Title
Process to detect the motion of a vehicle

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ABSTRACT

This invention pertains to a process to detect the motion of a vehicle as well as to the use of an acceleration sensor in an arrangement to prevent the starting of a vehicle.

The important part here is that a reliable declaration can be made as to whether the vehicle had been driven or not.

In the process to detect the motion of a vehicle, the acceleration forces acting on the vehicle are measured as time-dependent functions and are subjected to a discrete Fourier analysis. If a majority of the determined frequencies are below a preset cut-off frequency, for example 0.3 Hertz, it can be assumed that the vehicle had been driven; otherwise it is a case of inconsequential vibration.

In the use of an acceleration sensor according to the invention in an arrangement to prevent the starting of a vehicle, the process described above is used to reliably verify that the block was circumvented.
Application Number:

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Invention Title:  PROCESS TO DETECT THE MOTION OF A VEHICLE

The following statement is a full description of this invention, including the best method of performing it known to us:
PROCESS TO DETECT THE MOTION OF A VEHICLE

This invention pertains to a process to detect the motion of a vehicle and to the use of an acceleration sensor in an arrangement to prevent the starting of a vehicle.

Interlock systems are installed in vehicles for the purpose of preventing unauthorized starting of the vehicle. Unauthorized starting could occur if a vehicle is stolen or if the operator of the vehicle is under the influence of alcohol, for example. In the latter case, in a vehicle with an interlock system installed the starter can only be activated if the operator has first submitted a breath alcohol test and if the value measured is below a specific limit. Since a breath alcohol test of this type is not supervised as in the breath alcohol tests used in traffic stops by the police, attempts at deception are to be expected in which either the breath alcohol test is circumvented or the vehicle is push-started or started through foreign means, despite the fact that the value measured in the breath alcohol test is above the limit. Attempts such as this break legal regulations, have broad consequences for the parties involved and must therefore be reliably detected or prevented. Current interlock systems monitor the vehicle’s system voltage, for example, including when the vehicle is parked and the ignition is not switched on. However, the only time a sample is required for the breath alcohol test is when switching on the ignition. In this case, the drop in the system voltage that occurs when the vehicle is cranked serves as a criterion as to whether a start has occurred. If a system voltage drop has actually been registered and the breath alcohol test had failed, an entry is made in the interlock system’s memory, which is read out at monthly intervals by a monitoring agency, for example. However, the detection of the system voltage is not a reliable criterion in deciding whether the vehicle has been started or not. This is because the system voltage drop can also be caused by turning on the air conditioner, the radio, windshield wipers or a fan inside the vehicle.

Another possibility of detecting the unauthorized starting of a vehicle is described in US 2002/0039951 A1. Here, an acceleration sensor is used on a motorcycle together with a control device for ignition and for fuel feed. The acceleration sensor also takes gravitational acceleration into consideration and in a preferred embodiment can measure accelerations in two directions.
perpendicular to one another. Signal noise and vibrations to be ignored are removed by a downstream filter.

The object of this invention is to provide a process with which a reliable declaration can be made as to whether a vehicle has been driven or not.

This object is met according to the invention through a process of detecting the motion of a vehicle according to claim 1, and through the use of an acceleration sensor in an arrangement to prevent the starting of a vehicle.

In the process for detecting the motion of a vehicle, the acceleration forces acting on a vehicle are measured as time-dependent functions in a predetermined time interval by an acceleration sensor and forwarded to an evaluation and control unit. There, the time-dependent functions are subjected to a Fourier analysis, also known as a harmonic analysis. In this manner, the associated frequency spectrum can be determined. If a predetermined portion of the frequency spectrum lies below an established cut-off frequency, the evaluation and control unit saves information indicating that the vehicle was driven. If this condition is not met, that is, if the predetermined portion of the frequency spectrum does not lie below the established cut-off frequency, then the evaluation and control unit saves information indicating that the vehicle was not driven.

Advantageous embodiments of the process are the subject of the subordinate claims.

In a preferred embodiment of the process, the acceleration forces acting on the vehicle are measured by the acceleration sensor in at least two directions that are independent of one another. This ensures that one component of the acceleration forces detected is in the horizontal direction. The acceleration sensor can then be installed in the vehicle without having to observe any special spatial orientation.

Depending on whether a continuous or a discrete frequency spectrum is desired, the time-dependent functions of the acceleration forces are subjected to either a continuous or a discrete Fourier transformation. For the purposes of the following evaluation of whether a vehicle was driven or not, a discrete Fourier transform is sufficient and is preferable to a continuous Fourier transform due to its comparatively simpler processing in an evaluation and control unit.
It is advantageous to establish the cut-off frequency used to decide whether the vehicle had been driven or not in relation to the suspension system and weight of the vehicle. For example, 0.3 Hertz is used as the cut-off frequency for a common personal vehicle. In case of a heavier vehicle and in case of a softer suspension, the cut-off frequency is selected correspondingly lower.

The recommended prescribed time interval, within which the acceleration forces acting on the vehicle are measured, in the form of time-dependent functions, is a time frame of between 30 and 60 seconds.

When using an acceleration sensor in an arrangement to prevent the starting of a vehicle, the acceleration forces measured by the acceleration sensor are evaluated by an evaluation and control unit, for example as per the process according to the invention. Independent of this, the evaluation and control unit receives a breath alcohol concentration of an operator, which is measured by a connected handset in the vehicle. Depending on the measured breath alcohol concentration, the evaluation and control unit controls a relay which then interrupts or closes a switching circuit leading to a starter by opening or closing a corresponding switch.

The measured value of the breath alcohol concentration and the measured values of the acceleration forces acting on the vehicle evaluated by the process according to the invention are stored by the evaluation and control unit and made available to be checked at intervals of approximately one month.

An exemplary embodiment of the invention is detailed below with the aid of drawings.

Shown are in:

Figure 1 an arrangement to prevent the starting of a vehicle,

Figure 2 a first temporal plot of acceleration forces acting on a vehicle,

Figure 3 the distribution of the frequencies in a discrete Fourier analysis of the function from Figure 2

Figure 4 a second temporal plot of acceleration forces acting on a vehicle,

Figure 5 the distribution of the frequencies of a discrete Fourier analysis of the function from Figure 4.
In Figure 1, an arrangement to block the starting of a vehicle is shown. The arrangement includes an acceleration sensor 1 that detects the acceleration forces acting on a vehicle in two independent directions. It can thus be installed below the dashboard of a vehicle in any orientation, and horizontal components of acceleration forces are always detected. The measurement of acceleration forces in two directions independent of one another is symbolized by the schematically shown coordinate cross. The values measured by acceleration sensor 1 are continuously forwarded to an evaluation and control unit 2. Two functions are recorded: the temporal plot $g_x(t)$ of the acceleration forces acting on the vehicle in the x-direction and the temporal plot $g_y(t)$ of the acceleration forces acting on the vehicle in the y-direction. Both functions $g_x(t)$ and $g_y(t)$ undergo a Fourier analysis by the evaluation and control unit 2. The Fourier analysis provides information as to which frequencies are involved in the respective acceleration forces. In case of a forward motion of the vehicle, as corresponds to an acceleration or a drive around a curve, most frequency portions of the Fourier analysis lie below 0.3 Hertz. In the case of a bouncing or a slight shaking of the vehicle, vibrations occur to the vehicle that lead to frequencies that in lie largely above 0.3 Hertz. The evaluation as to whether the major portion of frequencies lies above or below a predetermined value, in this example 0.3 Hertz, is performed as follows: the frequencies determined for $g_x(t)$ and for $g_y(t)$ are added. In case of a continuous Fourier analysis, the frequency portion from 0 to 0.3 Hertz would then be integrated, and the portion from 0.3 Hertz and up would be integrated. If, for example, the frequency portion from 0 to 0.3 Hertz constitutes more than 50% of the overall integral, it can be assumed that the vehicle has been driven. If the frequency portion from 0 to 0.3 Hertz constitutes less than 50% of the overall integral, a driving of the vehicle is ruled out. In case of a discrete Fourier analysis with frequencies at constant intervals, the frequency portion from 0 to 0.3 Hertz would be added up as would the portion from 0.3 Hertz and above. If the sum of the frequency portion from 0 to 0.3 Hertz exceeds the sum of the frequency portion from 0.3 Hertz and above, it can be assumed that the vehicle was driven. If, on the other hand the sum of the frequency portion from 0 to 0.3 Hertz is less than the sum of the frequency portion above 0.3 Hertz, an inconsequential vehicle motion is assumed that cannot be attributed to its having been driven.
The arrangement to block the starting of a vehicle is explained below procedurally:

First, the vehicle is started by an operator. To do this, an ignition switch shown in Figure 1 is closed. Then, the evaluation and control unit 2 turns on a handset 8 via line 7. Line 7 supplies power to the handset 8 and facilitates the exchange of data between the handset 8 and the evaluation and control unit 2. The handset 8 is kept easily accessible inside the vehicle and can be moved. A breath alcohol sample is submitted by the operator through a mouthpiece 9 attached to the handset. If the alcohol concentration of the breath alcohol sample is below a prescribed limit, a relay 3 is turned on by the evaluation and control unit 2 and a switch 5 is closed (shown as open in Figure 1) so that a starter 4 can be started.

The evaluation and control unit 2 of the arrangement to block the starting of a vehicle receives and processes both the signals from the handset 8 as well as those of the acceleration sensor 1. The signals are evaluated, stored and in general read out at monthly intervals to a corresponding monitoring agency. If it is found in the process that a breath alcohol sample was above a prescribed limit but the acceleration sensor had shortly thereafter measured acceleration forces that indicate, through subsequent Fourier analysis, that most of the frequency portions lay in the range between 0 and 0.3 Hertz, it must be assumed that the vehicle had been driven even though the breath alcohol sample tested positive. This can have broad consequences for the operator of the vehicle. This shows clearly that the determination of whether the vehicle had been driven or had only been subjected to minimal inconsequential shaking must be highly reliable.

A first temporal plot $g_{x1}(t)$ of the acceleration forces acting on a vehicle is plotted in Figure 2 in one direction $x$ of the two independent directions measured by the acceleration sensor 1 in Figure 1. The time interval plotted on the abscissa is 40 seconds, indicated in steps of 5 seconds each. Plotted on the ordinate are the measured acceleration forces in meters per second squared. The two horizontal strips in Figure 2 correspond to $1 \text{ m/s}^2$ (meters per second squared), indicated by the double vertical arrow.

Figure 3 represents the distribution of frequencies of a discrete Fourier analysis of function $g_{x1}(t)$ from Figure 2. The frequency level is plotted on the
abscissa in Hertz. A step size of 0.02 Hz (Hertz) was selected. The dimensionless amplitude of each respective frequency is indicated on the ordinate. The vertical line at 0.3 Hz marks the cut-off point for the decision of whether a forward motion of the vehicle had taken place. This is the case here since the majority of the frequencies are less than 0.3 Hz. Thus, this is not a case of some inconsequential, minimal shaking. If it were, the majority of the frequencies would be above 0.3 Hz.

Figure 4 shows a second temporal plot $g_{x2}(t)$ of the acceleration forces acting on a vehicle plotted in the same manner as in Figure 2. Here as well, 40 seconds are recorded on the abscissa at a step size of 5 seconds. Also plotted on the ordinate are the acceleration forces in meters per second squared. However, in this case, the two horizontal strips correspond to $0.2 \text{ m/s}^2$, shown by way of a double vertical arrow.

Figure 5 shows the distribution of frequencies of a discrete Fourier analysis of function $g_{x2}(t)$ in Figure 4. Here, as in Figure 3, the frequency is plotted on the abscissa with a step size of 0.02 Hz. The dimensionless amplitude of the respective frequency is indicated on the ordinate. The majority of the frequencies is above 0.3 Hz here, that is, to the right of the vertical boundary line at 0.3 Hz. In this case, a bouncing of the vehicle is assumed, but no forward motion.
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process to detect the motion of a vehicle, characterized by the following steps:
   1.1 the acceleration forces acting on the vehicle are measured within a prescribed time interval by an acceleration sensor (1) as time-dependent functions and forwarded to an evaluation and control unit (2),
   1.2 the evaluation and control unit (2) determines a frequency spectrum for each of the functions through a Fourier analysis,
   1.3 if a preset portion of the frequency spectrum is below an established cut-off frequency, the evaluation and control unit (2) saves information indicating that the vehicle had been driven, and if the preset portion of the frequency spectrum is not below the established cut-off frequency, the evaluation and control unit (2) saves information indicating that the vehicle had not been driven.

2. A process according to claim 1, characterized in that the acceleration forces from step 1.1 acting on the vehicle are measured by the acceleration sensor (1) in at least two directions that are independent of one another.

3. A process according to claim 1 or 2, characterized in that in step 1.2, the frequency spectrum is determined using a discrete Fourier analysis.

4. A process according to one of the previous claims, characterized in that in step 1.3 the cut-off frequency is established in relation to the suspension system and weight of the vehicle.

5. Use of an acceleration sensor in an arrangement to block the starting of a vehicle comprising
   5.1 an evaluation and control unit (2) to evaluate the acceleration forces acting on the vehicle and measured by the acceleration sensor (1),
   5.2 a handset (8) connected to the evaluation and control unit (2), through which the breath alcohol concentration of an operator is measured and forwarded as a signal to the evaluation and control unit (2),
5.3 a relay (3) operated by the evaluation and control unit (2) that, depending on the signal, either opens or closes a switching circuit to a starter (4) by opening or closing a switch (5).

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Fig. 2

The graph shows a time series of acceleration $g_x(t)$, with time $t$ in seconds ($s$) on the x-axis and acceleration in $m/s^2$ on the y-axis. The data points are connected by a line, and a vertical line indicates a range of 1 unit on the y-axis. The graph indicates fluctuations in acceleration over time.
Fig. 3
Fig. 4.
Fig. 5