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(54) Benævnelse: **FREMGANGSMÅDE OG ANORDNING TIL BESTEMMELSE AF ET BEVÆGELIGT OBJEKTS POSITION, SAMT SYSTEM DER OMFATTER ANORDNINGEN**

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METHOD AND DEVICE FOR DETERMINING A POSITION OF A MOVABLE OBJECT AND SYSTEM COMPRISING THE DEVICE

Technical Field

Exemplary embodiments relate to the determination of the position of movable objects. In particular, exemplary embodiments relate to a method for determining a position of a movable object, an apparatus for determining a position of a movable object and a system comprising the above apparatus.

Background

In many fields of application, it is required to know the position of a movable object and/or to be able to determine the same.

In logistics, for example, it may be required to know and/or determine the location of the access of a picker into a rack. A check may thus be performed as to whether the picker has taken goods from the correct rack shelf and/or onto what rack shelf if has placed goods.

Determining a position of a movable object may also be required in the field of sports, for example in order to know and/or determine the position of a gaming device. For example, it may be required to determine whether a ball and/or a puck crossed a goal line or whether a player is in a certain area of the playing field (e.g., in order to detect a goalmouth offside in the case of ice hockey).

Likewise, the position of a movable object may be required in generating virtual realities in order to detect a position, an orientation, and/or a movement of a user in the real environment and to take these into account in the representation of the virtual reality.

Methods for determining the position of objects are described, for example, in printed publications EP 2 813 114 A1, US 2014/266164 A1, US 2010/022904 A1, US 6 789 043 B1, US 7 139 582 B2, US 6 316 934 B1, CN 105 222 772 A, and US 2010/271012 A1.

A need exists to provide an additional possibility for determining the position of a movable object.

Summary

Exemplary embodiments of a method for determining a position of a movable object make this possible. The method according to independent method claim 1 comprises the generation of an electromagnetic exciter field. The electromagnetic exciter field is configured to excite the movable object in order to establish a magnetic response field.

Furthermore, the method comprises determining a plurality of measurement values for the magnetic response field by measuring the magnetic response field at a plurality of predetermined measuring positions. Furthermore, the method comprises determining the position of the movable object based on a comparison of the plurality of measurement values with reference measurement values. Here, one position of the movable object is associated with each of the reference measurement values. Furthermore, the reference measurement values are each determined by means of a simulation.

Further exemplary embodiments relate to an apparatus for determining a position of a movable object. The apparatus according to independent device claim 19 comprises an exciter module that is configured to generate an electromagnetic exciter field. The electromagnetic exciter field is configured to excite the movable object in order to develop a magnetic response field. Furthermore, the apparatus comprises a measurement module that is configured to determine a plurality of measurement values for the magnetic response field by measuring the magnetic response field at a plurality of predetermined measuring positions. The apparatus further comprises an evaluation module that is configured to determine the position of the movable object based on a comparison of the plurality of measurement values with reference measurement values. Here, one position of the movable object is associated with each of the reference measurement values. Furthermore, the reference measurement values are each determined by means of a simulation.

Additionally, further embodiments relate to a system according to claim 20 comprising at least a movable object and abovementioned apparatus for determining a position of a movable object. The movable object is configured so as to develop a magnetic response field as a reaction to an electromagnetic exciter field.

Brief description of the figures

Exemplary embodiments are explained in greater detail with reference to the accompanying figures, in which:

Fig. 1 shows a flowchart of an exemplary embodiment of a method for determining a position of a movable object;

Figs. 2a and 2b show an exemplary embodiment of an approximation of a conductor loop;

Fig. 3 shows an exemplary embodiment of a system with a movable object and an apparatus for determining a position of the movable object;

Fig. 4 shows a further exemplary embodiment of a system with a movable object and an apparatus for determining a position of the movable object from the field of logistics; and

Fig. 5 shows yet another exemplary embodiment of a system with a movable object and an apparatus for determining a position of the movable object from the field of sports.

Description

Various exemplary embodiments will now be described with reference to the accompanying drawings, in which some exemplary embodiments are illustrated. In the figures, the thicknesses of lines, layers, and/or regions may be exaggerated for clarity.

Like numbers refer to like or similar components throughout the following description of the appended figures, which merely show some exemplary embodiments. Moreover, summarizing reference symbols will be used for components and objects which occur multiple times in one exemplary embodiment or in one figure but are described at the same time in relation to one or more features. Components and objects that are described with like or summarizing reference signs can be implemented in the same manner or also differently, if applicable, in relation to one or more or all of the features (e.g., their dimensioning) unless explicitly or implicitly stated otherwise in the description.

Although exemplary embodiments can be modified and changed in different ways, exemplary embodiments are illustrated as examples in the figures and are described herein in detail. It should be noted, however, that it is not intended to restrict embodiments to the respectively disclosed forms; rather, exemplary embodiments are intended to cover any and all functional and/or structural modifications, equivalents, and alternatives that fall within the scope of the invention. Same reference numerals designate same or similar elements throughout the complete description of the figures.

Note that an element that is referred to as being “connected” or “coupled” to another element may be directly connected or coupled to the other element, or intervening elements may be present.

The terminology used herein only serves for the description of specific exemplary embodiments and is not intended to limit the exemplary embodiments. As used herein, the singular form such as “a,” “an,” and “the” also include the plural forms insofar as the context does not clearly indicate otherwise. It is also clarified that terms such as “comprises,” “comprising,” “includes,” and/or “including,” as used herein, specify the presence of the stated features, integers, steps, operations, elements, and/or components but do not preclude the presence or addition of one and/or more other features, integers, steps, operations, elements, components, and/or any group thereof.

Unless otherwise defined, all terms (including technical and scientific terms) are used herein in the ordinary meaning attributed to them by a person of ordinary skill in the art to which the exemplary embodiments belong. It is further clarified that terms — e.g., those which are defined in widely used dictionaries — are to be interpreted to have the meaning that is consistent with the meaning in the context of the relevant technology insofar as not expressly defined otherwise herein.

Fig. 1 shows a method 100 for determining a position of a movable object. The method 100 comprises generating 102 an electromagnetic exciter field. The electromagnetic exciter field is configured to excite the movable object in order to develop a magnetic response field. Furthermore, the method 100 comprises determining 104 a plurality of measurement values for the magnetic response field by measuring the magnetic response field at a plurality of predetermined measuring positions. Furthermore, the method 100 comprises determining 106 the position of the movable object based on a comparison of the plurality of measurement values with reference measurement values. In this context, one position of the movable object is associated with each of the reference measurement values. Furthermore, the reference measurement values are each determined by means of a simulation.

The method 100 can enable a localization of the movable object in real time. Based on the determination of the reference measurement values by means of a simulation, both a time requirement and also a complexity for generating the reference measurement values may be reduced. In particular, it is possible to react to changes in the environment and/or in the movable object quickly and with little effort by updating the reference measurement values by means of an adapted simulation. Complex measurements for determining the reference measurement values can be avoided.

The movable object can be any movable object that can move in space and/or develop and/or generate a magnetic response field in reaction to an electromagnetic exciter field. For example, the movable object can be and/or comprise a coil and/or a coil system. For example, the movable object may be a piece of clothing (e.g., shoe, jacket, trousers, shirt, glove, head cover), an accessory item (e.g., necklace, bracelet, belt, glasses), a gaming device (e.g., ball, puck, bowl, football) or sports equipment (e.g., helmet, glove, trainers, racket, protective equipment) comprising a component (element, device) that can develop and/or generate a magnetic response field in reaction to an electromagnetic exciter field. For example, the movable object may be a wristband, a ball, a puck, a glove, a shoe or a trainer comprising a coil and/or a coil system.

The electromagnetic exciter field can be any electromagnetic field that can excite the movable object in order to develop a magnetic response field. For example, the electromagnetic exciter field can be an alternating magnetic field. An alternating magnetic

field can, for example, be generated by means of coils or conductor loops through which AC current flows. The electromagnetic exciter field can comprise one or more frequency components. Furthermore, a frequency of the electromagnetic exciter field can vary.
The plurality of measurement values for the magnetic response field are represented by states of the magnetic response field at the plurality of predetermined measuring positions. For example, the plurality of measurement values can indicate the respective strength of the response field at the plurality of predetermined measurement positions. The plurality of predetermined measurement points comprises two or more known measurement points for the magnetic response field. The number of measurement points can be selected as a function of a desired dimension or a desired accuracy of the position of the movable object to be determined. For example, the magnetic response field can be measured at two, three, four, five, or more different positions. In order to measure the magnetic response field, one or more receive antennae can be arranged at one measurement position, for example. A voltage that is induced in the receive antenna is proportional to the local strength of the magnetic response field at the measurement position.
The comparison of the plurality of measurement values with reference measurement values can be achieved, for example, by comparing the measurement values with reference measurement values stored in a table. To achieve this, a similarity or a match between a measurement value and the reference measurement values can be determined, for example. Based on the comparison results, for example, the position of the movable object associated with a reference value can be determined to be the position of the movable object, or a combination of a plurality of positions of the movable object associated with the reference measurement values can be determined to be the position of the movable object. A reference value and its allocated position of the movable object can, for example, be stored as a tuple of two in a table. Accordingly, the comparison of the plurality of measurement values to reference measurement values can, for example, include searching a table.
As the reference measurement values are each determined by means of a simulation, both a time requirement and also a complexity for generating the reference measurement values can be reduced. Complex measurements for determining the reference measurement values can be avoided. Likewise, updated reference values can be generated by adapting the simulation and/or simulation parameters.
In some exemplary embodiments, further an orientation of the movable object can be associated with each of the reference measurement values. This can facilitate the

determination of an orientation of the movable object in addition to the position of the movable object. This enables the position of the movable object in space to be determined more accurately. By using a simulation, the determination of the reference measurement values can be substantially simplified as changes of the orientation of the object only require an adaptation of the simulation parameters. Complex measurements for determining the reference measurement values for different orientations can thus be avoided.

For example, in some exemplary embodiments, one of the reference measurement values can be determined through the simulation based on a geometry of an exciter system used for generating the electromagnetic exciter field, and/or a geometry of a response system used for emitting the magnetic response field, and/or a geometry of a measurement system used for measuring the magnetic response field and/or an impedance of the response system. The geometries (set-ups, structures) of the exciter system, the response system, and the measurement system, as well as the impedance of the response system fundamentally determine the characteristics of the magnetic response field at the plurality of measurement points. Knowing the abovementioned parameters can thus enable an exact and/or detailed simulation of the magnetic response field. Accordingly, realistic reference measurement values can be generated for the positional determination of the movable object.

The basis for the comparison can be a fingerprint table with the reference measurement values, for example. In that case, the reference measurement values form the characteristic “fingerprint” of the movable object at a certain position and/or in a certain orientation in space. The basis for a fingerprint-based localization can thus be a table that allocates measurable characteristics to each position and/or orientation. This table is generated in advance. In the case of the technology presented here, the table can, for example, contain the three-dimensional position of a coil system in space and optionally its orientation. The allocated field strengths of the secondary field (i.e., the magnetic response field) measured in the receive antennas (forming the measurement system) can, for example, be associated with this position and orientation tuple. Traditionally, fingerprint tables are calibrated. However, that requires time-consuming and complex measurement actions which must be carried out again each time there is a change in the configuration of the system. The advantage of the method presented here is the simulative generation of the fingerprint table. Here, for a known configuration of the exciter coil of the primary field (i.e., for the exciter system of the electromagnetic exciter field), of the coil system (i.e., the response system), and the receive antennas (i.e., the measurement system), the configuration parameters need only be entered into a simulation software and the simulation software automatically generates a fingerprint table. The parameters are, for example, the geometric shapes of the exciter (i.e., for the exciter system), the coils, and the receive antennas. In addition, the impedance of the coil can be taken into account for the simulation.

The primary field (i.e., the electromagnetic exciter field) can be calculated, for example, via the magnetic vector potential $\vec{A}(P)$ at the place P according to the following formulae (1) and (2):

$$\overrightarrow{A_\iota}(\overrightarrow{r_P}) = \frac{\mu_0 I}{4\pi} \cdot (\overrightarrow{q_{\iota+1}} - \overrightarrow{q_\iota}) \int_0^1 \frac{1}{r(\overrightarrow{x_\iota}(t))} dt \qquad (1)$$

$$\vec{A}(P) = N \cdot \sum_{i=0}^{n} \overrightarrow{A_\iota}(P) \qquad (2)$$

As is shown in **Figs. 2a and 2b**, it is possible, for example, for any current-carrying conductor loop 200 (serving as an exciter and/or exciter system) to be divided into any number of small straight conductor pieces 210, 220, 230, 240, 250, 260, 270 in order to thus approximate randomly shaped conductors. Formula (1) can now be applied to every single conductor piece 210, 220, 230, 240, 250, 260, 270. The sum of the individual amounts then, according to formula (2), results in the overall magnetic vector potential $\vec{A}(P)$ at the place P.

In order to now be able to calculate the voltage on the basis of a primary alternating field (i.e., the electromagnetic exciter field) in a randomly shaped, randomly oriented, and randomly positioned coil in space, the magnetic vector potential calculated according to formula (2) can be integrated according to the following formula (3) via the contour of the coil:

$$U_{ind} = -N \cdot 2\pi f \cdot \oint_{\partial F} \vec{A} \cdot d\vec{s} \qquad (3)$$

Here, too, approximations of the coil by straight conductor pieces can be used if necessary. Here, N represents the number of windings of the coil and f the frequency of the alternating field (i.e., of the electromagnetic exciter field).

It is also possible to calculate the current I through the coil via the impedance Z of the coil according to the following formula (4):

$$I = \frac{U_{ind}}{Z} \qquad (4)$$

Analog methods can be used to calculate the magnetic vector potential of the coil field (i.e., of the magnetic response field) and, from that, the voltages induced in the receive antennas.

In the case of mathematically closed, writable geometries such as ellipses for exciters, coils, or antennas, analytic formulas can also be used when calculating the generated vector fields and the induced voltages. These can be rotated into the correct orientation by means of vector field transformations such as quaternions or rotation matrices.

The calculated induced voltages in the receive antennas calculated in this manner are associated with the allocated positions and/or orientations of the coil system in the fingerprint table. This table is used for the localization. The position and/or orientation grid of the simulated points can depend on the application.

During localization, for example, the field currently being measured with the receive antennas is then measured at different predetermined positions in space (receive antenna positions, i.e., the plurality of predetermined measuring positions) and compared to entries in the fingerprint table.

According to some exemplary embodiments, determining 106 the position of the movable object can, for example, comprise determining a similarity of one of the plurality of measurement values to one of the reference measurement values according to a predetermined metric. The similarity here indicates to what extent a measurement value corresponds to one of the reference measurement values. The Euclidian metric can be used as a metric, for instance. Alternatively, other metrics can also be used for the comparison. For example, if the distribution of errors in the measurement signal is known (e.g., a Gaussian distribution), a Gaussian distribution can be used as a (distance) metric and provide better results.

Accordingly, in some exemplary embodiments, determining 106 the position of the movable object can further comprise determining the one position of the movable object that is associated with a reference value as the position of the movable object whose reference value has the greatest similarity to the plurality of measurement values according to the metric. In other words: The position of the movable object associated with the most similar reference measurement value can be determined to be the position of the movable object.

If the Euclidian distance is used as a metric, for example, the position of the movable object can be determined according to the following formula (5):

$$argmin \sum_{i=1}^{a} \left(U_{sim,i} - U_{mess,i}\right)^2 \qquad (5),$$

where a is the number of used measurement antennas, $U_{mess,i}$ indicates the measured voltage in the antenna i, and $U_{sim,i}$ is the simulated voltage for the antenna i in the table. According to formula (5), the entry in the table with the smallest Euclidian distance is ascertained (selected) to be the estimated position and/or orientation.

Alternatively, in some exemplary embodiments, determining 106 the position of the movable object can further comprise determining a number of reference values which have the greatest similarity to the plurality of measurement values according to the metric. Furthermore, determining 106 the position of the movable object can, in some embodiments, further comprise determining a weighted average value of the positions of the movable object associated with the number of the reference values as the position of the movable object. In other words: Also a weighted average value can be determined from a number of entries in the table with the smallest distance to the measurement values.

A weighted k-nearest localization method can be used for this purpose, for example.

During the localization, not only the entry with the smallest Euclidian distance is outputted as an estimate, but rather a weighted average value is formed from the k entries with the smallest distance. The distance d can, for example, be determined according to the following formula (6):

$$d = \sum_{i=1}^{a}\left(U_{sim,i} - U_{mess,i}\right)^2 \qquad (6)$$

Weightings w_n can be allocated to the k most similar entries in the database — that is, to the entries with the smallest distance between the measured antenna voltages and the antenna voltages stored in the table, for instance — according to the following formula (7), for example:

$$w_n = \frac{d_k - d_n}{d_k - d_1}, n = 1 \dots k \qquad (7)$$

w_n represents the weight of the n-nearest table entry (i.e., the reference measurement value with the n-nearest similarity), w_1 represents the weight for the table entry with the smallest Euclidean distance, and w_k represents the weight for the entry within the k entries with the greatest distance.

In some exemplary embodiments, a weighting of a position of the movable object that is associated with one of the number of reference values can thus be based on the similarity of the one of the number of reference values to the plurality of measurement values.

The averaged, estimated position $\bar{x}$ can, for example, be determined according to the following formula (8):

$$\bar{x} = \frac{\sum_{n=1}^{k} x_n w_n}{\sum_{n=1}^{k} w_n} \qquad (8)$$

There, x_n indicates the estimated position in space of the object to be localized for the n-th entry within the k most similar entries.

Using this method, positions can be estimated which are not within the grid of the table. Thus, an interpolation effect can be achieved which increases the accuracy of the

positional estimate far beyond the grid of the table. For that reason, the position grid in the simulation of the table can be selected coarser than in the embodiments represented above, for example. This means that an exact localization can be acquired without simulating a very fine grid at positions with many table entries. This can shorten a simulation period, reduce a memory occupancy of the table, and shorten a search in the table in the actual localization. Real-time localization can thus be made possible. A weighted k-nearest localization method can thus simultaneously enable an increase of the localization accuracy and a size reduction of the table to be achieved.
Among other things, the computing time in localization can be reduced substantially, since a smaller table has to be searched. Making the grid coarser brings about a cubic decrease in the size of the table. Thus, the time duration of the search within the table can be reduced cubically during the localization process, which can make real-time localization possible while at the same time offering the advantage of increased localization accuracy.
Depending on the distance metric, the weighting can typically be linear here. If a non-linear distance metric is used, or if the measurement values are non-linear, non-linear weighting can also be advantageous here. This can improve localization.
Due to interference or noise processes, erroneous position values can also be estimated in isolated cases. As a result of such erroneous estimates, the position of the object cannot be estimated in a stable manner and might jump to and fro between far-apart positions. In some exemplary embodiments, determining 106 the position of the movable object thus further comprises filtering a candidate for the position of the movable object using a Kalman filter. The Kalman filter is based on a movement model for the movable object. The movement model describes an ordinary (usual) movement of the movable object. The Kalman filter can enable the interference to be removed.
In some exemplary embodiments, filtering the candidate for the position of the movable object can, for example, comprise determining, using the movement model, a predicted position of the movable object based on previously determined positions of the movable object. Furthermore, filtering the candidate for the position of the movable object can comprise comparing the predicted position of the movable object to the candidate for the position of the movable object.
Filtering the candidate for the position of the movable object can further comprise, for example, discarding the candidate for the position of the movable object if a difference between the predicted position of the movable object and the candidate for the position of the movable object is greater than a threshold value.

In other words: A (standard) Kalman filter can be used which is based on a movement model. In this filter, a position and speed, for example, can be calculated on the basis of positional estimates from the past. Based on these values, a prediction for the position can be made in the next time increment and be filtered with the subsequent positional estimate based on the new measurement values. This Kalman filtering with a movement model can mean that non-plausible leaps in estimated position are regarded as measurement errors from one time increment to the next and are thus not introduced into the positional estimate. The stability of the positional estimate can by enhanced by this method.

As an alternative to discarding the candidate for the position of the movable object, the candidate can also be imbued with less trust if a difference from the predicted position of the movable object is sizable (e.g., greater than a threshold value). For example, a weighting of the predicted position and a weighting of the position based on measurement data (i.e., the candidate for the position of the movable object) can be carried out, and this weighted position can be used. This approach can also enhance the stability of the positional estimate.

In some exemplary embodiments, the magnetic response field can, for example, be generated by three coils orthogonal to one another. As an example, the three coils can be configured to substantially generate equal magnetic partial response fields with an identical orientation relative to the electromagnetic exciter field. In other words, the first coil generates a first magnetic partial response field, the second coil generates a second magnetic partial response field, while the third coil generates a third magnetic partial response field. The first, second, and third magnetic partial response fields can be either identical or also substantially identical, i.e., only deviate a little relative to one another in terms of their characteristics.

With a coil system to be localized consisting of three coils behaving in an electrically similar manner and being orthogonal to one another, the direction and amplitude of the secondary field (i.e., the magnetic response field) of this coil system only changes marginally with the orientation of the coil system. For the same orientation at the same position in the primary field (i.e., the electromagnetic exciter field), each one of these three individual coils is capable — for example through the combination of their characteristics (number of windings, shape, and impedance) of providing a secondary field having a geometrically similar shape and similar strength (magnetic partial response field) in a similar phase position. This similar reaction to the primary field can enable a secondary field (magnetic response field) to be formed independent of the rotation. In summary, these orthogonally assembled coils behave like one single coil perpendicular to the primary field. Such a coil system can be advantageous, since only the position and not the orientation of such a coil system has to be stored in the table. This can drastically facilitate the search for the right position as the table can require less entries by the factor $N_{alpha} * N_{beta} * N_{gamma}$. This can reduce the memory requirement of the table and enable a real-time search of the position in the table to be performed.

Furthermore, it can be of interest to determine an orientation of the movable object in space. In some exemplary embodiments, the magnetic response field can be generated by three coils that are orthogonal to one another. In that case, the three coils can be configured to generate differentiable magnetic partial response fields with an identical orientation relative to the electromagnetic exciter field. In other words, the first coil generates a first magnetic partial response field, the second coil generates a second magnetic partial response field, and the third coil generates a third magnetic partial response field. The first, second, and third magnetic partial response fields deviate substantially from one another in terms of their characteristics. For example, the three coils can have different resonance frequencies. Alternatively or additionally, the respective magnetic partial response fields of the three coils can also be modulated with different code sequences.

To determine the orientation of a coil system, the coil system can, for example, have three coils that are disposed orthogonally to one another whose secondary fields can be differentiated. This can be achieved, for example, by tuning each of the three coils to a different resonance frequency. There are other possibilities, however, such as modulating a distinct code sequence to each of the three coils. Apart from that, the three coils can also be caused to react sequentially one after the other to the primary field (i.e., the electromagnetic exciter field). This would have brought about a temporal separation of the signals. The coils need not have the same shape or the same number of windings. By means of a scaling factor for each frequency and/or each coil, the signals of the three coils can be calculated such that each coil provides the same (scaled) signal when at the same position with the same orientation. The signals can now be used to determine the 3D position of the coil system using the above-described method. Since the position is now known, the orientation of each coil can be estimated individually at this position. This can also be done using a fingerprint table. The use of the above-described positional estimate can further facilitate the elimination of ambiguities occurring during the simultaneous position and orientation estimate. By estimating a plurality of coils, a plausibility decision can be made as to which of the possible position/orientation combinations are worthy of consideration. Alternatively, this ambiguity can be counteracted using a Kalman filter having a motion/rotation model.

If parameters like the exciter current (i.e., the current used for generating the electromagnetic exciter field) or the impedance of a response system (such as a coil and/or a coil system, for example) change dynamically, the measured antenna signals (i.e., the plurality of measurement values) may deviate from the theoretical values in the table (i.e., the reference measurement values). In this case, however, the interference would have an equal effect on all antenna signals. For that reason, determining 104 the plurality of measurement values for the magnetic response field can include normalizing the measurement value determined for one of the plurality of predetermined measurement positions based on the sum of the measurement values determined for all of the plurality of predetermined measurement positions.

It can thus be advantageous to compare a standardized value of the measured and simulated antenna signals. As an example, to achieve this, each of the measured antenna voltages $U_{mess,i}$ can be normalized with the sum of measured voltages of all measurement antennas according to the following formula (9):

$$U_{mess,i,norm} = \frac{U_{mess,i}}{\sum_{i=1}^{a} U_{mess,i}} \qquad (9)$$

A normalized measurement value can thus be determined for each of the a antennas.

The voltages stored in the table can also be calculated according to formula (9). That is, the method 100 can further comprise normalizing one of the reference values based on the sum of the measurement values determined for all of the plurality of predetermined measurement positions.

It can be advantageous in the case of such a normalization that the antenna signal of each individual receive antenna be a percentage of the overall voltage measured by all receive antennas. If, due to an interference, the current in the exciter of the coil system suddenly changes, the absolute values of the receive voltages change but not the percentages (normalized values). The absolute values measured would no longer correspond to the absolute entries in the table. If the table is normalized according to formula (9), however, an allocation of the measured normalized antenna voltages to the simulated normalized voltages can be possible.

Depth information is lost as a result of the normalization, however. This means that the distance of the coil system (or another movable object) from the exciter level (on which the receive antennas can also be arranged, for example) can no longer be determined. Accordingly, an exact positional estimate would be possible only on the exciter level. This deficiency can be counteracted with a shift of the receive antennas outside the exciter level. In some exemplary embodiments, the plurality of predetermined measurement positions can thus be located out of a plane in which the generation of the electromagnetic exciter field takes place.

If further (e.g., large) objects are located in the localization environment, they may distort the primary field (i.e., the electromagnetic exciter field), so that the simulated table (i.e., the reference measurement values) no longer reflects the real environment. This may reduce the localization accuracy in the environment of this interference object.

Therefore, the method 100 can further comprise determining that the movable object is not located within a predetermined radius around a location in which the electromagnetic exciter field is being generated. Here, the determination is based on a frequency sweep of the electromagnetic exciter field. Furthermore, the method 100 can comprise determining a plurality of auxiliary measurement values at the plurality of predetermined measurement positions. The plurality of auxiliary measurement values represent a magnetic response field of an interference object at the plurality of predetermined measuring positions. The method 100 can further comprise estimating a position of the interference object based on a comparison of the plurality of auxiliary measurement values with the reference measurement values (e.g., according to the above principles). Then, taking the interference object into account, method 100 can further comprise determining an updated reference measurement value for a position that is located at a predetermined maximum distance from the position of the interference object. This way, updated reference measurement values can be determined in the environment of the interference object which take the interference effects caused by the interference object into account. The position of a movable object can thus be determined accurately even in the presence of an interference object.

For example, a frequency sweep can first be performed using the primary field frequency (i.e., the frequency of the electromagnetic exciter field) in order to check whether a coil is nearby. If there is no coil nearby, the position of an interference object can be roughly estimated based on the currently measured antenna voltages. The table can then be simulated again dynamically in the environment of the interference object. For example, now the interference object is simulated as a coil with the known, measured phase position. The amplitude of this secondary interference field can also be estimated. In the simulation, a voltage based on the primary field of the exciter (i.e., the exciter system) and also based on the secondary field of the interference object is now induced into the coil system that is to be localized (i.e., the movable object). Using this table which better

maps reality, an optimized localization can now be executed close to the interferer. The influence of a large, field-distorting interference object can thus be reduced.
It may also be of interest to identify and localize a plurality of movable objects simultaneously (i.e., in parallel). To this end, the method 100 can, for example, comprise determining a plurality of second measurement values at the plurality of predetermined measurement positions. The plurality of second measurement values represent a second magnetic response field of a second movable object at the plurality of predetermined measuring positions. A first resonance frequency of a first response system of the movable object used for sending out the magnetic response field is different here from a second resonance frequency of a second response system of the second movable object used for sending out the second magnetic response field. Furthermore, the method 100 can comprise determining the position of the second movable object based on a comparison of the plurality of second measurement values with the reference measurement values. By tuning the two movable objects to different resonance frequencies, the second measurement values for the second movable object can be differentiated from the measurement values for the (first) movable object, and the position of the second movable object can be determined according to the above principles.
If two or more coil systems are simultaneously positioned in the primary field and the coil systems are tuned to the same frequency, the individual secondary fields of the coil systems in the receive antennas cannot be differentiated from one another. The consequence is that neither of the coils can be localized.
As indicated above, this can be remedied by tuning the respective coil systems to different resonance frequencies. This way, the signals can be separated in the receiver and further processed for localization. The simultaneous identification and localization of a plurality of coil systems can thus be facilitated by tuning the coils to different frequencies.
Alternatively, the method 100 for the simultaneous (i.e., parallel) identification and localization of a plurality of movable objects can, in turn, further comprise determining a plurality of second measurement values at the plurality of predetermined measurement positions. Here too, the plurality of second measurement values represent a second magnetic response field of a second movable object at the plurality of predetermined measuring positions. The magnetic response field and the second magnetic response field are modulated in this case with codes that are orthogonal to one another. Furthermore, the method 100 can comprise determining the position of the second movable object based on a comparison of the plurality of second measurement values with the reference measurement values. By using orthogonal codes for the modulation,

the second measurement values for the second movable object can be differentiated from the measurement values for the (first) movable object, and the position of the second movable object can be determined according to the above principles.
One further possibility for a simultaneous identification and localization of coil systems can thus be provided through a modulation of the secondary field of the coils (i.e., the magnetic response fields), each with orthogonal codes. Suitable code sequences can all be code sequences that are orthogonal to one another — i.e., have good cross-correlation characteristics — such as M-sequences or gold-codes, for example. In the receiver, the received signal of each antenna can be correlated with the known bit patterns. The respective height of the correlation peak in each antenna can then be directly proportional to the field strength in the antennas and thus be used as an indicator for the field strength. After suitable scaling, for example, these correlation peaks can now be used as replacements for the voltages induced in the receive antennas. These can thus be used to conduct a search within the fingerprint tables.
This can be advantageous in that all coils can be tuned to the same frequency, and a plurality of orthogonal codes with good cross-correlation characteristics exist for a certain bit length. A plurality of different coils can thus be simultaneously identified and localized. One additional positive effect can be the code gain, which can lift the signals out of the noise. This enables signals with a low signal amplitude and of increasing code length to be better detected. The simultaneous identification and localization of a plurality of coil systems can thus be facilitated through modulation.
The methods presented here can thus enable relatively interference-resistant localization and/or orientation estimation of, for example, a passive coil system to be performed in real time with changing but known configurations of the system characteristics.
Additional details and aspects of the method 100 will be described in the following in connection with one or more exemplary embodiments (e.g., Fig. 4 and Fig. 5). The method can comprise one or more optional features according to one or more of the above-described exemplary embodiments.
In the following, **Fig. 3** shows a system 300 with a movable object 320 and an apparatus 310 for determining a position of the movable object. The movable object 320 is configured so as to develop or generate a magnetic response field 340 as a reaction to an electromagnetic exciter field 330.
The apparatus 310 comprises an exciter module 311 that is configured to generate an electromagnetic exciter field 330. The electromagnetic exciter field 330 is configured so as to excite the movable object 320 to develop (generate) a magnetic response field 340.

Furthermore, the apparatus 310 comprises a measurement module 312 that is configured to determine a plurality of measurement values for the magnetic response field 340 by measuring the magnetic response field 340 at a plurality of predetermined measuring positions.

The apparatus 310 further comprises an evaluation module 313 that is configured to determine the position of the movable object based on a comparison of the plurality of measurement values with reference measurement values. Here, one position of the movable object 320 is associated with each of the reference measurement values. The reference measurement values are each determined by means of a simulation.

The apparatus 310 can enable a localization of the movable object 320 to be performed in real time. Based on the determination of the reference measurement values by means of a simulation, both the time requirement and complexity for generating the reference measurement values can be reduced. In particular, a reaction to changes in the environment and/or the movable object can be achieved quickly and with little effort by updating the reference measurement values by means of an adapted simulation. Complex measurements for determining the reference measurement values can be avoided.

As indicated above, the movable object can be any object that can move in space and/or develop and/or generate a magnetic response field in reaction to an electromagnetic exciter field. For example, the movable object can be and/or comprise a coil and/or a coil system.

The exciter module 311 can be configured so as to generate the electromagnetic exciter field 330 according to the above-described principles and develop the same in its environment. In particular, in this respect the exciter module 311 can comprise one or more coils, one or more conductor loops, and/or one or more coil systems through which an electric current flows.

The measurement module 312 can be configured so as to receive the magnetic response field 340 according to the above-described principles and determine the measurement values for the magnetic response field 340. In particular, the measurement module 312 can comprise a plurality of receive antennas arranged at the plurality of predetermined measurement positions. It is possible both for a single measurement antenna and also a plurality of measurement antennas to be arranged here at one or more of the plurality of predetermined measurement positions. The measurement module 312 can further comprise one or more suitable read-out electronics for preparing the signals measured

by the receive antennas for further processing by the evaluation module 313. For example, read-out electronics can filter and/or digitize the measured signals.
The evaluation module 313 can be configured so as to determine the position of the movable object 320 according to the above-described principles from the plurality of measurement values and the reference measurement values. The evaluation module (or any other module) can, for example, comprise a processor, a Central Processing Unit (CPU), a Graphics Processing Unit (GPU), a computer, a computer system, an Application-Specific Integrated Circuit (ASIC), an Integrated Circuit (IC), a System on a Chip (SoC), a programmable logics element, or a Field Programmable Gate Array (FPGA) comprising a microprocessor on which software for controlling the evaluation module 313 is run according to the above principles. Furthermore, the evaluation module 313 can comprise one or more memories in which the reference measurement values or other data can be stored, for example in order to control the evaluation module 313.
Additional details and aspects of the apparatus 310 and the movable object 320 are described above in connection with one or more additional exemplary embodiments (e.g., Figs. 1, 4, and 5). The apparatus 310 and also the movable object 320 can comprise one or more optional features according to one or more of the additional exemplary embodiments.
Two exemplary application scenarios for the proposed positional determination of movable objects will then be described in greater detail in Figs. 4 and 5. It will be readily understood that the proposed positional determination of movable objects is not restricted to exactly the described application scenarios, but rather that it is possible to determine the position of any movable objects that can develop and/or generate a magnetic response field as a reaction to an electromagnetic exciter field.
Fig. 4 shows a system 400 for determining a location of access into a rack. In logistics it can be necessary, for example, to know and/or determine the location of the access of a picker into a rack. A check can thus be performed as to whether the picker has taken goods from the correct rack shelf and/or into what rack shelf if has placed goods. The system 400 can make this possible.
For example, the picker can wear a passive coil system 420 around his wrist. The coil system 420 can be arranged in an accessory like a wristband or a watch, for example. The coil system 420 is configured so as to develop or generate a magnetic response field as a reaction to an electromagnetic exciter field. The coil system 420 is thus an example of a movable object as described generally above.

The coil system 420 to be localized can, for example, consist of three equally shaped, orthogonally mounted individual coils, one single randomly shaped coil or also three randomly shaped orthogonal coils. The coils can be tuned so as to be resonant at a single frequency. Alternatively, also any coil can be tuned to a different frequency.

The system 400 further comprises an apparatus for determining a location of access into the rack according to the abovementioned principles. As indicated in Fig. 4, the apparatus comprises an exciter module for generating the electromagnetic exciter field. The electromagnetic exciter field is configured so as to excite the coil system 420 in order to develop (generate) the magnetic response field. To generate the primary alternating magnetic field required here (i.e., the electromagnetic exciter field), the exciter module is configured as an exciter coil 411 that is attached around the rack.

A current is induced by the primary alternating magnetic field (i.e., the electromagnetic exciter field) in the coil of the coil system 420. As a result, the coil generates a secondary magnetic field (i.e., a magnetic response field).

The secondary magnetic field that is generated by current in the coil system is measured by a measurement module at a plurality of predetermined measuring positions in order to determine a plurality of measurement values for the secondary magnetic field. In this respect, the measurement module can comprise a plurality of frame antennas (receive antennas) 412-1, 412-2, 412-3, 412-4 arranged around the rack. The secondary magnetic field developed by the current in the coil system is thus measured by the frame antennas (receive antennas) 412-1, 412-2, 412-3, 412-4 arranged around the rack.

In the case of industrially manufactured standard tube racks, the receive antennas 412-1, 412-2, 412-3, 412-4 can be introduced into the tube structure. For this purpose, the tubes can consist of suitable materials that enable an at least partial penetration of a magnetic field. The user can thus mount the rack in any arbitrary manner and then indicate afterward (in table generation software, for example) where the antennas are located and how big the rack is. The tube systems can have a modular construction for this purpose, for example, and comprise terminals for the antennas.

As will be readily understood, the number of receive antennas is not restricted to the four antennas illustrated in Fig. 4. Instead, any number of antennas can be used. The number of receive antennas can be selected on the basis of a desired dimension or a desired accuracy of the position of the location of access to be determined. Likewise, the number of receive antennas can be scaled to the size of the rack.

The location of the access into the rack (i.e., the position of the coil system) can now be determined by an evaluation module (not shown) from the measurement values of the

receive antennas according to the principles specified above on the basis of a comparison of the plurality of measurement values with reference measurement values to each of which a position of the coil system 420 is allocated.
Based on the determination of the reference measurement values by means of a simulation, both the time requirement and the complexity involved in generating the reference measurement values can be reduced. In particular, changes in the environment and/or the coil system 420 can be reacted to quickly and with little effort by updating the reference measurement values by means of an adapted simulation. Complex measurements for determining the reference measurement values can be avoided.
The system 400 thus represents an inductive solution for the localization of the location of the access of a picker into a rack shelf.
The system 400 detects what shelves the picker accesses. This can be achieved even in the case of a changing rack shelf configuration and a changing rack structure. As an example, the antennas 412-1, 412-2, 412-3, 412-4 for measuring the secondary magnetic field and the coil 411 for generating the primary field can be geometrically displaced by the user and attached to other locations if necessary. Accurate localization can be ensured here by updating the reference measurement values by means of an adapted simulation. The use of passive coils can also make it possible to omit a mobile current supply for the object to be localized.
Fig. 5 shows an apparatus for determining a position of an ice-hockey puck 520. The apparatus can, for example, be used to determine whether the puck 520 is in a goal 500, that is, whether it has crossed a goal line 550.
The apparatus comprises an exciter module 511 that is configured to generate an electromagnetic exciter field 530. The electromagnetic exciter field 530 is configured to excite the puck 320 in order to develop (generate) the magnetic response field 540. The exciter module 511 can, for example, generate an electromagnetic exciter field according to the previously described principles. For example, the exciter module 511 can generate an alternating magnetic field. As indicated in Fig. 5, the exciter module 511 can, for example, be arranged in or at a goal post and/or a crossbar 501 of the goal 500. For example, the exciter module 511 can comprise one or more conductor loops, one or more coils, or one or more coil systems that are arranged in or at the goal post and/or the crossbar 501 of the goal 500.
The puck 520, which can consist substantially of hard rubber and have a disc shape, is configured to develop and/or generate the magnetic response field 540 as a reaction to the electromagnetic exciter field 530. The puck 520 can, for example, comprise one or

more coils (not illustrated) or also one or more coil systems (not illustrated). For example, the coil or the coil systems can be configured according to the above-described principles. The apparatus further comprises a measurement module that is configured to determine a plurality of measurement values for the magnetic response field 540 by measuring the magnetic response field 540 at a plurality of predetermined measuring positions. In the example shown in Fig. 5, the measurement module comprises a plurality of measurement sub-modules 512-1, 512-2, 512-3 arranged at the plurality of predetermined measurement positions. The measurement sub-modules 512-1, 512-2, 512-3 can, for example, be receive antennas that measure the magnetic response field 540. As indicated in Fig. 5, the plurality of measurement positions can, for example, be arranged in or at a goal post and/or a crossbar 501 of the goal 500. It is thus possible for a plurality of receive antennas to be arranged in or at a goal post and/or a crossbar 501 of the goal 500. Alternatively, the measurement sub-modules 512-1, 512-2, 512-3 can be located below the goal 500 (e.g. in or below the ice surface). As will be readily understood, the number of receive antennas is not restricted to the three antennas that are illustrated in Fig. 5. Rather, any number of antennas (i.e., measurement sub-modules) can be used. The number of receive antennas (i.e., measurement modules) can be selected based on a desired dimension or a desired accuracy of the position of the puck 520 to be determined.

The goal post and/or a crossbar 501 of the goal 500 can consist at least in part of suitable materials that enable at least partial penetration of a magnetic field.

The apparatus further comprises an evaluation module 513 that is configured to determine the position of the puck 520 based on a comparison of the plurality of measurement values with reference measurement values. Here, one position of the movable object 520 is associated with each of the reference measurement values. The reference measurement values are each determined by means of a simulation. As indicated in Fig. 5, the evaluation module 513 can, for example, be arranged in or at a goal post and/or a crossbar 501 of the goal 500 and pass on the result of the positional determination to a further entity, for example by means of radio technology. Alternatively, the evaluation module 513 can also be located outside the goal or the ice-hockey field. Accordingly, the plurality of measurement values can, for example, be transferred via radio technology from the measurement module to the evaluation module and evaluated there.

The apparatus can enable localization of the puck 520 to be performed in real time. Based on the determination of the reference measurement values by means of a simulation, both a time requirement and also a complexity for generating the reference measurement values can be reduced. Complex measurements for determining the reference measurement values can be avoided.

In order to determine whether the puck 520 is in the goal 500, i.e., whether it has crossed the goal line 550, the position of the puck 520 that was just determined can now be compared to a position of the goal line 550, for example.

Additional details and aspects of the puck 520 and of the apparatus for determining a position of the puck are described above in connection with one or more additional exemplary embodiments (e.g., Figs. 1 and 3). The puck 520 as well as the apparatus for determining a position of the puck can comprise one or more optional features according to one or more of the additional exemplary embodiments.

An example of the determination of a position of a puck in an ice-hockey game was described in relation to Fig. 5. However, it will be readily understood that the described methods are not restricted to this. For example, according to the above principles, the position of one or more ice-hockey players or of one or more pieces of equipment of one or more ice-hockey players can also be determined. For this purpose, the one or more ice-hockey players and/or the one or more pieces of equipment can be provided with a component (element, device) which can develop and/or generate a magnetic response field as a reaction to an electromagnetic exciter field. For example, one or more coils or one or more coil systems can be attached to a body of an ice-hockey player or to a piece of equipment of an ice-hockey player. A goalmouth offside of an ice-hockey player can be determined.

It is obvious that determining whether the puck 520 is in the goal 500 is only one example of the determination of a passage of a movable object through a plane of interest. Generally speaking, the position of a movable object can be determined and compared to the position of a plane of interest according to the abovementioned principles.

It will also be readily understood, however, that the described methods are not restricted to ice-hockey. For example, it is also possible according to the abovementioned principles to determine the position of any athlete, any piece of sport equipment, and/or any piece of equipment. Reference is made here merely exemplarily to the determination of a position of the game ball in football, in basketball, in handball, in baseball, in American football, in volleyball, in beach volleyball, in beach soccer, in water polo, in tennis, in table tennis, in street hockey, in hockey, in lacrosse, in badminton, in handball, in softball, in cricket, in shot-putting, or any other ball sports game. Of course, it is also possible to determine the position of one or more players and/or of one or more pieces of equipment

according to the aforementioned principles in the aforementioned types of sports. This can provide support for a referee and/or a game master in conducting the game. For example, using a positional determination according to the principles presented above, a referee can be supported in reaching a decision about whether a goal has been made or not, or in a decision regarding whether a player is in a certain area of the field he is not allowed to be in (e.g., offside in football or ice-hockey).
The positional determination according to the above principles is not restricted to ball sports, however. The position of any athlete, any piece of sports equipment, and/or any piece of equipment can be determined.
As indicated above, positional determination according to the above principles can, for example, also be used when generating virtual realities to detect a position, an orientation, and/or a movement of a user in the real environment and consider the same in the representation of the virtual reality. For example, according to the above principles, it is also possible for a position, an orientation, and/or a movement of an object held and/or carried by a user to be detected and taken into account in the representation of the virtual reality.
In principle, the positional determination according to the above presented principles can be used for the determination of a position of an object in any application scenario.
The features disclosed in the above description, the enclosed claims, and the enclosed figures can be of importance and implemented both individually and in any combination in order to realize an exemplary embodiment in its various forms.
Although some aspects have been described in connection with an apparatus, it will be readily understood that these aspects also illustrate a description of the corresponding method, so that a block or a device of an apparatus is also to be understood as a method step or as a feature of a method step. Analogously, aspects described in the context of or as a method step also represent a description of a corresponding block or detail or feature of a corresponding apparatus.
Depending on certain implementation requirements, exemplary embodiments of the invention or aspects thereof can be implemented in hardware or in software. The implementation can be achieved using a digital storage medium, for example a floppy disk, a DVD, a Blue-Ray, a CD, a ROM, a PROM, an EPROM, an EEPROM or a FLASH memory, a hard disc, or another magnetic or optical memory having electronically readable control signals stored thereon, which cooperate or are capable of cooperating with a programmable hardware component such that the respective method is carried out.

A module or programmable hardware component can be instantiated by a processor, a CPU, a GPU, a computer, a computer system, an ASIC, an IC, a SoC, a programmable logics element, or an FPGA.

Therefore, the digital storage medium can be machine- or computer-readable. Some embodiments also comprise a data carrier comprising electronically readable control signals which are capable of cooperating with a programmable computer system or programmable hardware component such that one of the methods described herein is carried out. One exemplary embodiment is thus a data carrier (or a digital storage medium or a computer-readable medium) on which the program for executing one of the methods described herein is stored.

Generally speaking, exemplary embodiments of the present invention or aspects thereof can be implemented as a program, firmware, a computer program or a computer program product having a program code, or as data, the program code or the data being effective for carrying out one of the methods or aspects thereof when the program is executed on a processor or on a programmable hardware component. The program code or the data can, for example, also be stored on a machine-readable carrier or data carrier. The program code or the data can be present *inter alia* as source code, machine code, or byte code, or as any other intermediate code.

Another exemplary embodiment is a data stream, a signal sequence, or a sequence of signals which can represent the program in order to carry out one of the methods or aspects thereof described herein. The data stream, the signal sequence, or the sequence of signals can, for example, be configured so as to be transferred via a data communication connection, for example via the internet or another network. Exemplary embodiments thus also include signal sequences representing data suitable for being transferred via a network or a data communication connection, in which case the data constitutes the program.

A program according to one exemplary embodiment can implement one of the methods or aspects thereof during its execution, for example by reading out memory locations or writing one or more data into the same, whereby switching processes or other processes in transistor structures, in amplifier structures, or in other electrical, optical, magnetic, or other members operating according to another functional principle are brought about. Accordingly, data, values, sensor values, or other information can be detected, determined, or measured by a program by reading out a memory location. By reading out one or more memory locations, a program can detect, determine, or measure variables, values, measured quantities, and other information and, by writing into one or more memory locations, cause, trigger, or execute an action and control other devices, machines, and components.

The above-described exemplary embodiments are merely an illustration of the principles of the present invention. It will be readily understood that modifications and variations of the arrangements and the details described herein will be apparent to others skilled in the art. The intention, therefore, is that this invention be limited only by the scope of the appended patent claims and not by the specific details presented by way of description and explanation of the exemplary embodiments herein.

FREMGANGSMÅDE OG ANORDNING TIL BESTEMMELSE AF ET BEVÆGELIGT OBJEKTS POSITION, SAMT SYSTEM DER OMFATTER ANORDNINGEN

Patentkrav

1. Fremgangsmåde (100) til bestemmelse af et bevægeligt objekts position i rummet til lokalisering af dette objekt, hvilken fremgangsmåde omfatter:
generering (102) af et elektromagnetisk excitationsfelt, hvor det elektromagnetiske excitationsfelt er indrettet til at excitere det bevægelige objekt for at udvikle et magnetisk responsfelt; og
bestemmelse (104) af en flerhed af måleværdier for det magnetiske responsfelt ved at måle det magnetiske responsfelt ved en flerhed af forudbestemte målepositioner;
kendetegnet ved
bestemmelse (106) af det bevægelige objekts position baseret på en sammenligning af flerheden af måleværdier med referencemåleværdier, hvor referencemåleværdierne hver er tildelt en position for det bevægelige objekt, og hvor referencemåleværdierne hver er bestemt via en simulering.

2. Fremgangsmåde ifølge krav 1, hvor bestemmelse (106) af det bevægelige objekts position omfatter:
bestemmelse af en lighed af en af flerheden af måleværdier med en af referencemåleværdierne ifølge en forudbestemt metrik.

3. Fremgangsmåde ifølge krav 2, hvor bestemmelse (106) af det bevægelige objekts position endvidere omfatter:
bestemmelse af den position af det bevægelige objekt, der er tildelt en referenceværdi som det bevægelige objekts position, hvis referenceværdi ifølge metrikken har en største lighed med flerheden af måleværdier.

4. Fremgangsmåde ifølge krav 2, hvor bestemmelse (106) af det bevægelige objekts position endvidere omfatter:
bestemmelse af et antal referenceværdier, som ifølge metrikken har en største lighed med flerheden af måleværdier; og
bestemmelse af en vægtet middelværdi for positionerne af det bevægelige objekt, der er tildelt antallet af referenceværdier, som det bevægelige objekts position.

5. Fremgangsmåde ifølge krav 4, hvor en vægtning af en position af det bevægelige objekt, som er tildelt en af antallet af referenceværdier, er baseret på ligheden mellem en af antallet af referenceværdier med flerheden af måleværdier.

6. Fremgangsmåde ifølge et af de foregående krav, hvor bestemmelse af det bevægelige objekts position (106) endvidere omfatter:
filtrering af en kandidat til det bevægelige objekts position ved hjælp af et Kalman-filter, hvor Kalman-filteret er baseret på en bevægelsesmodel for det bevægelige objekt.

7. Fremgangsmåde ifølge krav 6, hvor filtreringen af kandidaterne til det bevægelige objekts position omfatter følgende:
bestemmelse, ud fra bevægelsesmodellen, af en forudsagt position af det bevægelige objekt baseret på tidligere bestemte positioner af det bevægelige objekt; og
sammenligning af det bevægelige objekts forudsagte position med kandidaten til det bevægelige objekts position.

8. Fremgangsmåde ifølge krav 7, hvor filtreringen af kandidaterne til det bevægelige objekts position endvidere omfatter følgende:
kassering af kandidaten til det bevægelige objekts position, hvis forskellen mellem det bevægelige objekts forudsagte position og kandidaten til det bevægelige objekts position er større end en tærskelværdi.

9. Fremgangsmåde ifølge et af de foregående krav, hvor referencemåleværdierne envidere hver er tildelt en orientering af det bevægelige objekt.

10. Fremgangsmåde ifølge et af kravene 1 til 8, hvor det magnetiske responsfelt genereres af tre indbyrdes ortogonale spoler, og hvor de tre spoler er indrettet til at generere i det væsentlige ens magnetiske respons-delfelter ved en identisk orientering i forhold til det elektromagnetiske excitationsfelt.

11. Fremgangsmåde ifølge et af kravene 1 til 8, hvor det magnetiske responsfelt genereres af tre indbyrdes ortogonale spoler, og hvor de tre spoler er indrettet til at generere indbyrdes forskellige magnetiske respons-delfelter ved en identisk orientering i forhold til det elektromagnetiske excitationsfelt.

12. Fremgangsmåde ifølge krav 11, hvor de tre spoler har forskellige resonansfrekvenser, og/eller hvor de respektive magnetiske respons-delfelter for de tre spoler er moduleret med forskellige kodesekvenser.

13. Fremgangsmåde ifølge et af de foregående krav, hvor bestemmelsen (104) af flerheden af måleværdier for det magnetiske responsfelt omfatter følgende:
normering af den måleværdi, der er bestemt for en af flerheden af forudbestemte målepositioner, baseret på summen af de måleværdier der er bestemt for alle i flerheden af forudbestemte målepositioner.

14. Fremgangsmåde ifølge krav 13, hvor flerheden af forudbestemte målepositioner befinder sig uden for et plan, hvor genereringen af det elektromagnetiske excitationsfelt finder sted.

15. Fremgangsmåde ifølge et af de foregående krav, hvor en af referencemåleværdierne baseret på en geometri af et excitationssystem, som bruges til at generere det elektromagnetiske excitationsfelt, en geometri af et responssystem, som bruges til at udsende det magnetiske responsfelt, en geometri af et målesystem, som anvendes til at måle det magnetiske responsfelt, og en impedans af responssystemet er bestemt via simuleringen.

16. Fremgangsmåde ifølge et af de foregående krav, hvor fremgangsmåden endvidere omfatter følgende:
bestemmelse af, på basis af et frekvensgennemløb af det elektromagnetiske excitationsfelt, at det bevægelige objekt ikke befinder sig i en forudbestemt omkreds omkring et genereringssted for det elektromagnetiske excitationsfelt;
bestemmelse af en flerhed af hjælpemåleværdier ved flerheden af forudbestemte målepositioner, hvor flerheden af hjælpemåleværdier repræsenterer et magnetisk responsfelt for et interfererende objekt ved flerheden af forudbestemte målepositioner;
estimering af en position af det interfererende objekt baseret på en sammenligning af flerheden af hjælpemåleværdier med referencemåleværdier; og
bestemmelse, under hensyntagen til det interfererende objekt, af en opdateret referencemåleværdi for en position, der har en forudbestemt maksimal afstand til det interfererende objekts position.

17. Fremgangsmåde ifølge et af de foregående krav, hvor fremgangsmåden endvidere omfatter følgende:
bestemmelse af en flerhed af andre måleværdier ved flerheden af forudbestemte målepositioner, hvor flerheden af andre måleværdier repræsenterer et andet magnetisk responsfelt for et andet bevægeligt objekt ved flerheden af forudbestemte målepositioner, og hvor en første resonansfrekvens for et første responssystem for det bevægelige objekt, som anvendes til udsendelse af det magnetiske responsfelt, er forskellig fra en anden resonansfrekvens for et andet responssystem for det andet bevægelige objekt, som anvendes til at udsende det andet magnetiske responsfelt; og
bestemmelse af det andet bevægelige objekts position baseret på en sammenligning af flerheden af andre måleværdier med referencemåleværdier.

18. Fremgangsmåde ifølge et af kravene 1 til 16, hvor fremgangsmåden endvidere omfatter følgende:
bestemmelse af en flerhed af andre måleværdier ved flerheden af forudbestemte målepositioner, hvor flerheden af andre måleværdier repræsenterer et andet magnetisk responsfelt for et andet bevægeligt objekt ved flerheden af forudbestemte målepositioner, og hvor det magnetiske responsfelt og det andet magnetiske responsfelt er moduleret med indbyrdes ortogonale koder; og
bestemmelse af det andet bevægelige objekts position baseret på en sammenligning af flerheden af andre måleværdier med referencemåleværdier.

19. Anordning (310) til bestemmelse af et bevægeligt objekts (320) position i rummet til lokalisering af dette objekt, hvilken anordning omfatter:
et excitationsmodul (311), som er indrettet til at generere et elektromagnetisk excitationsfelt (330), hvor det elektromagnetiske excitationsfelt (330) er indrettet til at excitere det bevægelige objekt (320) for at udvikle et magnetisk responsfelt (340); og
et målemodul (312), som er indrettet til at bestemme en flerhed af måleværdier for det magnetiske responsfelt (340) via måling af det magnetiske responsfelt (340) ved en flerhed af forudbestemte målepositioner; kendetegnet ved
et evalueringsmodul (313), der er indrettet til at bestemme det bevægelige objekts (320) position baseret på en sammenligning af flerheden af måleværdier med referencemåleværdier, hvor referencemåleværdierne hver er tildelt en position af det bevægelige objekt (320), og hvor referencemåleværdierne hver er bestemt via en

simulering.

20. System (300), som omfatter:
mindst ét bevægeligt objekt (340), der er indrettet til at udvikle et magnetisk responsfelt (340) som reaktion på et elektromagnetisk excitationsfelt (330); og
en anordning (310) til bestemmelse af en position af et bevægeligt objekt ifølge krav 19.

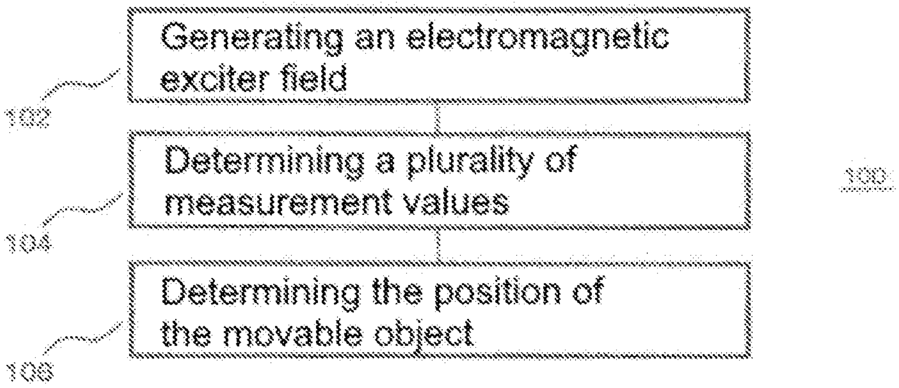

Fig. 1

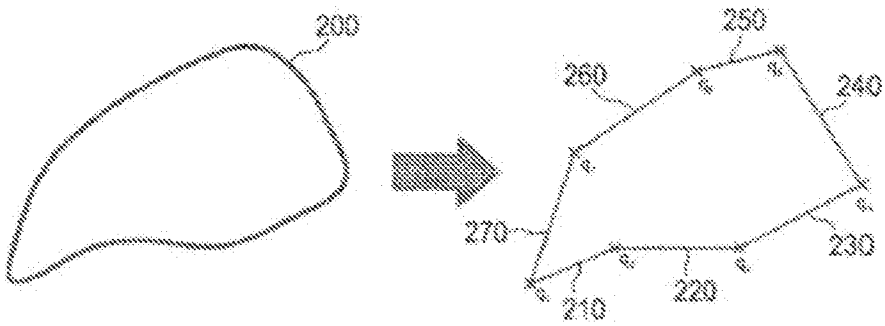

Fig. 2a

Fig. 2b

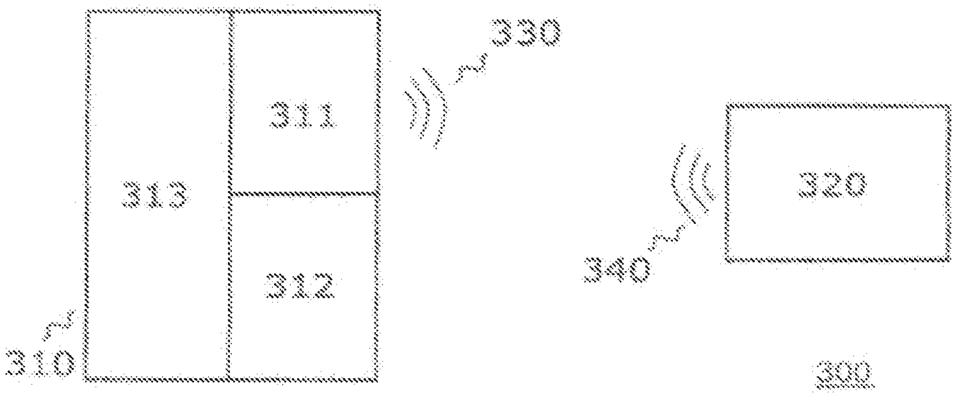

Fig. 3

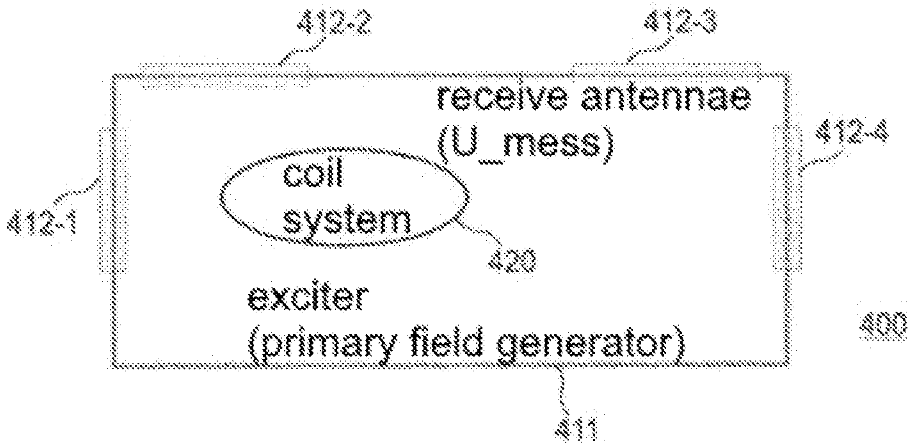
412-2
412-3
receive antennae
(U_mess)
412-4
coil
system
412-1
420
exciter
(primary field generator)
400
411

Fig. 4

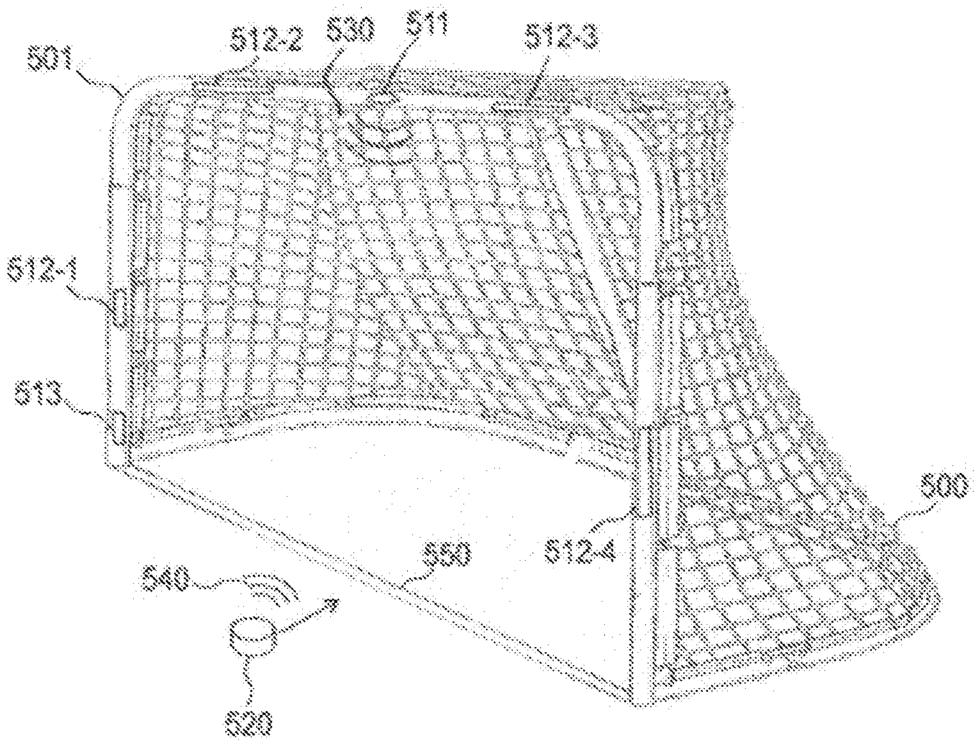
501
512-2
530
511
512-3
512-1
513
500
540
550
512-4
520

Fig. 5