

**System for determining the position of a vehicle, vehicle
therewith, and method therefor**

The present invention relates to a system for
5 determining the position of a vehicle.

The invention further relates to a vehicle
comprising such a system.

The invention also relates to a method for
determining the position of a vehicle.

10 Systems for determining the position of a vehicle
are known for many years. One such known system makes use of
a grid of magnets that is provided in the surface whereon
the vehicle moves. The system comprises a plurality of
sensors that are able to sense the strength of a magnetic
15 field. The plurality of sensors is arranged in a lateral
direction of the vehicle, in order to ensure that a magnet
arranged in the ground surface is detected when the vehicle
passes over the magnet. The signals from the sensors are
periodically sampled and provided to computation means to
20 calculate the position of the sensed magnet with respect to
the sensors. The described detection of magnets is usually
not sufficient to determine the position, as individual
magnets can normally not be distinguished from each other.
Therefore, in one prior art system, rotational counters are
25 installed on at least two wheels to keep track of the wheel
rotation in order to determine a position change and
therewith the position. The detection of the magnets
prevents the occurrence of an accumulation of errors in the
determination of the position and therefore position drift.

30 A drawback of this known system is that when the
vehicle negotiates a bend, the sensors at the outer side of
the bend are undersampling the magnetic field strength,
while the sensors at the inner side of the bend are

oversampling the magnetic field strength. Although the latter causes less problems with the processing power available to present day digital signal processors, the former causes a deterioration of the accuracy of the determined position when the vehicle negotiates a bend.

The object of the present invention is to provide a system for determining the position of a vehicle, wherein the deterioration of the accuracy when the vehicle negotiates a bend, is substantially less compared to the described prior art.

This object is realised by the present invention by providing a system for determining the position of a vehicle comprising: a plurality of sensors for measuring the magnetic field strength of a magnet; computation means for determining the position of the magnet with respect to the plurality of sensors; wherein the plurality of sensors are arranged in a two-dimensions array.

In the system according to the prior art, the acquisition of samples from the sensors is fixed in time and the position of the samples in the space domain is depend on and varies with the movement of the vehicle. In the present embodiment the plurality of sensors no longer solely serve to prevent missing a magnet when a magnet passes underneath the vehicle off-centerline, but serves to take a complete snapshot in two-dimensional space of the magnetic field of the magnet. To this end it is preferable that the array of sensors is arranged substantially parallel to the surface comprising the magnets, when the system is in use. This way determining the position of the magnet with respect to the sensors does not depend on any time related sampling rate and therefore the movement of the vehicle, but solely on the sensor arrangement. Because the determining of the position is independent of the vehicle movement, also the accuracy of

the determined position is independent of the vehicle movement. This way undersampling and oversampling can not occur, not when travelling in a substantially straight line, nor when negotiating a bend. The accuracy (for determining a
5 single position) is fixed by the sensors' arrangement.

In a further embodiment, the present invention provides a system, wherein the sensors are evenly interspaced in both dimensions. This way the samples are evenly spaced.

10 According to another embodiment, a system is provided, further comprising means for fitting the magnetic field strengths measured by the plurality of sensors to a spatial model of the magnetic field of a magnet. Although computationally expensive, fitting the acquired magnetic
15 field strengths to a spatial model of a magnet, results in high accuracy positions.

In a further embodiment, the present invention provides a system, wherein the sensitivity of the sensors for a magnetic field component perpendicular to the plane
20 wherein the plurality of sensors are arranged is substantially higher than the sensitivity for magnetic field components parallel to this plane. Such an embodiment has the advantage that inaccuracies due to spatial variations in the earth's magnetic field are minimised, as this
25 perpendicular component can be considered constant within a typical action radius of a surface bound vehicle. In a further embodiment, the system estimates a constant background magnetic field and compensates during the measurement of the magnets for this constant background
30 field. This background field may constitute a magnetic field caused by components of the vehicle itself, but also a remaining perpendicular component of the measured magnetic field of the earth.

In again a further embodiment, the present invention provides a vehicle comprising a system as described above.

In a further embodiment, the system is arranged
5 such that the positions of multiple magnets are determined from a single measurement by the two-dimensional array of sensors. In order for this feature to be advantageous, the magnets in the surface are to be arranged sufficiently close in order for the array to detect at least part of the
10 magnetic fields of the multiple of magnets.

In again a further embodiment, the system is arranged to decode information that is coded by means of a mutual arrangement of a group of magnets in the surface and/or the polarity of the individual magnets in a group of
15 magnets. To that end, it is preferred to arrange the magnets in clusters, wherein each cluster of magnets provides position information or for deriving position information analogous to the description of the previous embodiments, and wherein the arrangement of magnets in the cluster and/or
20 the polarity of magnets in the cluster provides additional information, either additional positional information, or non-positional information. In one particular embodiment, position coordinates are directly encoded in the mutual arrangement. However, in a preferred alternative
25 arrangement, the mutual arrangement encodes for a key for a lookup table that is stored in the vehicle. In accordance with another aspect of the present invention, a method is provided for determining a position of a vehicle, comprising the steps of: acquiring from a plurality of
30 sensors, the magnetic field strengths measured by the sensors; determining the position of a sensed magnet with respect to the plurality of sensors; wherein the plurality of sensors are arranged in a two-dimensional array.

According to another aspect of the invention a method is provided, wherein the position of a sensed magnet is determined by fitting the acquired magnetic field strengths to a spatial model of the magnetic field of a magnet.

Further embodiments and advantages thereof will be described below with reference to the accompanying drawings, wherein:

Figure 1 shows a vehicle according to the present invention.

Figure 2 shows a system according to the present invention that is comprised in the vehicle of figure 1.

Figure 3 shows a hierarchy for data-processing produced by a system according to the present invention.

A surface suitable for a vehicle 12 (figure 1) to drive on is provided with magnetic marker elements 14. The vehicle 12 comprises a plurality of magnetic sensors 20 (figure 2), arranged in two dimensions, forming an array 10 of magnetic sensors.

When a magnetic marker element 14 passes under a certain minimum number of sensors 20, the position of the vehicle 12 relative to the magnetic marker element 14 can be estimated. The minimum number of sensors required can be obtained by means of, for example, the Fisher Information Matrix. The magnetic field generated by the magnetic marker element 14 is sensed in one or more of the magnetic sensors 20. The magnetic sensors 20 are connected to a digital signal processor (DSP) 24. The DSP 24 fits the signals coming from the magnetic sensors 20 to a 3-dimensional model of the magnetic field of a magnetic marker element 14. From the fitted model, the position of the magnetic marker element 14 is obtained relative to the array 10 of magnetic sensors. Consequently, from a known position of a magnetic

marker element 14, the position of the vehicle 12 is obtained, which is done by the navigation computer 26.

The position of the magnetic marker elements 14 is shown in figure 1 as a grid-like pattern. For the present:
5 invention, it is not necessary for the pattern of magnetic marker elements 14 to be grid-like. It is sufficient if the position of the magnetic marker elements 14 is known. A regular pattern like the grid-like pattern in figure 1 is advantageous though, as no position of individual marker
10 elements need to be stored, as the positions are easily derivable from the pattern. In one particular embodiment the vehicle travels along a predetermined path, and the grid is a one dimensional grid that extends along the predetermined path.

15 The pattern of the magnetic sensors 20 is not bound to any specific pattern either. In principle, the pattern could be random, as long as the position estimation algorithm takes the location of the individual magnetic sensors 20 within the array into account.

20 The hierarchical functionality 30 provided by the DSP 24 and the navigation computer 26 is the following (figure 3): the lowest level is the IO level 32. The IO level 32 is responsible for obtaining the magnetic field strength readouts from the sensors 20.

25 In the next level, the scanner level 34, a position within the array 10 of sensors 20 is associated with each individual magnetic field strength measurement. As these positions are fixed in two-dimensions, this activity is rather straightforward in contrast to the embodiments
30 from the prior art, that only employ magnetic sensors in a single dimension, as time does no longer play a role.

Subsequently, the set of magnetic field strength positions is fitted in a fitter-level 36 to a 3-dimensional

model of a magnetic marker element 14. This results in an estimated position of the magnetic marker element 14 relative to the array 10 of sensors 20.

5 Finally, the estimated relative position of the magnetic marker element 14 is used in the last level, the coding level 38, to determine the position of the vehicle 12. In one particular embodiment the position is related to a particular moment in time, for example as a time elapsed since the occurrence of a time synchronisation signal.

10 It should be noted that the embodiments shown and described only serve as example embodiments of the invention, and that the invention is not limited to these embodiments. Many modifications of and variations on the embodiments shown and described are possible without
15 departing from the scope of the present invention. For example, it is without limitation, possible to combine embodiments shown and described. The scope of protection sought is therefore only determined by the following claims.

Claims

1. System comprising:

- 5 - a vehicle comprising a positioning determining system, said positioning determining system comprising:
- a plurality of sensors for measuring the magnetic field strength of a magnetic marker element;
 - computation means for determining the position
 - 10 of the sensed magnetic marker element with respect to the plurality of sensors;
- wherein
- the plurality of sensors are arranged in a two dimensional array;
- 15 wherein
- said computation means is configured for:
 - obtaining the magnetic field strength measurements from the plurality of sensors;
 - associating a position within the array of
 - 20 sensors with each individual magnetic field strength measurement;
 - fitting the set of magnetic field strength measurements and associated positions to a spatial model of the magnetic field of a magnetic marker
 - 25 element; and
 - determining the position of the sensed magnetic marker element with respect to the plurality of sensors; and
 - multiple individual magnetic marker elements
 - 30 provided in a surface suitable for said vehicle to drive on;
- wherein

- the positions of multiple magnetic marker elements are determined from a single measurement by the two-dimensional array of sensors,

wherein hierarchical functionality provided by a Digital
5 Signal Processor (DSP) and a navigation computer is the following:

a first level which is the Input/Output (IO) level, wherein the first level is responsible for obtaining the magnetic field strength readouts from the array of sensors,

10 a second level, wherein a position within the array of sensors is associated with each individual magnetic field strength measurement,

a third level, wherein the set of magnetic field strength positions is fitted in a fitter-level to
15 a 3-dimensional model of a magnetic marker element, this resulting in an estimated position of the magnetic marker element relative to the array of sensors,

wherein the estimated relative position of the magnetic marker element is used in a fourth level,
20 to determine a position of the vehicle.

2. System according to claim 1, wherein the sensors are evenly interspaced in both dimensions.

25 3. System according to any of claims 1 or 2, wherein the sensitivity of the sensors for a magnetic field component perpendicular to the plane wherein the plurality of sensors are arranged is higher than the sensitivity for magnetic field components parallel to this plane.

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4. System according to any of claims 1 to 3, wherein the positioning determining system is arranged to decode

information that is coded by means of a mutual arrangement of a group of magnetic marker elements in the surface and/or the polarity of the individual magnetic marker elements in a group of magnetic marker elements.

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5. System according to any of claims 1-4,
wherein

- the position of the magnetic marker elements is
a grid-like pattern.

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6. Method for determining a position of a vehicle,
comprising the steps of:

- acquiring from a plurality of sensors
arranged in a two-dimensional array, the magnetic field
15 strengths of a magnetic marker element measured by the
sensors;

- associating a position within the array of
sensors with each individual magnetic field strength
measurement;

20 - fitting the set of magnetic field strength
measurements and associated positions to a spatial model of
the magnetic field of a magnetic marker element; and

- determining the position of said magnetic marker
element with respect to the plurality of sensors
25 on the basis of the set of magnetic field strength
measurements and associated positions fitted to said spatial
model of the magnetic field of a magnetic marker element.

7. Method according to claim 6,
30 further comprising the step of:

- determining the position of said vehicle
using said determined position of the sensed magnetic marker

element with respect to the plurality of sensors.