

Description

The invention relates to a system according to the preamble of claim 1, as known from JP-A-55513.

This publication proposes a guiding method for an unmanned carrying truck using markers buried at predetermined positions of the surface; it also shows some of said markers being arranged according to a grid. The vehicle carries means (not specified) to detect the passing of the markers and to provide position information.

This known system can only be used to navigate and travel along paths which are defined by direct connections between aligned markers (and thus by mutually perpendicular lines) so that the routing possibilities of this known system are limited to predefined routes.

The invention aims to improve this known system in such a way that the vehicle can follow a unique path between any arbitrary starting point and any arbitrary destination point - in which it is not necessary that these points each coincide with a marker - taking into account all circumstances prevailing at the moment such as forbidden areas on the surface (i.e. because of obstacles on the surface such as stores or temporary structures).

This aim is achieved by the measures according to the characterizing clause of claim 1.

The system according to the invention is extremely flexible and can be used practically anywhere and under all circumstances with a minimum of changes in the existing surface and environment. The marker elements, which can be embedded in the surface, do not hinder movements over this surface by other users.

A vehicle equipped with the proposed navigation system is able to compute a path to any position in the work area that is physically accessible. This means that the number of different routes generated by the path planner is almost unlimited, just like the number of different destinations.

The fact that the routes are computer-generated rather than fixed and embedded in the floor as in conventional automated guided vehicle systems (AGVS) allows the system to cope with changes in the environment in a matter of minutes by updating the layout stored in the vehicle's memory. This can be achieved by updating the layout on a stationary computer and sending down the changes over a wireless link to the vehicle computer.

Preferred embodiments of the system are described in the claims 2-8 while a method of navigating a vehicle, using the system according to the invention, is subject of the claims 9 and 10.

It is observed that US-A-4.278.142 (= DE-A-2.910.490) describes an automatic guidance system for vehicles using markers on the surface with mutually different shape and dimension so as to make a visual recognition of said markers by optical scanning possible. Thus this known system is based on an entirely different principle.

The invention is elucidated on the hand of the drawings.

Fig. 1 is a schematic view of a surface provided with a grid of line-shaped markers and elucidates the navigation on such a grid;

Fig. 2 is a top view of a surface provided with a grid of discrete markers and elucidates the navigation on such a grid.

Figs. 3a, 3b and 3c relate to the navigation on parts of a surface provided with line-shaped markers;

Fig. 3d elucidates another way of navigating, using a grid of discrete markers, if necessary combined with odometry;

Fig. 4a is an upper view of a part of a line-shaped marker;

Fig. 4b is a section over the line IVa-IVa in fig. 4a;

Fig. 5a is a top view of a part of a grid made from Stelcon^(R) plates;

Fig. 5b is a cross section over the line Vb-Vb in fig. 5a;

Fig. 6a is a schematic top view of a vehicle provided with a number of detectors;

Fig. 6b is a schematic top view of part of a modified vehicle according to the invention to be used with discrete markers;

Fig. 7 shows the use of a discrete marker of the transponder-type in combination with a suitably equipped vehicle.

Fig. 1 shows an example in which the vehicle, provided with a very simple navigating system, can range over a surface from a starting point to its destination, by following a path which consists of essentially straight parts which are interconnected by standard turns. This path is determined by line-shaped marker elements. Fig. 1 shows a surface, indicated generally with reference numeral 1, and provided with a grid of line-shaped markers which are arranged according to an orthogonal coordinate system with origin 0; the marker lines are indicated with respectively x1, x2,... and y1, y2,...

Each square on the surface 1 is thus defined by an X- and Y-coordinate and the complete track of a

vehicle over the surface 1 is in this simple example of navigating obtained by covering track parts in the X and Y direction respectively. Other track parts at an angle with these directions are also possible, as will be described later on.

Fig. 1 shows three hatched surface parts indicated with respectively 2, 3 and 4. These are surface parts which cannot be covered by a vehicle, for instance because they are used for storing materials. A vehicle which leaves from the point of departure 5 and has as its destination the point of arrival 6 could follow a route such as indicated with the line 7; this route comprises a succession of straight line elements, starting with a part 7a in the Y-direction, thereafter a part 7b in X-direction, followed by a part 7c in Y-direction, a part 7d in X-direction and once again a part 7e in the Y-direction. In which way the drive- and control mechanism of the vehicle will receive the various necessary commands will be explained later, but from the above it will be clear that the route as covered is in fact determined by continuously determining the position of the vehicle with respect to the marker elements of which the position is known and by counting the number of passed markers.

Fig. 2 shows a surface which is in principle the same; corresponding parts are here indicated with the same reference numerals as used in fig. 1 but provided with an accent mark. In this embodiment the markers consist of discrete marker elements 20 provided on the crossing points of the X- and Y-lines of an orthogonal coordinate system. While a vehicle which is guided by means of line-shaped marker elements can use a relatively simple set of detectors for example proximity switches to follow these marker elements a vehicle which is used in combination with the discrete marker elements according to fig. 2 must be provided with a more elaborate control system which is able to follow, starting from a certain known starting point, a predetermined track to the next discrete marker element and which is capable to execute turns to the right and to the left with a standard radius. The counting-off of the marker elements is effected in principle in the same way as in the embodiment according to fig. 1.

A vehicle which leaves at point x'6 must thus after the passing of two markers, initiate a right hand turn which brings it above the marker 21 at the crossing point of - imaginary - coordinate line x'7 and y'3 and then go straight on; after passing the second next marker 22 a left hand turn must be initiated which brings it above the marker 23 at the crossing point of the - imaginary - line x'10 and y'4 whereafter it goes straight on to the marker 24, etc. A specific embodiment of such a discrete marker will be described later on.

Fig. 3a elucidates the way in which navigation is possible over a grid of line-shaped marker elements when traversing an arbitrary route across the surface, from a first position to a second position.

Firstly it must be pointed out that navigation according to this example presupposes that the route to be followed consists of moving from one, known, point to the next point and determining the position of this next point. In fig. 3a it is presumed that the vehicle starts at P1 of which the position is known and must move to P2, from P2 to P3, from P3 to P4 and so on. Fig. 3b elucidates this and relates to the route part between P3 and P4.

At the moment t1 (vide fig. 3b) the right hand detector 22a of the schematically shown vehicle 21 passes the vertical line-shaped marker 25 (X1) and at moment t2 the left hand detector 22b passes this vertical marker 25. By using odometry - for instance employing rotary encoders coupled to the rear wheels, combined with digital counters the paths, covered by the detectors 22a and 22b in the direction of the route 26 can be measured. As the distance d between the detecting elements 22a, 22b is known the value of angle α is known from $\tan \alpha = \frac{d}{s_1}$ and from α follows, as

$$\beta = (90^\circ - \alpha) \cdot s_1$$

and d being known.

The exact position P4' at which detector 22b causes the horizontal marker element can be computed when s_2 (distance between crossing point of vertical marker P3' and crossing point horizontal marker) is measured as $OP4' = s_2 \sin \alpha$

In the same way, P5 (fig. 3a) can be determined starting from the now known position P4. The fact that at each crossing point of a line-shaped marker the angle between the actual track and said, marker is known, results, combined with information about the position of the preceding crossing point into information of the actual crossing point of said marker. It must be born in mind that the nominal positions of the points P1, P2, etc. are computed and stored in advance in the central computer of the vehicle. By comparing the position of the actual crossing points with the pre-computed data steering corrections can be made when the vehicle deviates from its planned route.

Of course it is advantageous when the vehicle is also capable of negotiating turns which interconnect one track part with another. Fig. 3c relates to this situation. In fig. 3c is assumed that the vehicle makes a turn with a known radius R and travels with a constant speed v. Here, too, the vehicle 21 is provided with two detectors 22a, 22b at a distance d.

It follows from fig. 3c that the detector 22b will be the first one to cross the horizontal line-shaped

element 23 at the moment t_1 and at this moment detector 22b emits a signal to 8 central control- and computing unit (to be described later). When a few moments later detector 22a crosses the horizontal marker element 23 at moment t_2 it also emits a signal; upon reaching the vertical marker element 24 the right hand detector 22a will be the first on to emit a signal at moment t_3 and thereafter the left hand detector 22b will emit a signal at moment t_4 .

It can be shown that the following equations are valid:

$$\operatorname{tg} \alpha = \frac{v}{d} (t_2 - t_1) \quad (1)$$

$$\operatorname{tg} \beta = \frac{d}{v(t_4 - t_3)} \quad (2)$$

$$R(\beta - \alpha) = v(t_3 - t_2) \quad (3)$$

From these equations α , β and R can be determined. It then follows:

$$OA = R(\cos \alpha - \cos \beta) \quad (4)$$

$$OB = R(\sin \beta - \sin \alpha) \quad (5)$$

Thus by measuring the time only between the moments on which the detectors 22a and 22b cross the horizontal marker element 23 and the vertical marker element 24 respectively the exact position of the vehicle with respect to these marker elements and the route which it has been following is known.

Another solution would be the use of odometry (measuring the distance travelled by two wheels of the vehicle, said wheels being at a known distance d) in combination with the measurement as described before of the angle at which the vehicle crosses a certain marker element; then the angle at which the next marker element is expected to be crossed can be computed.

The nominal crossing angle is known and on the basis of the difference between the actual crossing angle and the nominal crossing angle, the position error can be computed and the path of the vehicle corrected.

Of course combining time measurement with odometry will result into an even more foolproof navigation.

Fig. 3d shows an example of navigating using a grid of discrete marker elements. The vehicle 21 with its longitudinal axis 21a is provided with two linear arrays of detectors 27a, 27b respectively to the right and to the left of the longitudinal axis 21a and perpendicular thereto. In fig. 3d it is presumed that the path 28 to be followed is in line with the longitudinal axis 21a of the vehicle and that this path does not coincide with the coordinate system according to which the markers 20 are arranged.

At the moment t_1 the left hand array 27b - after having travel led a known distance s_0 from a known starting point - detects the marker 20a at a distance l_1 to the left of the axis 21a. Then follows the sequence: After distance s_1 array 27a detects marker 20b at l_2 to the right -

After s_2 array 27a detects marker 20c at l_3 to the right -

After s_3 array 27b detects marker 20d at l_4 to the left -

After s_4 array 27b detects marker 20e at l_5 to the right -

After s_5 array 27b detects marker 20f at l_6 to the right - and so on.

Thus when the respective detected lateral distances of the successive marker elements with respect to the longitudinal axis 21a correspond with the data as stored in the navigating computer of the vehicle, the vehicle "knows" that it is following the correct track; if not so corrections can be made. Note that detecting the travelled distances s_0 , s_1 , etc. is not really necessary but results as said above into an advantageous redundancy.

Line-shaped markers are possible in various embodiments. They can, as known, consist of light-reflecting material and be painted in each desired configuration on the surface.

Scanning of such lines with optics sensors is known but such markers have to drawback that they get dirty; preferably one will use markers which consist of magnetically conducting material. They can be embedded in the floor such as shown in the figs. 4a and 4b. Reference numeral 30 indicates the floor; the line-shaped marker 31 is embedded a short distance under the surface.

Many advantages are obtained when the grid consists of the metal frames of the well-known concrete floor elements bestknown under the trademark "Stelcon"^(R). Figs. 5a and 5b show a number of such plates of which some are indicated with 32a - 32c. Each plate has, as known, a metal frame of which a number are indicated with 33a - 33c and which, as shown, in combination constitute a perfect grid of mutually perpendicular lines 34a - 34d and 35a - 35d respectively. Such a grid of marker elements is eminently suitable for use in the system according to the invention.

Fig. 6a shows a vehicle with detectors and control means for navigating across a surface with line-shaped marker elements. The vehicle 40 comprises front wheels 41a, 41b, a steering unit 42, rear wheels 43a, 43b driven by the motor 44 and is surrounded by a safety fender 45. The central control unit 46 receives signals from detectors 47a, 47b placed at the front of the vehicle and responding to the presence of marker elements.

Detectors 49a, 49b at the respective sides of the longitudinal axis 49 can be used in a simple navigating system to follow a longitudinal marker element. The central unit 46 receives commands from the program- and control unit 47 via the connection 48; the unit 37 can be provided with a keyboard 49' to input data and information about the track to be followed but such information can also be transmitted wirelessly by means of a receiver 50 and from a distant control unit 51 with an emitter 52 and keyboard 53.

The control unit 46 controls via the two-way connection 45 the steering device 42 and receives back steering angle information; the drive unit 44 is controlled via the connection 55.

Of course it is also possible that all information supplied by the sensors is fed back to the unit 47 as indicated schematically with the dot-lined connection 57, is then emitted to the central unit 51 and processed there. The unit 51 then returns the necessary steering commands to the vehicle. The abovementioned control- and navigation system can be completed by a device to determine the distance covered (odometry) in the direction of the track, for using instance encoders 58a, 58b, coupled to the rear wheels of the vehicle and cooperating with a revolution counter 59 which feeds this information to the control unit 46.

Fig. 6b shows the front part of a vehicle to be used for navigating over a surface provided with a regular grid of discrete marker elements, such as the surface shown in fig. 2, and in the way as described hereinbefore with reference to fig. 3d. The vehicle 40 is provided at its front end with two linear arrays of detecting elements 60a, 60b. These arrays are scanned under the control of the central unit 64 and they feed back their information to this central unit as indicated schematically by the connections 61a and 61b. The other parts of the vehicle are not shown and they are the same as those shown in fig. 6a. The detectors can be known proximity switches.

Fig. 7 relates to the use of marker elements of the so-called "transponder"-type. Such elements are marketed by the Dutch firm of Nedap, Groenlo, and have the shape of a small cylinder, about 8 cm long and with a diameter of about 4 cm. They have the property that when they are excited by irradiation with electromagnetic energy with a frequency of about 100 kHz, they respond by emitting a coded signal at the same frequency. This makes it possible to use them not only as marker element, but also to transmit to the vehicle explicit information about its actual position on the grid which can be very useful.

According to fig. 7 the schematically shown vehicle 110 has a front wheel 111 with its driving motor 112, rear wheels 113 and 114, each with an odometry encoder 113a and 114a respectively, an emitting loop 115, excited by the emitter 116 and, in this example, five receiver loops 117a..117e of which the outputs are connected to the circuit 118. This circuit 118 decodes the information present in the signals picked-up by the receiver loops 117a..117e, and emitted by a marker 119 which is in the vicinity of the vehicle 110 and close enough to the emitter loop 115 to be excited thereby. Another marker element, too far away to be detected in the shown position of the vehicle, is indicated with 119a.

Note that the position of the marker 119 with respect to the longitudinal axis 110a of the vehicle 110 can be derived from the relative strengths of the signals produced by the loops 117a..117d.

After the evaluation of the received signals, the decoder/level-detector 118 transmits the position information to the central computer 120.

Of course the discrete marker element can also consist of marker elements which can be scanned optically, for instance by having light reflecting surfaces or optically recognisable shapes. Examples of these elements are described in for instance, the German Patent Application 2.910.490, relating to a vehicle guidance system.

It is clear that within the framework of the invention many other embodiments are possible; a practical and working embodiment of the system according to the invention can be constructed by any expert using

the present-day systems and components known to him. Particularly in connection with the logistics of free ranging unmanned vehicle systems one can make use of existing technology and this is also valid with regard to the detectors which are necessary to sense the marker elements and the circuits for processing the signals resulting from the sensing.

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Claims

- 10 1. System for navigating and controlling an unmanned vehicle (21), provided with steering- and control means and marker detectors (22a, 22b; 47a, 47b; 49a, 49b; 27a,b; 117a--e), over a surface (1) which is provided with a number of marker elements (X1, X2 ... Y1, Y2) ...; 20) at predetermined positions, characterized in that
 said marker elements (X1, X2 ... Y1, Y2 ...; 20) are arranged according to a regular grid,
 15 said marker elements (X1, X2 ... Y1, Y2 ...; 20) are of the passive type, i.e. able to respond to or reflect incident energy and
 the vehicle (21) is provided with a computing system (46) with memory capacity to store information about the grid and forbidden areas (2, 3, 4) on the surface (1) and software including a program to compute paths (7) to be followed by the vehicle (21) between an arbitrary starting point (5) and an
 20 arbitrary destination (6) using the stored information about the surface (1), and a control program to correct the actual path towards the computed path during execution of a planned route, using position information derived from the marker detectors (22a, 22b; 47a, 47b; 49a, 49b; 27a, 27b; 117a--117e).
2. System according to claim 1, in which the marker elements (20) consist of discrete elements.
- 25 3. System according to claim 2, in which the discrete elements are transponders (119) to be activated by irradiation with electromagnetic energy and known in itself.
4. System according to claim 2, in which the discrete elements are of the type which can be scanned
 30 optically.
5. System according to claim 2, in which the discrete elements consist of magnetically conducting material.
- 35 6. System according to claim 1, in which the grid of marker elements is formed, by a pattern of essentially continuous lines (X1, X2, X3, ...; Y1, Y2, Y3, ...) to be detected by active detecting means and is arranged according to a coordinate system.
7. System according to claim 6, in which the marker elements (31) comprise magnetically conducting
 40 material.
8. System according to claim 6, in which these elements consist of the metal frames (33a, 33b) of floor elements (32a, 32b) which constitute the surface.
- 45 9. A method of navigating an unmanned vehicle, using the system according to any of the claims 1 and/or 6-8, comprising the steps of:
 - starting from a known starting point determining the angle (α) at which in a first interception point (P1) the first marker element is intercepted, by measuring the path (s) covered by the vehicle between the moment at which two respective detectors on the vehicle with a known
 50 mutual distance (d) passed said marker ($\tan \alpha = d/s$),
 - measuring the path travelled by the vehicle between said starting point and said first interception point (t),
 - determining from the above data the position of said first interception point (P1),
 - comparing said actual position data with the nominal position data stored in the computer,
 - 55 - and correcting if necessary, the path to be followed by the vehicle from said first interception point to the next interception point (P2) of which the nominal position data is stored in the computer,
 - repeating the above procedure for the subsequent interception points.

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 15 said marker elements (X1, X2 ... Y1, Y2 ...; 20) are arranged according to a regular grid,
 said marker elements (X1, X2 ... Y1, Y2 ...; 20) are of the passive type, i.e. able to respond to or reflect incident energy and
 the vehicle (21) is provided with a computing system (46) with memory capacity to store information about the grid and forbidden areas (2, 3, 4) on the surface (1) and software including a program to compute paths (7) to be followed by the vehicle (21) between an arbitrary starting point (5) and an
 20 arbitrary destination (6) using the stored information about the surface (1), and a control program to correct the actual path towards the computed path during execution of a planned route, using position information derived from the marker detectors (22a, 22b; 47a, 47b; 49a, 49b; 27a, 27b; 117a--117e).
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 30 optically.
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- 45 9. A method of navigating an unmanned vehicle, using the system according to any of the claims 1 and/or 6-8, comprising the steps of:
 - starting from a known starting point determining the angle (α) at which in a first interception point (P1) the first marker element is intercepted, by measuring the path (s) covered by the vehicle between the moment at which two respective detectors on the vehicle with a known
 50 mutual distance (d) passed said marker ($\text{tg}\alpha = d/s$),
 - measuring the path travelled by the vehicle between said starting point and said first interception point (1),
 - determining from the above data the position of said first interception point (P1),
 - comparing said actual position data with the nominal position data stored in the computer,
 - 55 - and correcting if necessary, the path to be followed by the vehicle from said first interception point to the next interception point (P2) of which the nominal position data is stored in the computer,
 - repeating the above procedure for the subsequent interception points.



10. Method of navigating an unmanned vehicle, using the system according to any of the claims 1 - 5, comprising the steps of:

- starting from a known starting point determining at the passing of the first discrete marker element the distance (l_1) thereof with respect to a reference point on the vehicle, together with the distance (s_0) travelled by the vehicle,
- comparing said actual data with the relative nominal data stored in the computer of the vehicle,
- correcting, if necessary, the path to be followed by the vehicle from said first interception point to the next interception point, of which the nominal position data with respect to the nominal path to be followed is stored in the computer,
- comparing when passing said next interception point, the distance (l_2) to the reference point on the vehicle and the distance (s_1) travelled by the vehicle when moving from the first interception point to the second interception point;
- repeating the abovementioned comparing and correcting step,
- repeat the above procedure for the subsequent interception points.

Revendications

1. Système pour diriger et commander un véhicule sans conducteur (21), qui comprend des moyens de direction et de commande et des détecteurs d'éléments de repérage (22a, 22b ; 47a, 47b ; 49a, 49b ; 27a, 27b ; 117a ... 117e), sur une surface (1) qui est munie d'un certain nombre d'éléments avertisseurs ($x_1, x_2 \dots y_1, y_2 \dots 20$) agencés en des positions prédéterminées, caractérisé en ce que :

- ces éléments avertisseurs ($x_1, x_2 \dots y_1, y_2 \dots 20$) sont disposés selon une grille régulière
- ces éléments avertisseurs ($x_1, x_2 \dots y_1, y_2 \dots 20$) sont du type passif, c'est-à-dire capables de répondre à de l'énergie incidente ou de la réfléchir,
- et que le véhicule (21) présente un système de calcul (46) muni d'une mémoire pour emmagasiner des informations concernant la grille et des zones interdites (2, 3, 4) de la surface (1) et d'un logiciel comprenant un programme pour calculer les voies (7) que le véhicule (21) doit suivre entre un point de départ arbitraire (5) et un point de destination arbitraire (6) en utilisant l'information mémorisée concernant la surface (1), et d'un programme de commande pour amener le véhicule de la voie suivie vers la voie calculée au cours de l'exécution d'un parcours programmé, en utilisant des informations de position dérivées des détecteurs (22a, 22b ; 47a, 47b ; 49a, 49b ; 27a, 27b ; 117a ... 117e).

2. système selon la revendication 1, dans lequel les éléments avertisseurs (20) sont des éléments numériques.

3. Système selon la revendication 2, dans lequel les éléments numériques sont des répondeurs (119) activés par un rayonnement électromagnétique et bien connus en soi.

4. Système selon la revendication 2, dans lequel les éléments numériques sont d'un type qui peut être détecté optiquement.

5. Système selon la revendication 2, dans lequel les éléments numériques sont réalisés en une matière magnétique douce.

6. Système selon la revendication 1, dans lequel la grille d'éléments avertisseurs est formée par un réseau de lignes sensiblement continues ($x_1, x_2, x_3 \dots y_1, y_2, y_3$) détectées par des moyens actifs de détection, cette grille étant agencée selon un système de coordonnées.

7. Système selon la revendication 6, dans lequel les éléments avertisseurs (31) comprennent un matériau magnétique doux.

8. Système selon la revendication 6, dans lequel ces éléments sont constitués par des châssis métalliques (33a, 33b) d'éléments de sol (32a, 32b) qui forment la surface.



9. Procédé de guidage d'un véhicule sans conducteur qui utilise le système selon l'une quelconque des revendications 1 et/ou 6 - 8, comprenant les opérations de :

- calcul, en partant d'un point de départ connu, de l' angle (α) sous lequel le premier élément avertisseur est intercepté à un premier point d'interception (P1), en mesurant la vole (s) parcourue par le véhicule entre l'instant où des détecteurs respectifs du véhicule qui sont séparés par une distance connue (d) ont passé ledit avertisseur ($\tan \alpha = d/s$) ;
- mesure du trajet parcouru par le véhicule entre ledit point de départ et ledit premier point d'interception (P1) ;
- en partant des données mentionnées ci-dessus, détermination de la position dudit premier point d'interception (P1) ;
- comparaison de ces données concernant la position effective avec les données concernant la position nominale, mémorisées dans l'ordinateur ;
- au besoin, correction du trajet que doit suivre le véhicule du premier point d'interception vers le point d'interception suivant (P2) dont les données nominales de position sont mémorisées dans l'ordinateur ;
- répétition du procédé mentionné ci-dessus pour les points d'interception suivants.

10. Procédé de guidage d'un véhicule sans conducteur, en utilisant le système selon l'une des revendications 1 à 5, comprenant les opérations suivantes :

- en partant d'un point de départ connu, la détermination au passage du premier élément avertisseur numérique, de la distance (l_1) de celui-ci par rapport à un point de référence situé sur le véhicule, ainsi que de la distance (s_0) parcourue par le véhicule ;
- comparaison de ces données effectives avec les données nominales relatives mémorisées dans l'ordinateur du véhicule ;
- au besoin, correction du trajet que le véhicule doit suivre à partir dudit premier point d'interception vers le point d'interception suivant, dont les données concernant la position nominale par rapport au trajet nominal à suivre sont mémorisées dans l'ordinateur ;
- comparaison, au passage du point d'interception suivant, de la distance (l_2) avec le point de référence situé sur le véhicule et de la distance (s_1) parcourue par le véhicule lorsqu'il se déplace du premier point d'interception vers le deuxième point d'interception ;
- répétition de l'opération de comparaison et de correction mentionnée ci-dessus ;
- répétition du procédé mentionné ci-dessus pour les points d'interception suivants.

35 Ansprüche

1. System zum Navigieren und Kontrollieren eines unbemannten Fahrzeuges (21), das mit Steuer- und Kontrollmitteln und Markierungsdetektoren (22a, 22b; 47a, 47b; 49a, 49b; 27a, 27b; 117a-e) ausgerüstet ist, über eine Fläche (1), die mit einer Anzahl von Markierungselementen (X1, X2 ... Y1, Y2 ...; 20) in vorherbestimmten Positionen versehen ist, dadurch gekennzeichnet, daß die Markierungselemente (X1, X2... Y1, Y2 ...; 20) gemäß einem regelmäßigen Raster angeordnet sind, die Markierungselemente (X1, X2 ... Y1, Y2 ...; 20) vom passiven Typ sind, d.h. auf einfallende Energie ansprechen oder diese reflektieren, und das Fahrzeug (21) mit einem Computersystem (46) mit Speicher-Kapazität zum Speichern von Informationen über den Raster und verbotene Zonen (2, 3, 4) auf der Fläche (1) und Software, einschließlich eines Programms zum Berechnen der von dem Fahrzeug (21) zwischen einem willkürlichen Startpunkt (5) und einem willkürlichen Bestimmungspunkt (6) unter Anwendung der gespeicherten Informationen über die Fläche (1) zu verfolgenden Wege (7), und einem Kontrollprogramm ausgerüstet ist, um den tatsächlichen Weg im Vergleich zum berechneten Weg während des Verfolgs einer geplanten Route zu korrigieren, wobei Informationen über die Position ausgewertet werden, die von den Markierungsdetektoren (22a, 22b; 47a, 47b; 49a, 49b; 27a, 27b; 117a-117e) geliefert werden.

2. System gemäß Anspruch 1, bei welchem die Markierungselemente (20) aus diskreten Elementen bestehen.

3. System gemäß Anspruch 2, bei welchem die diskreten Elemente Transponder (119) sind, die durch Strahlung elektromagnetischer Energie aktiviert werden und per se bekannt sind.



4. System gemäß Anspruch 2, bei welchem die diskreten Elemente zu einem Typ gehören, der optisch abgetastet werden kann,
5. System gemäß Anspruch 2, bei welchem die diskreten Elemente aus magnetisch leitendem Material bestehen.
6. System gemäß Anspruch 1, bei welchem der Raster der Markierungselemente durch ein Muster im wesentlichen kontinuierlicher Linien $X_1, X_2, X_3, \dots; Y_1, Y_2, Y_3, \dots$ gebildet wird, das durch aktive Detektormittel festzustellen und gemäß einem Koordinatensystem angeordnet ist.
7. System gemäß Anspruch 6, bei welchem die Markierungselemente (31) ein magnetisch leitendes Material umfassen.
8. System gemäß Anspruch 6, bei welchem diese Elemente aus den Metallrahmen (33a, 33b) von Bodenelementen (32a, 32b) bestehen, die die Fläche bilden.
9. Verfahren zum Navigieren eines unbemannten Fahrzeuges unter Verwendung des Systems gemäß irgendeinem der Ansprüche 1 und/oder 6 bis 8, das die Schritte umfaßt:
 - Starten von einem bekannten Startpunkt unter Bestimmung des Winkels (α), in welchem das erste Markierungselement in einem ersten Schnittpunkt (P1) geschnitten wird, indem man den Weg (s) mißt, der von dem Fahrzeug seit dem Augenblick zurückgelegt wurde, an dem zwei entsprechende Detektoren mit einem bekannten gegenseitigen Abstand (d) auf dem Fahrzeug diese Markierung passiert haben ($\tan \alpha = d/s$),
 - Messen des Weges, den das Fahrzeug zwischen dem Ausgangspunkt und dem ersten Schnittpunkt (1) zurückgelegt hat,
 - Bestimmen der Position des ersten Schnittpunktes (P1) aus diesen Daten,
 - Vergleichen der Daten über die tatsächliche Position mit den im Computer gespeicherten nominellen Positionsdaten,
 - falls notwendig, Korrigieren des vom Fahrzeug vom ersten Schnittpunkt zum nächsten Schnittpunkt (P2), dessen nominelle Positionsdaten im Computer gespeichert sind, zu verfolgenden Weges und
 - Wiederholen des obigen Verfahrens für die anschließenden Schnittpunkte.
10. Verfahren zum Navigieren eines unbemannten Fahrzeuges unter Verwendung des Systems gemäß irgendeinem der Ansprüche 1 bis 5, das die Schritte umfaßt:
 - Starten von einem bekannten Startpunkt, wobei beim Passieren des ersten diskreten Markierungselementes dessen Abstand (l_1) zu einem Bezugspunkt auf dem Fahrzeug sowie die vom Fahrzeug zurückgelegte Distanz (s_0) gemessen werden,
 - Vergleichen der tatsächlichen Daten mit den relativen nominellen Daten, die im Computer des Fahrzeuges gespeichert sind,
 - falls notwendig, Korrigieren des Weges, der vom Fahrzeug vom ersten Schnittpunkt zum nächsten Schnittpunkt, dessen nominelle Positionsdaten über den zu verfolgenden nominellen Weg im Computer gespeichert sind, zu verfolgen ist,
 - beim Passieren des nächsten Schnittpunktes Vergleichen des Abstandes (l_2) zu dem Bezugspunkt auf dem Fahrzeug und der vom Fahrzeug zurückgelegten Distanz (s_1), wenn sich das Fahrzeug vom ersten Schnittpunkt zum nächsten Schnittpunkt bewegt,
 - Wiederholen der obigen Schritte des Vergleichens und Korrigierens und
 - Wiederholen des obigen Verfahrens für die anschließenden Schnittpunkte.

