s value can be chosen such that the GPS period is an integer multiple of the timeslot size (i.e. $T_{GPS} = (M \times T_s)$, where M is a positive integer). This allows the accumulation interval start and end times t_s and t_e to be selected such that
- 25 a whole number of GPS data values are received over the accumulation interval. The pulses counted over the accumulation interval are used to produce an estimate of the vehicle speed at a representative time t_{Acc} associated with the accumulation interval. The representative time is typically the midpoint of the time interval, such that $t_{Acc} = (t_e + t_s)/2$ (i.e. the arithmetic average of the starting and ending times), as shown in
- 30 Figure 5a.

- The GPS interval is of duration equal to the accumulation interval duration (t_i), and has specific start and end times corresponding to when the most recent GPS data value was received, and when a previous GPS data value was received respectively.
- 35 An integer number of GPS data values ($N_{GPS} = t_i/T_{GPS}$) are received during the GPS interval, and these data values are processed to produce a GPS speed estimate at a

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GPS representative time t_{GPS} . The t_{GPS} value is determined for the GPS data interval as the average of the times at which the first and last GPS data values of the interval are received.

- 5 Hypothetically, if there was no delay associated with receiving the GPS data, then the vehicle speed could be calculated by counting the number of pulses that arrived during the GPS data interval (i.e. by setting the accumulation interval to be the same as the GPS data interval). That is, the accumulation interval representative time t_{Acc} is set equal to the GPS representative time t_{GPS} , as shown in Figure 5a.

10

The delay module 36 stores the values of the accumulation interval parameters, including the start t_s and end t_e times, the number of timeslots N_s , the timeslot length T_s , and the GPS period T_{GPS} , generated during the synchronisation process in memory 82.

15

Accommodating for GPS Delay

- Consider a hypothetical (if potentially unrealistic) example where the GPS period is $T_{GPS} = 1000ms$ (i.e. one second between receiving consecutive GPS values) and the timeslot length is $T_s = 500ms$ (in reality, it is more likely to be about 10ms). In this case, an accumulation interval of 8 timeslots would correspond to 4 consecutive received GPS values. If there was no delay in the GPS data relative to the sensor data, the GPS and accumulation intervals are identical, and the GPS speed at $t_{GPS} = t_{Acc} = 4s$ would correspond to the odometer speed calculated from pulses ending at $t_e = 6s$ and beginning at $t_s = 2s$, for an accumulation interval of $N_s = 8$ total timeslots each of duration $T_s = 500ms$ (see Figure 5a).

- However, in practice the received GPS data values are delayed with respect to the pulse data of the sensor 15. If the relative delay of the GPS data with respect to the pulse data D_{GPS} is known, then the accumulation interval can be defined over a time period that is offset by this delay, relative to the GPS data interval. That is, to synchronise the pulse data obtained from the sensor 15 with GPS data, the delay module 36 generates the accumulation interval with a representative time $t_{Acc} = t_{GPS} - D_{GPS}$, and this is implemented by selecting timeslots for the accumulation interval that are delayed by D_{GPS} , relative to the GPS interval representing time t_{GPS} . That is, the delay module selects N_{offset} earlier timeslots to determine the accumulation interval,

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relative to the timeslots that would otherwise be selected in the case where there is no GPS delay.

For example, assuming that GPS data is received in one second intervals (i.e. with a
 5 period of $T_{GPS} = 1000\text{ms}$), a timeslot size of $T_s = 500\text{ms}$ is used, and there is a relative
 GPS-to-sensor data delay of $D_{GPS} = 2000\text{ms}$, then the accumulation interval is
 determined such that the representative time t_{Acc} is 2000ms earlier than the
 corresponding GPS interval representative value t_{GPS} , as shown in Figure 5b.

10 The timeslot length (T_s) determines the precision with which the computed rotational
 speed and GPS speed values can be aligned in the presence of the GPS delay D_{GPS} ,
 and the number of timeslots required for a given accumulation (and GPS) interval
 duration. For example, for an accumulation interval of duration $t_i = 30$ seconds with a
 timeslot duration of $T_s = 500\text{ms}$ requires $N_s = 60$ timeslots to enable synchronisation
 15 to be performed.

Minimum Vehicle Speed for GPS Validity

The minimum vehicle speed (S_{min}) for the GPS data to be considered valid is calculated
 based on the required speed accuracy a , and the resulting minimum number of pulses
 20 P_{min} to be included in the accumulation interval, such that a difference of a single pulse
 results in a change of speed of less than the speed accuracy a . Given the P_{KM} value,
 this minimum speed S_{min} therefore represents the speed at which the vehicle needs to
 be travelling to receive the P_{min} pulses within the accumulation interval.

25 With reference to the above example, if the $P_{KM} = 1000$, the P_{min} value needed within
 each interval to maintain the required speed accuracy is $P_{min} = 200$, and if the
 accumulation interval length is $t_i = 30\text{s}$, then the vehicle must travel $200/1000$
 kilometres in 30 seconds or $(200/1000) * (3600/30) = 24$ kilometres per hour (kph).
 That is, in this example GPS data validity requires the vehicle to be travelling at, or
 30 above, a speed of $S_{min} = 24$ kph. If $T_s = 10\text{ms}$, then the accumulation interval is
 defined over $N_s = 3000$ timeslots. However, pulse counts from additional timeslots can
 be stored in order to allow for the lag of the GPS data signal. Assuming a GPS data
 period of $T_{GPS} = 1000\text{ms}$, and allowing for a maximum tolerance of twice this value, $2 \times$
 100 timeslots of size $T_s = 10\text{ms}$ are implemented by the delay module 36 to
 35 synchronise the rotational pulse data with the GPS values, giving 3200 timeslots in

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total (i.e. a total of $N_s + 200$ additional slots), where pulse counts are for each timeslot.

Data Buffering

- 5 The pulse count value for each timeslot is stored as a data sample in memory 82. In the described embodiments, the data samples are arranged within an accumulation buffer, where the minimum size of the buffer N_s^{Buff} is determined by the number of timeslots in the accumulation interval (N_s) plus any additional timeslots required, as described above. The N_s^{Buff} value is therefore dependent on: (i) the P_{KM} value, which
- 10 can vary according to the type of vehicle; and (ii) the maximum speed (S) at which the vehicle can travel during the speed calculation. For example, if $P_{KM} = 40,000$ and the vehicle is travelling at $S = 100$ kph, $N_s^{\text{Buff}} = P_{KM} * S * (\text{total accumulation time}) / 3600 = 40,000 * 100 * 32 / 3600 = 35,556$, which is the number of pulses that will be received in the 32 seconds of total accumulation time (which is $t_i = 30$ s for the
- 15 actual accumulation interval, plus 2s to allow for the GPS lag, as described above).

- The synchronisation mechanism is configured to reduce the amount of processing associated with storing a large number of pulse count values. For example, the system can be configured to count only one in every N pulses, which reduces the effective
- 20 number of pulses per kilometre, and consequently the minimum size of the accumulation buffer N_s^{Buff} . For example, in the example described above, counting only every 8th pulse lowers the N_s^{Buff} value from 35,556 to 4,445 when the vehicle is traveling at $S = 100$ kph. This method is advantageous in that the precision of the delay is determined by the timeslot size T_s , which allows the accumulation interval to
- 25 be offset with a high precision even when this interval is defined over fewer actual timeslots (i.e. when N_s is reduced).

Synchronisation of the Odometer Pulses with Actual Speed

- In cases where it is desired to accurately know the vehicle speed as a function of
- 30 absolute time (for past times), synchronisation can also account for delays between a change in the speed of the vehicle and the detection of this change in speed via the sampling of the odometer pulses by the sensor 15. Given knowledge of the odometer delay D_{odo} , which can be obtained by measurement or derived from knowledge of the vehicle components, the accumulation interval can be further offset, relative to the
- 35 GPS interval, to account for this odometer delay by selecting timeslots such that the

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representative time $t_{Acc} = t_{GPS} - D_{GPS} - D_{odo}$. Alternatively, the synchronisation process can be configured to ignore the odometer delay D_{odo} if this delay is small compared to the GPS delay D_{GPS} (i.e. where $D_{odo} \ll D_{GPS}$).

- 5 As will be apparent from the foregoing, the taxi meter 100 described includes a speedometer and an odometer. However, the principles of the invention may be applied in respect of a speedometer and/or odometer separate from a taxi meter. Figure 3 shows a combined speedometer/odometer 12 so formed. Like reference numerals denote like components in Figures 2 and 3, and these components function
10 in the same way as described with reference to Figure 2.

Implementations

- In some cases, a vehicle can experience changes in both its speed and heading during a particular period of travel. Furthermore, in practical situations it is likely that the net
15 variation in the heading of the vehicle over a given period of travel will be non-zero. Implementations of the system described herein are therefore advantageous in these situations due to their ability to produce accurate speed estimates when any one or more of the following apply: i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval; ii) the heading of the vehicle varies over
20 the accumulation interval and the GPS interval; and iii) the net variation in the heading of the vehicle is non-zero over the accumulation interval and the GPS interval.

- Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention.

- 25 The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general
30 knowledge.

CLAIMS

1. A vehicle speedometer, including:

5 a first component to generate first speed data representing speeds of a vehicle from rotation data representing rotations of a vehicle part, the rotational speed of which is proportional to the vehicle speed, and a conversion factor for converting the rotations of the vehicle part to corresponding speeds of the vehicle;

a second component to generate second speed data representing speeds of the vehicle from GPS signals; and

10 a speed correction component to process delay data, the second speed data, and the rotation data or the first speed data to update the conversion factor so that the first component can generate further first speed data representing speeds of the vehicle with improved accuracy;

15 wherein the delay data represents at least a relative delay between a speed of the vehicle represented by the first speed data and a corresponding speed of the vehicle represented by the second speed data; and

20 wherein the speed correction component is configured to process the second speed data and the rotation data or the first speed data in accordance with the delay data over accumulation intervals and respective GPS intervals, with a relative delay between the accumulation intervals and respective ones of the GPS intervals to synchronise the second speed data and the rotation data or the first speed data even when any of the following apply:

- (i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval;
- 25 (ii) the heading of the vehicle varies over the accumulation interval and the GPS interval; and
- (iii) the net variation in the heading of the vehicle is non-zero over the accumulation interval and the GPS interval,

30 the conversion factor being updated on the basis of the synchronised second speed data and rotation data or first speed data.

2. The vehicle speedometer of claim 1, wherein at least one of the second component and the speed correction component is configured to process the GPS signals to generate usability data such that the speed correction component only

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updates the conversion factor if the usability data indicates that the GPS signals are usable to update the conversion factor.

3. The vehicle speedometer of claim 2, wherein the usability data indicates that
5 the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of at least one sudden change of direction.

4. The vehicle speedometer of claim 2 or 3, wherein the usability data indicates
10 that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of any combination of:

i) a change in altitude of the vehicle over a corresponding time period exceeding a corresponding threshold value; and

ii) a change in the heading of the vehicle over a corresponding time period exceeding a corresponding threshold value.

15

5. The vehicle speedometer of any one of claims 2 to 4, wherein the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals appear to be unreliable.

20 6. The vehicle speedometer of any one of claims 1 to 5, wherein the delay data represents a first delay of a speed of the vehicle determined from the first speed data and a second delay of the corresponding speed of the vehicle determined from the second speed data.

25 7. The vehicle speedometer of any one of claims 1 to 6, wherein the synchronisation of the second speed data and the rotation data or the first speed data includes:

generating data defining the duration of the accumulation interval;

30 selecting at least one of: the start time; and the end time, of the accumulation interval according to the delay data; and

processing a subset of the rotation data or first speed data corresponding to the accumulation interval and the second speed data corresponding to the corresponding GPS interval.

35

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8. The vehicle speedometer of claim 7, wherein the accumulation interval is defined over a number of timeslots, where each timeslot is of a predetermined duration which determines the precision of the time delay that may be associated with the accumulation interval, such that the processing of the first speed data over the
5 accumulation interval involves accumulating information relating to the rotation of a vehicle part collected within each of the timeslots of the interval.

9. A method for determining vehicle speed, including:
generating first speed data representing speeds of a vehicle from rotation data
10 representing rotations of a vehicle part, the rotational speed of which is proportional to the vehicle speed, and a conversion factor for converting the rotations of the vehicle part to corresponding speeds of the vehicle;
generating second speed data representing speeds of the vehicle from GPS signals; and
15 processing delay data, the second speed data, and the rotation data or the first speed data to update the conversion factor so that the first component can generate further first speed data representing speeds of the vehicle with improved accuracy,
wherein the delay data represents at least a relative delay between a speed of the vehicle represented by the first speed data and a corresponding speed of the
20 vehicle represented by the second speed data, and
wherein the processing of the second speed data and the rotation data or the first speed data in accordance with the delay data over accumulation intervals and respective GPS intervals, with a relative delay between the accumulation intervals and respective ones of the GPS intervals to synchronise the second speed data and the
25 rotation data or the first speed data even when any of the following apply:
i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval;
ii) the heading of the vehicle varies over the accumulation interval and the GPS interval; and
30 iii) the net variation in the heading of the vehicle is non-zero over the accumulation interval and the GPS interval,
the conversion factor being updated on the basis of the synchronised second speed data and rotation data or first speed data.

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10. The speed determination method of claim 9, wherein the GPS signals are processed to generate usability data such that the conversion factor is only updated if the usability data indicates that the GPS signals are usable to update the conversion factor.

5

11. The speed determination method of claim 10, wherein the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of at least one sudden change of direction.

10 12. The speed determination method of claim 10 or 11, wherein the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of any combination of:

i) a change in altitude of the vehicle over a corresponding time period exceeding a corresponding threshold value; and

15 ii) a change in the heading of the vehicle over a corresponding time period exceeding a corresponding threshold value.

13. The speed determination method of any one of claims 9 to 12, wherein the usability data indicates that the GPS signals are not usable to update the conversion
20 factor if the GPS signals appear to be unreliable.

14. The speed determination method of any one of claims 9 to 13, wherein the delay data represents a first delay of a speed of the vehicle determined from the first
25 speed data and a second delay of the corresponding speed of the vehicle determined from the second speed data.

15. The vehicle speed determination method of any one of claims 9 to 14, wherein the synchronisation of the second speed data and the rotation data or the first speed
30 data includes:

generating data defining the duration of the accumulation interval;

selecting at least one of: the start time; and the end time, of the accumulation interval according to the delay data; and

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processing a subset of the rotation data or first speed data corresponding to the accumulation interval and the second speed data corresponding to the corresponding GPS interval.

5 16. The vehicle speed determination method of claim 15, wherein the accumulation interval is defined over a number of timeslots, where each timeslot is of a predetermined duration which determines the precision of the time delay that may be associated with the accumulation interval, such that the processing of the first speed data over the accumulation interval involves accumulating information relating to the
10 rotation of a vehicle part collected within each of the timeslots of the interval.

17. A method for determining vehicle travel distance, including:

generating first speed data representing speeds of a vehicle from rotation data representing rotations of a vehicle part, the rotational speed of which is proportional
15 to the vehicle speed, and a conversion factor for converting the rotations of the vehicle part to corresponding speeds of the vehicle;

generating second speed data representing speeds of the vehicle from GPS signals; and

processing the delay data, the second speed data, and the rotation data or the
20 first speed data to update the conversion factor so that the first component can generate further first speed data representing speeds of the vehicle with improved accuracy,

wherein the delay data represents at least a relative delay between a speed of the vehicle represented by the first speed data and a corresponding speed of the
25 vehicle represented by the second speed data, and

wherein the speed correction component is configured to process the second speed data and the rotation data or the first speed data in accordance with the delay data over accumulation intervals and respective GPS intervals, with a relative delay between the accumulation intervals and respective ones of the GPS intervals to
30 synchronise the second speed data and the rotation data or the first speed data even when any of the following apply:

- i) the speed of the vehicle varies substantially over the accumulation interval and the GPS interval;
- ii) the heading of the vehicle varies over the accumulation interval and the
35 GPS interval; and

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iii) the net variation in the heading of the vehicle is non-zero over the accumulation interval and the GPS interval,
the conversion factor being updated on the basis of the synchronised second speed data and rotation data or first speed data.

5

18. The vehicle travel distance determination method of claim 17, wherein the GPS signals are processed to generate usability data such that the conversion factor is only updated if the usability data indicates that the GPS signals are usable to update the conversion factor.

10

19. The vehicle travel distance determination method of claim 18, wherein the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of at least one sudden change of direction.

15

20. The vehicle travel distance determination method of claim 18 or 19, wherein the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals are indicative of any combination of:

i) a change in altitude of the vehicle over a corresponding time period exceeding a corresponding threshold value; and

20

ii) a change in the heading of the vehicle over a corresponding time period exceeding a corresponding threshold value.

25

21. The vehicle travel distance determination method of any one of claims 18 to 20, wherein the usability data indicates that the GPS signals are not usable to update the conversion factor if the GPS signals appear to be unreliable.

30

22. The vehicle travel distance determination method of any one of claims 17 to 21, wherein the delay data represents a first delay of a speed of the vehicle determined from the first speed data and a second delay of the corresponding speed of the vehicle determined from the second speed data.

35

23. The vehicle travel distance determination method of any one of claims 17 to 22, wherein the synchronisation of the second speed data and the rotation data or the first speed data includes:

generating data defining the duration of the accumulation interval;

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selecting at least one of: the start time; and the end time, of the accumulation interval according to the delay data; and
processing a subset of the rotation data or first speed data corresponding to the accumulation interval and the second speed data corresponding to the corresponding
5 GPS interval.

24. The vehicle travel distance determination method of claim 23, wherein the accumulation interval is defined over a number of timeslots, where each timeslot is of a predetermined duration which determines the precision of the time delay that may
10 be associated with the accumulation interval, such that the processing of the first speed data over the accumulation interval involves accumulating information relating to the rotation of a vehicle part collected within each of the timeslots of the interval.

25. A taxi meter having a vehicle speedometer as claimed in any one of claims 1 to
15 8.

26. A method of determining a taxi charge in which the charge is based at least in part on vehicle travel distance determined by the method of any one of claims 17 to
24.

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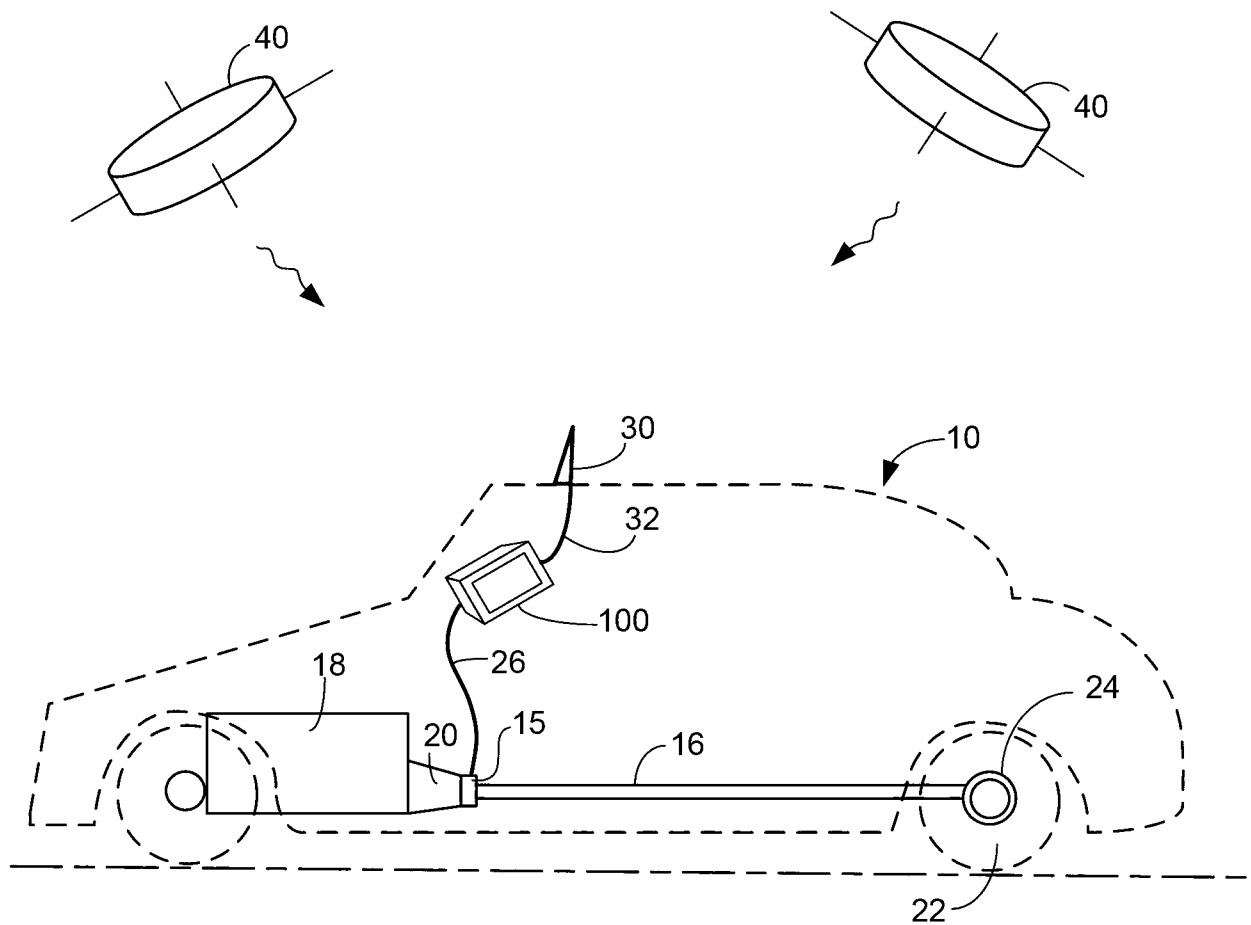


Figure 1

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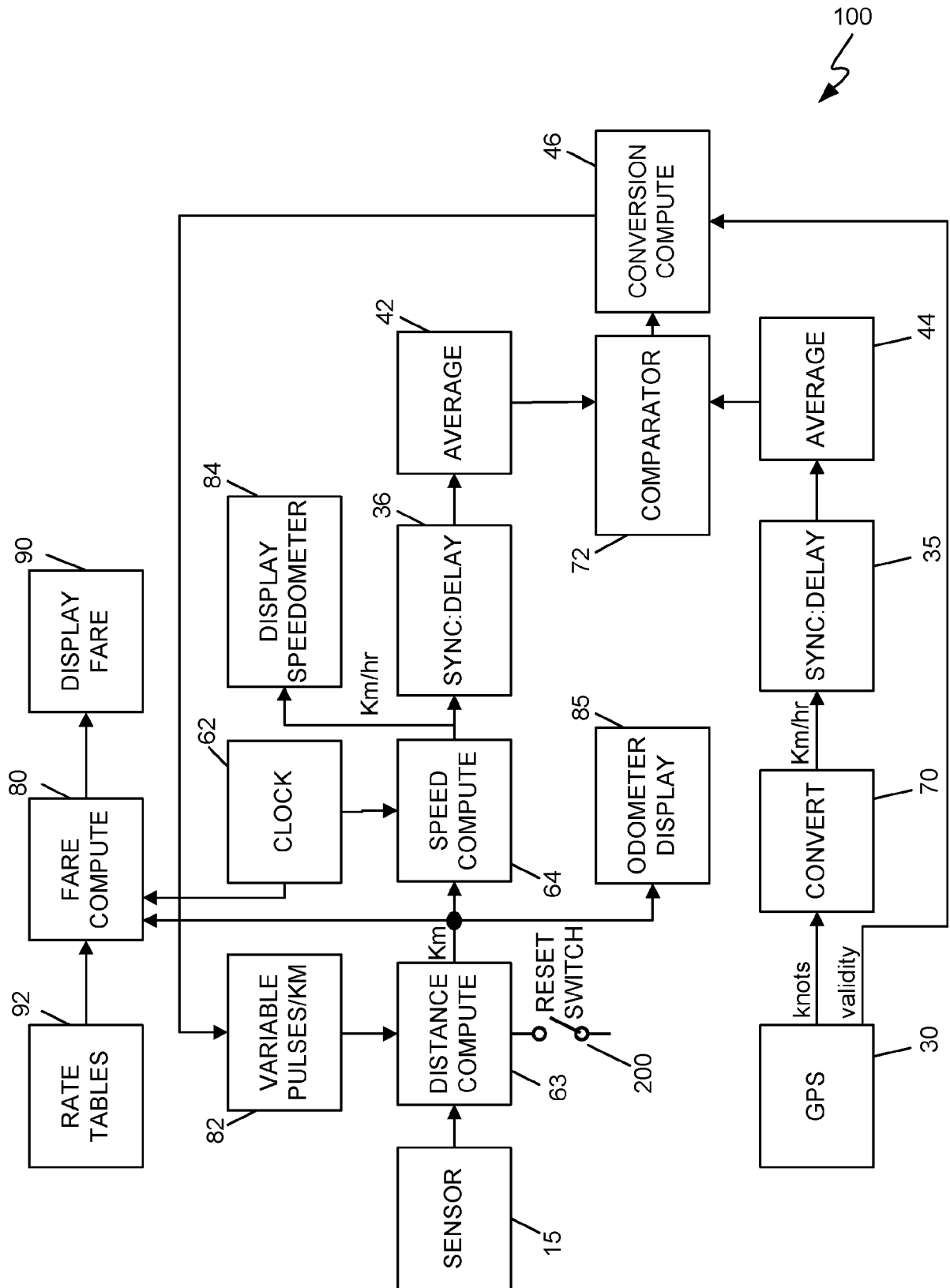


Figure 2

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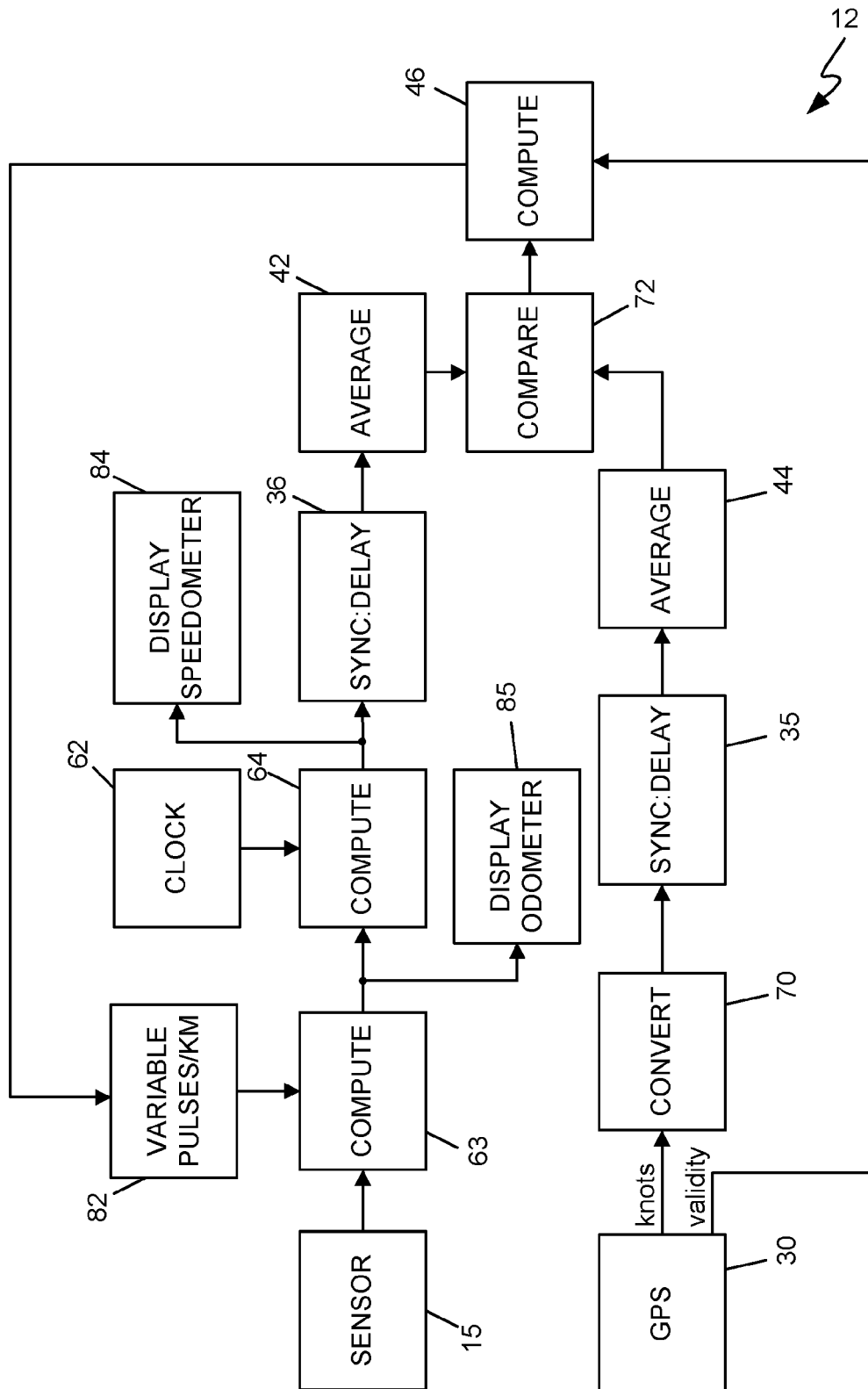


Figure 3

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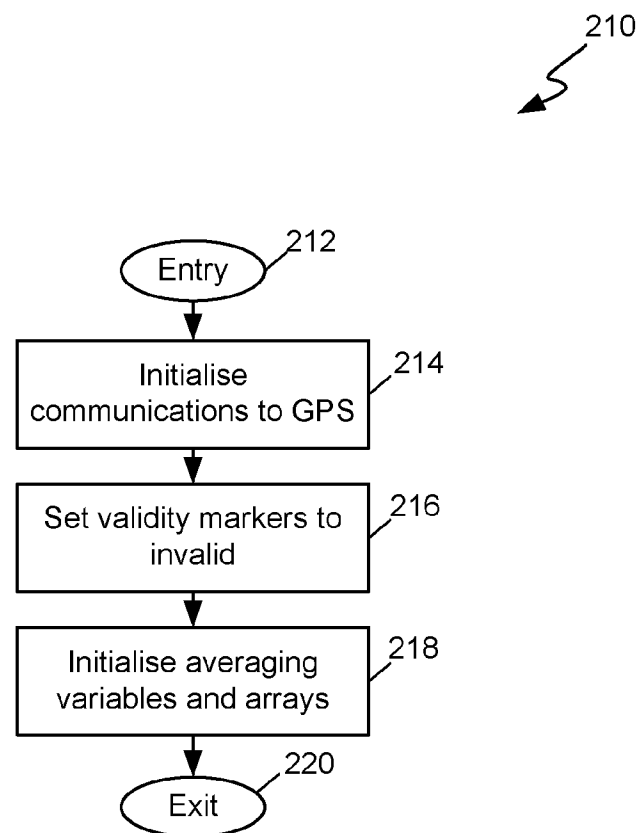


Figure 4a

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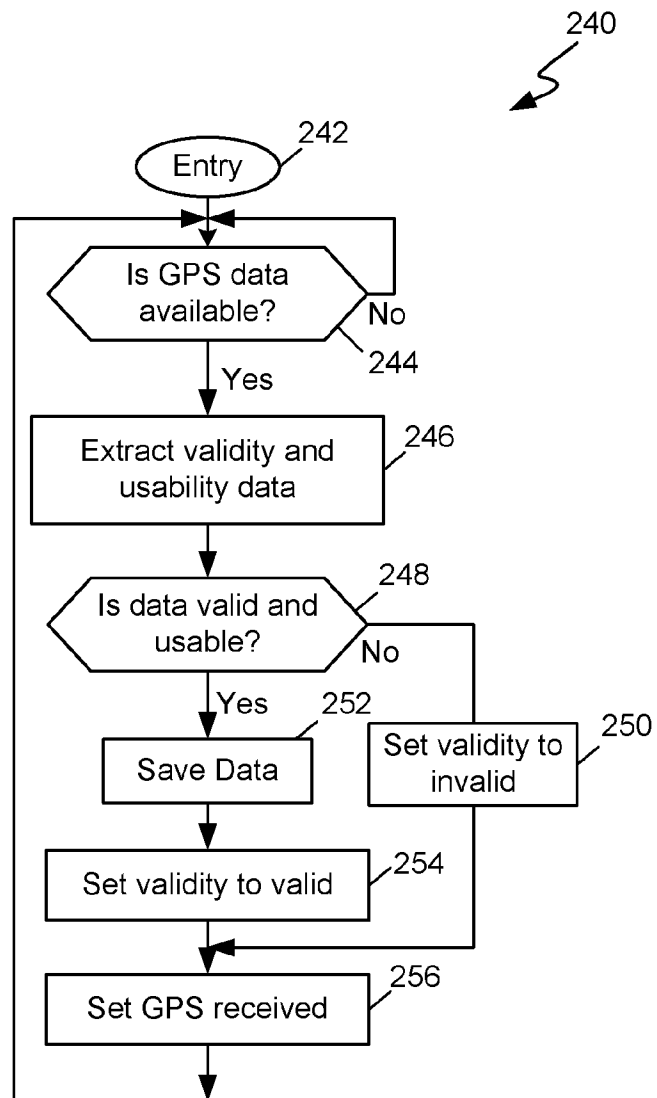


Figure 4b

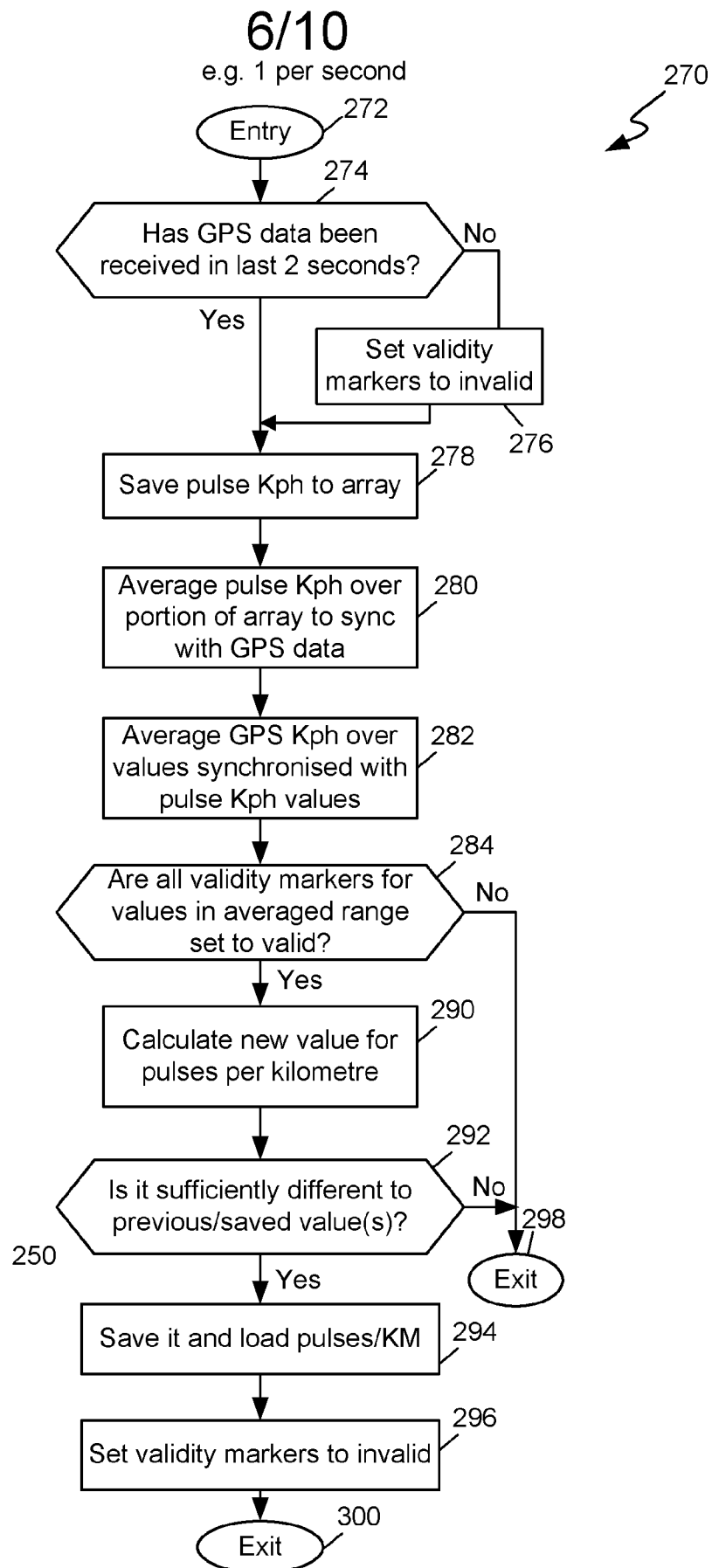


Figure 4c

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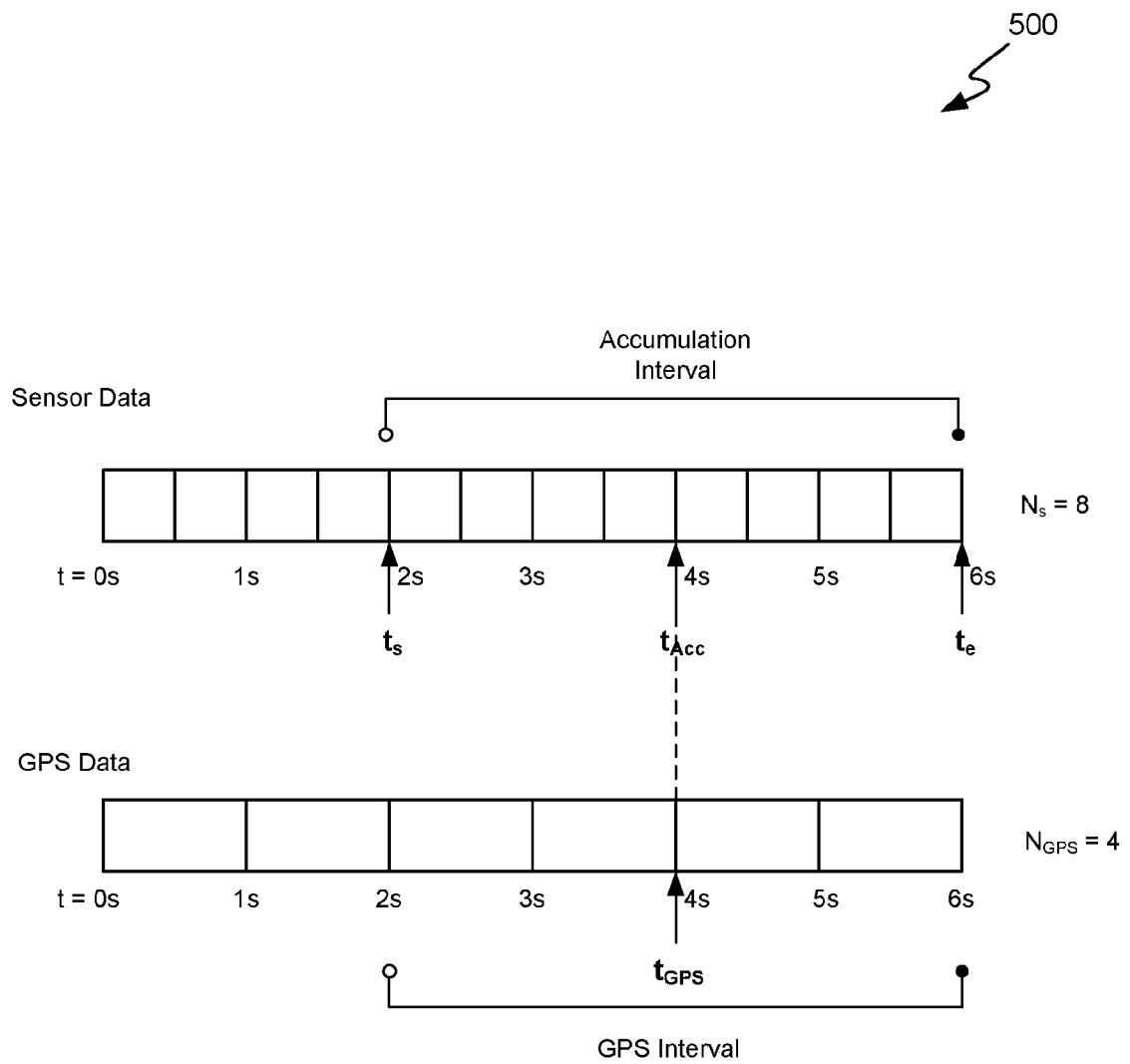


Figure 5a

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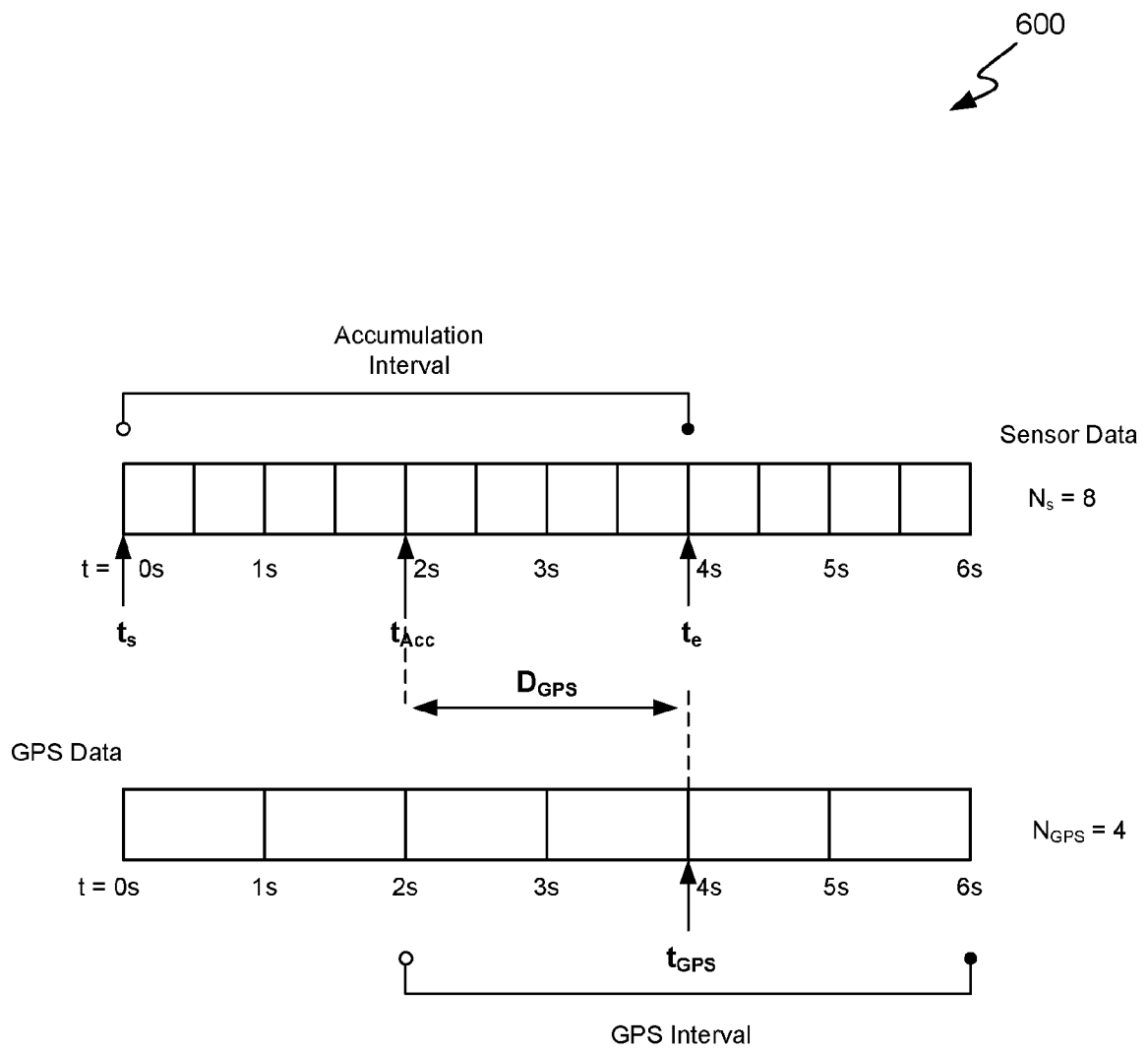


Figure 5b

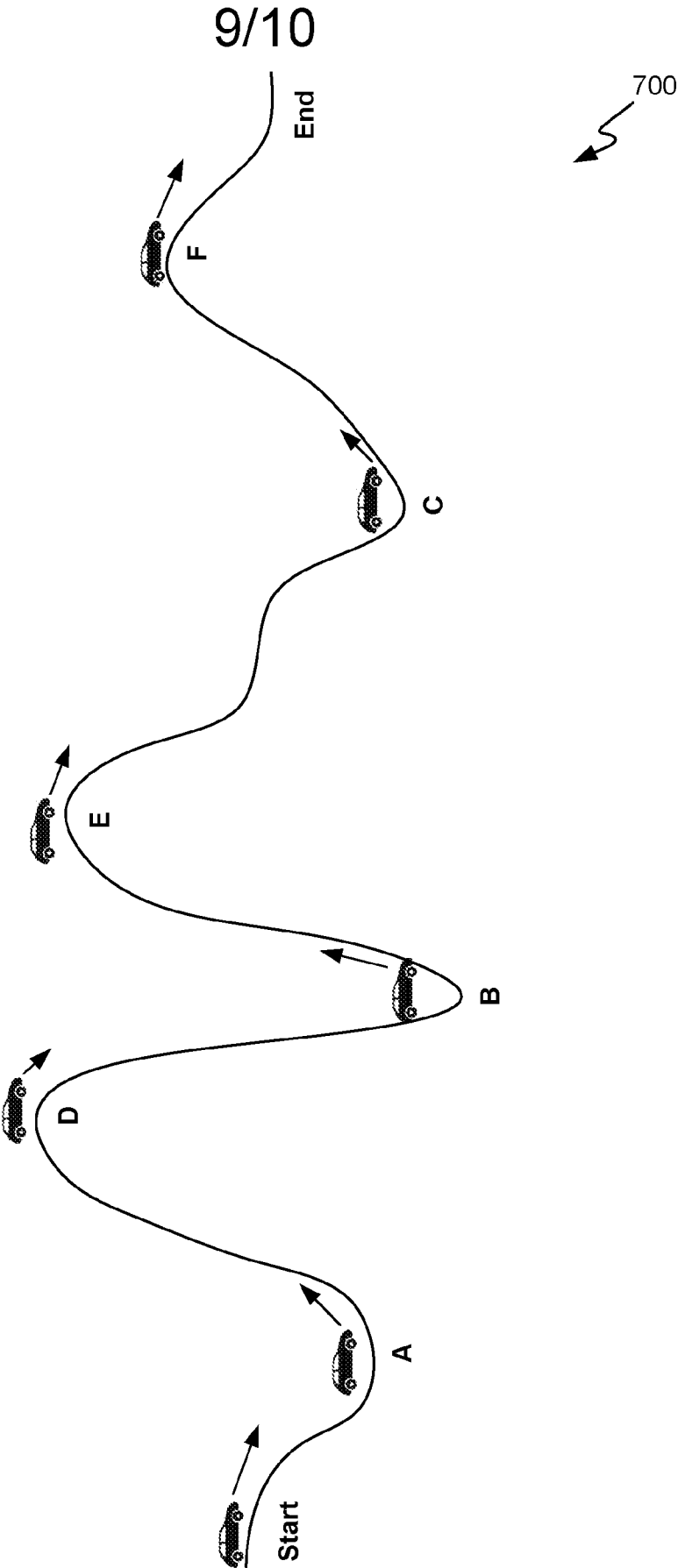


Figure 6a

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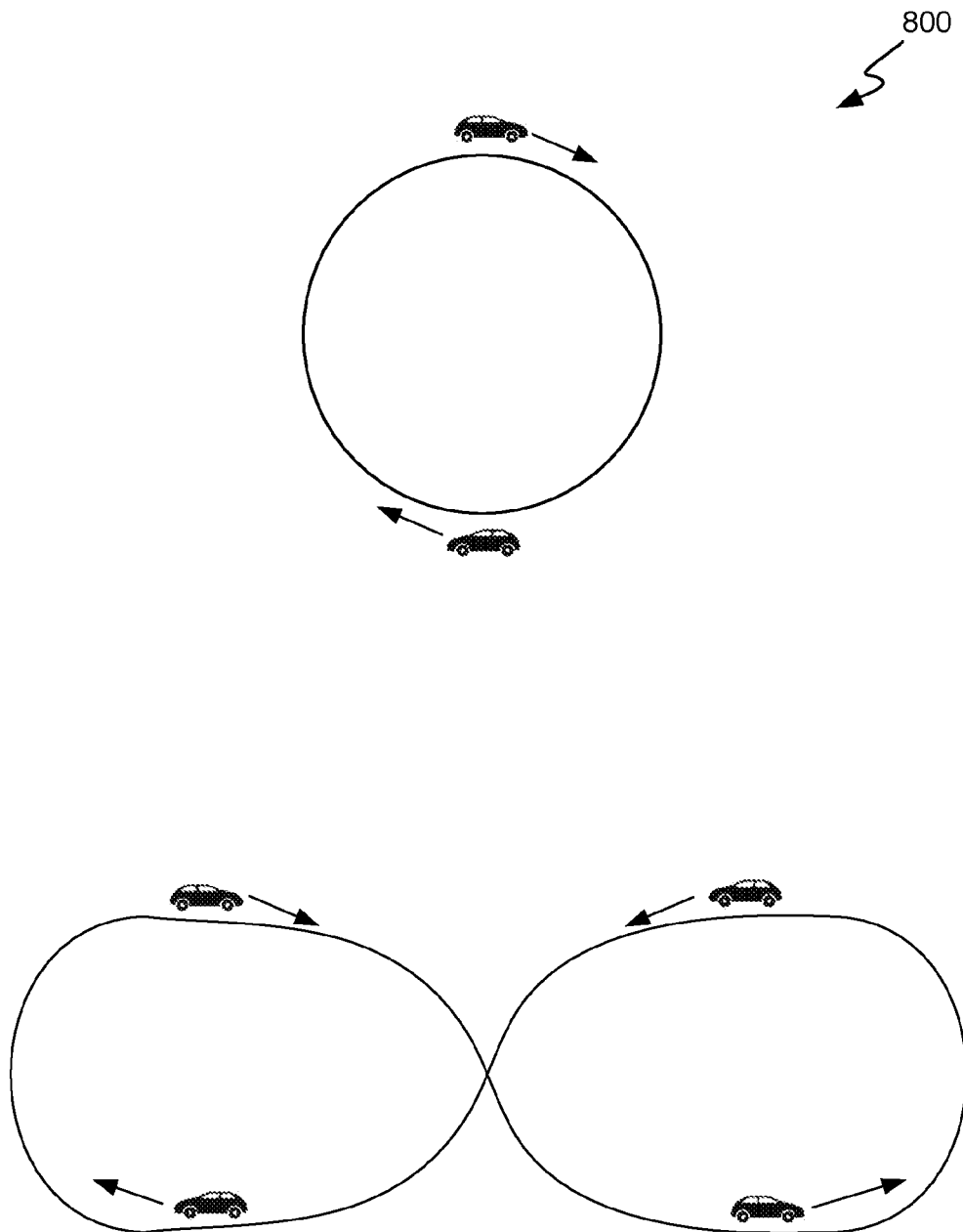


Figure 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2016/050589

A. CLASSIFICATION OF SUBJECT MATTER

G06G 7/78 (2006.01) G01C 25/00 (2006.01) H04B 7/185 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Google scholar: Speedometer correction by GPS; vehicle meter calibration by navigation system and similar related terms.

E-spacenet: Applicant's name search (Transcom R & D Pty Ltd.), Inventor's name search and terms such as vehicle meter, speedometer; odometer and similar related words in the title/abstract

PAMS Nose: Applicant's name search and Inventor's name search.

EPOQUE Internal: WPI and EPODOC: IPC Mark- G06G7/78, G01C 25/00, H04B7/185 and keywords- vehicle?, speed+, correct+, GPS, rotat+, measure and similar related words.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ Further documents are listed in the continuation of Box C

☒ See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 12 September 2016		Date of mailing of the international search report 12 September 2016	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au		Authorised officer Jyoti Shamdasani AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832836	

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including
2. ☒ Claims Nos.: **25-26**
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
See Supplemental Box
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2016/050589
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5828585 A (WELK et al.) 27 October 1998 Entire document including abstract and drawings particularly columns 2, 7-11, 13	1-24
X	US 6087965 A (MURPHY) 11 July 2000 Entire document including abstract and drawings particularly Fig. 2, columns 1-7	1-24
X	JP 2007322323 A (DENSO CORP.) 13 December 2007 Entire document including abstract and drawings particularly paragraphs [0007], [0014], [0016], [0025] - [0029]	1, 9, 17

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2016/050589**Supplemental Box****Continuation of Box II**

The claims do not comply with Rule 6.2(a) because they rely on references to the description and/or drawings.

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2016/050589	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
US 5828585 A	27 October 1998	US 5828585 A	27 Oct 1998
US 6087965 A	11 July 2000	US 6087965 A	11 Jul 2000
		US 5917434 A	29 Jun 1999
JP 2007322323 A	13 December 2007	JP 2007322323 A	13 Dec 2007
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			