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[54] NAVIGATION SYSTEM AND PROCESS FOR GUIDING UNMANNED INDUSTRIAL TRUCKS WITHOUT GUIDE WIRE

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **180/168**; 180/169; 318/587; 364/424.02

[58] **Field of Search** 180/167, 168, 169; 318/587; 358/103; 364/424.02

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Assistant Examiner—Richard Camby
Attorney, Agent, or Firm—McGlew and Tuttle

[57] **ABSTRACT**

A navigation system for guiding unmanned vehicles with any desired wheel configuration without guide wire for free movement on paths and along curves along a virtual reference path having at least one straight and/or curved section. Discrete elements are floor-installed which are in operative conneciton with a vehicle internal path control device via the vehicle's internal sensory analysis system for correcting the course of the industrial truck. The discrete elements are arranged at spaced locations exclusively along the area of the reference path forming a linear formation chain as navigation reference points P. The distance between the reference points P are either regular or irregular and may be relatively great distances equal to a multiple of the wheel base of the vehicle. The on-board sensory analysis system exclusively determines the distances and measures the distance between the longitudinal axis of the industrial truck and the navigation reference point P.

16 Claims, 6 Drawing Sheets

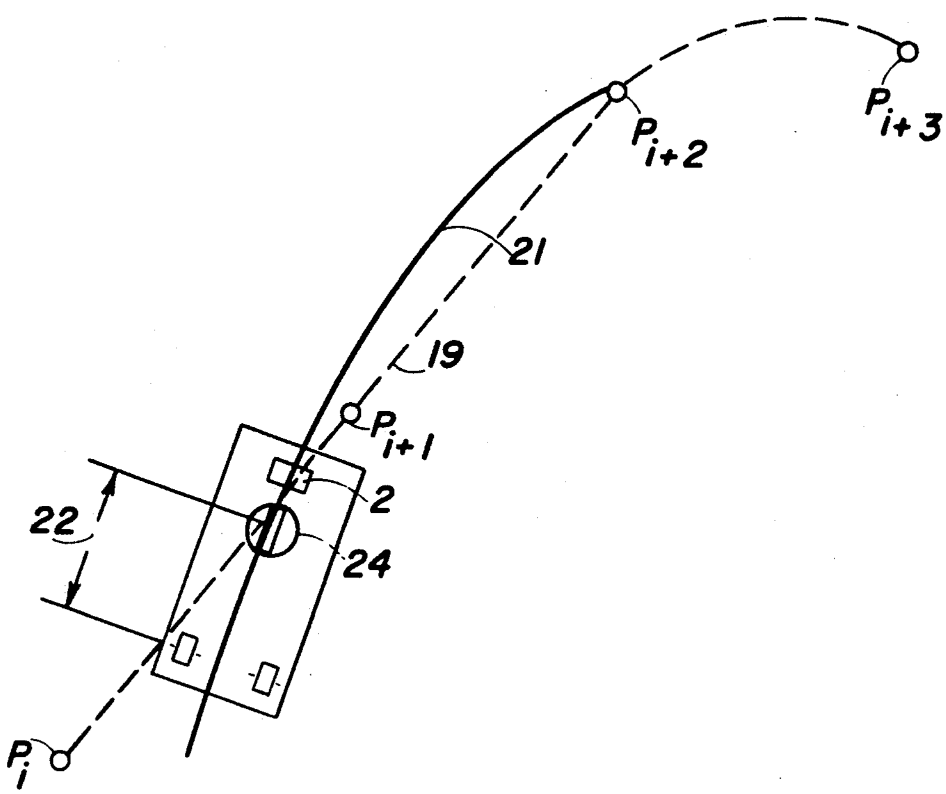


FIG. 1

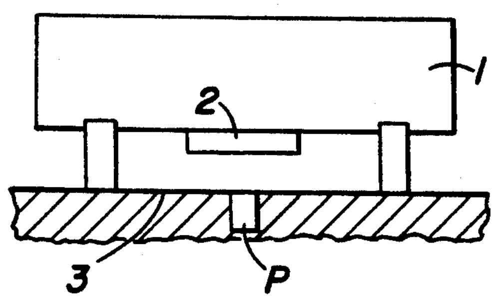


FIG. 2

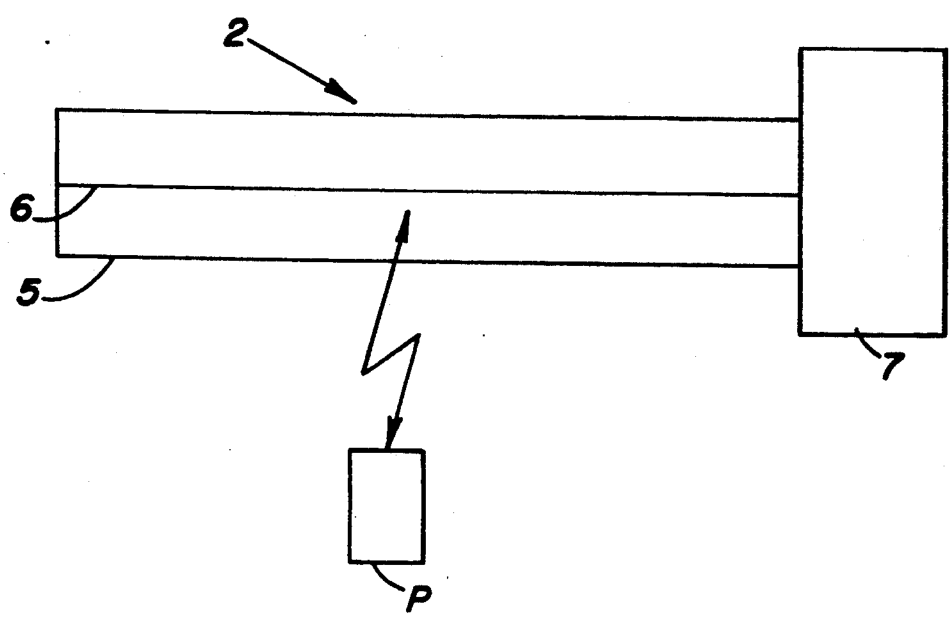
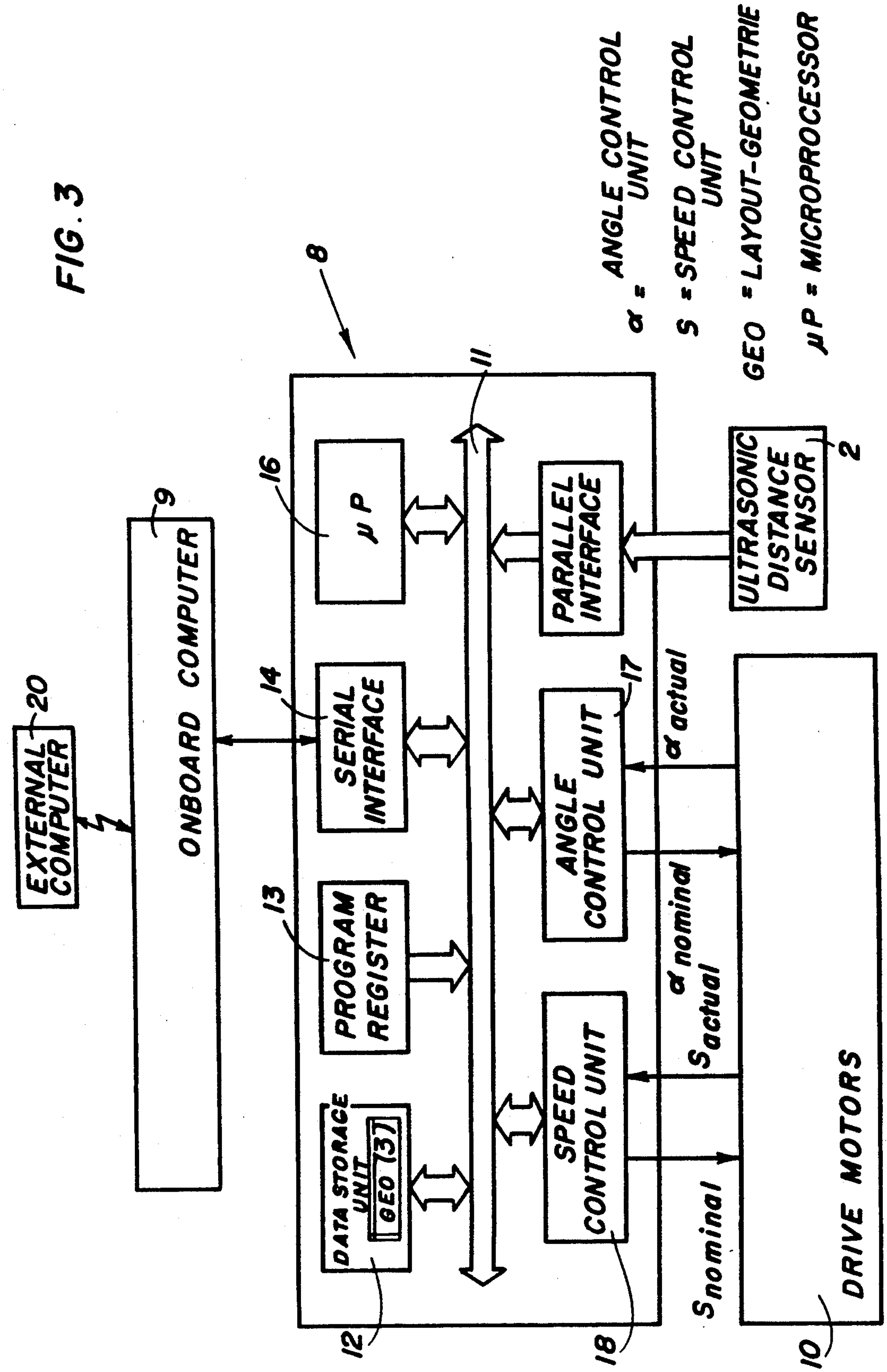
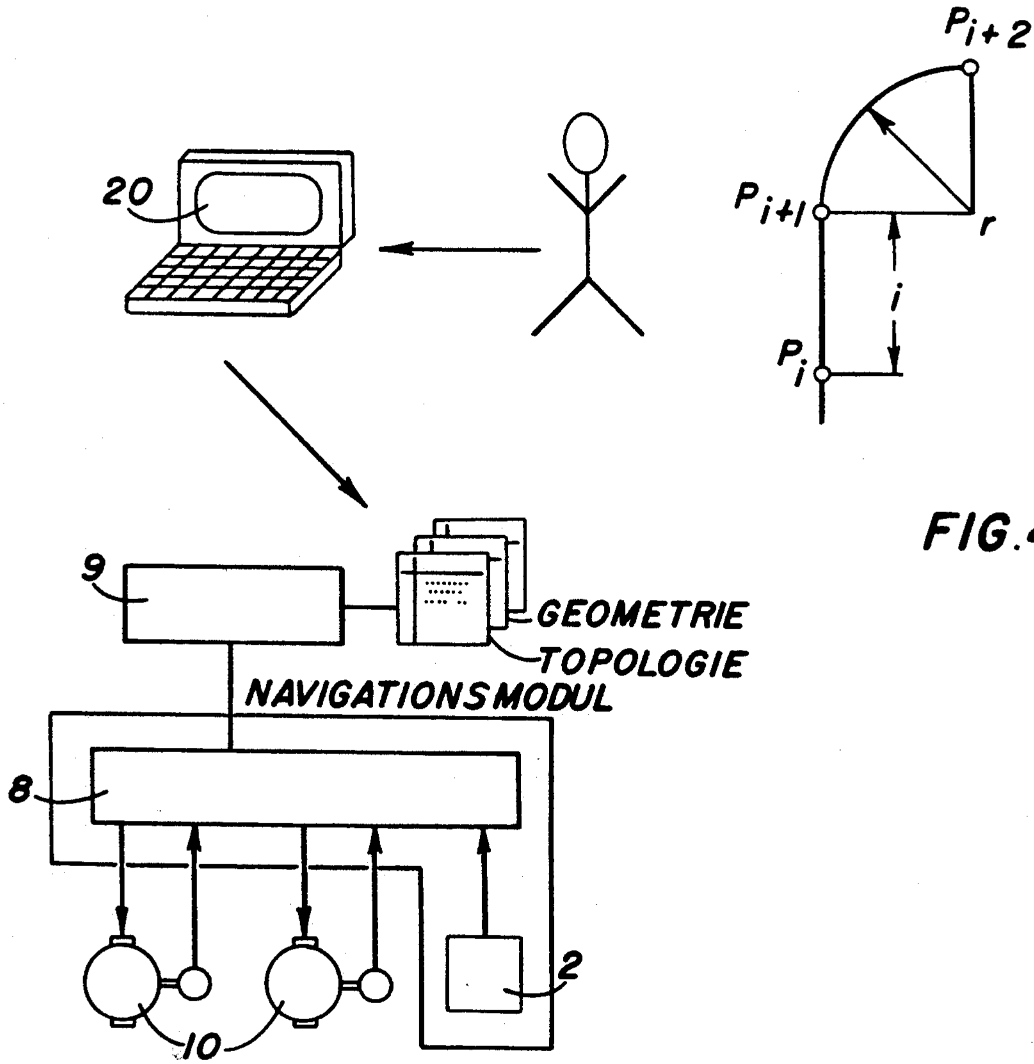


FIG. 3


EXTERNAL COMPUTER
20
ONBOARD COMPUTER
9
8
16
μP
14
SERIAL INTERFACE
13
PROGRAM REGISTER
DATA STORAGE UNIT
GEO (3)
12
11
PARALLEL INTERFACE
ANGLE CONTROL UNIT
17
SPEED CONTROL UNIT
18
ULTRASONIC DISTANCE SENSOR
2
α actual
α nominal
S actual
S nominal
DRIVE MOTORS
10
α = ANGLE CONTROL UNIT
S = SPEED CONTROL UNIT
GEO = LAYOUT-GEOMETRIE
μP = MICROPROCESSOR



P_{i+2}
20
P_{i+1}
r
i
P_i
9
GEOMETRIE
TOPOLOGIE
NAVIGATIONSMODUL
8
2
10

FIG. 4

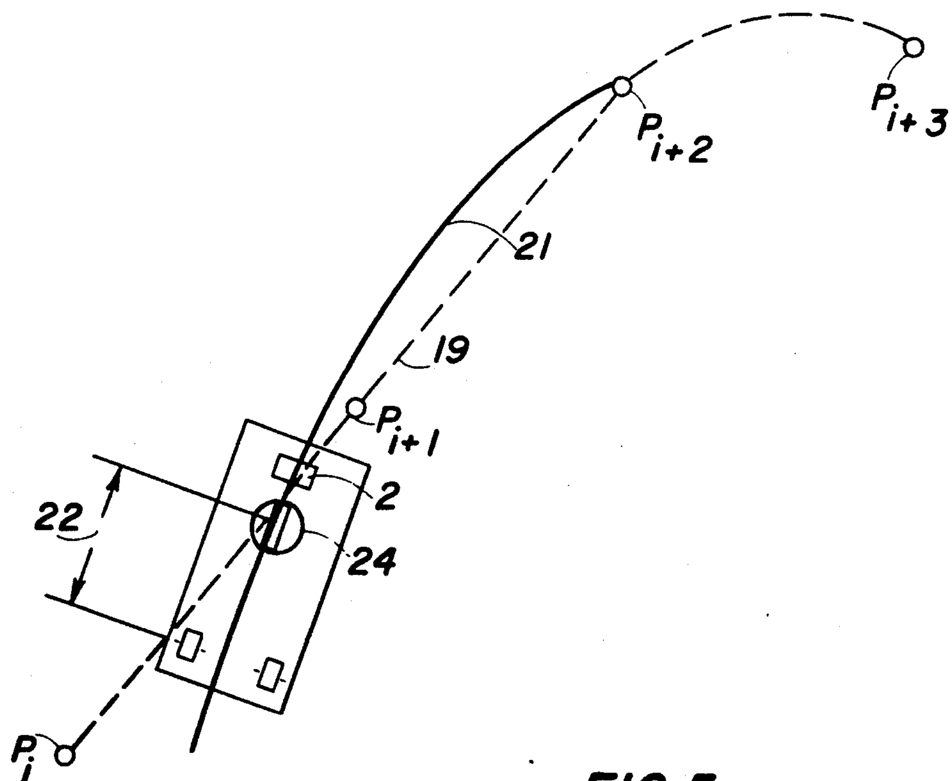


FIG. 5

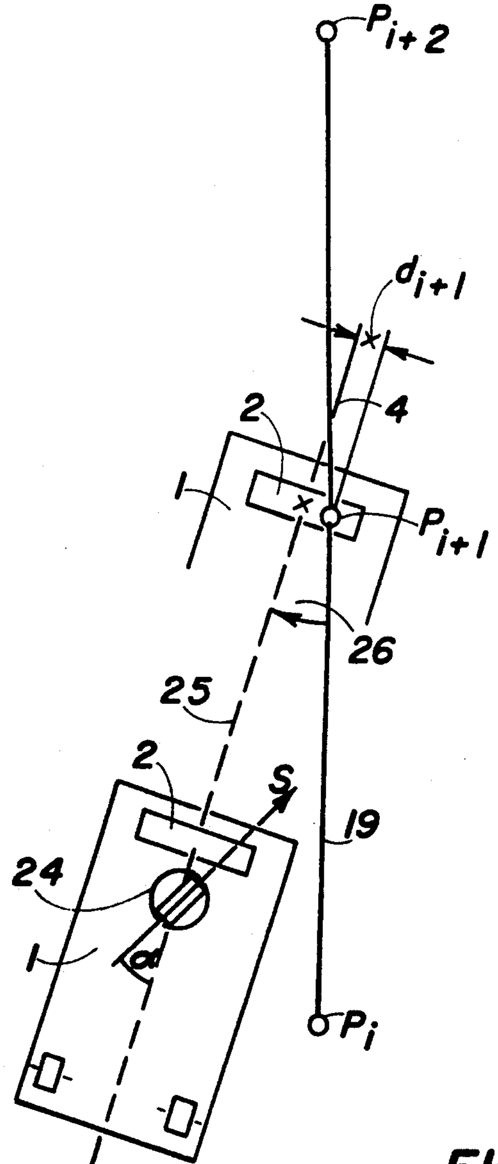
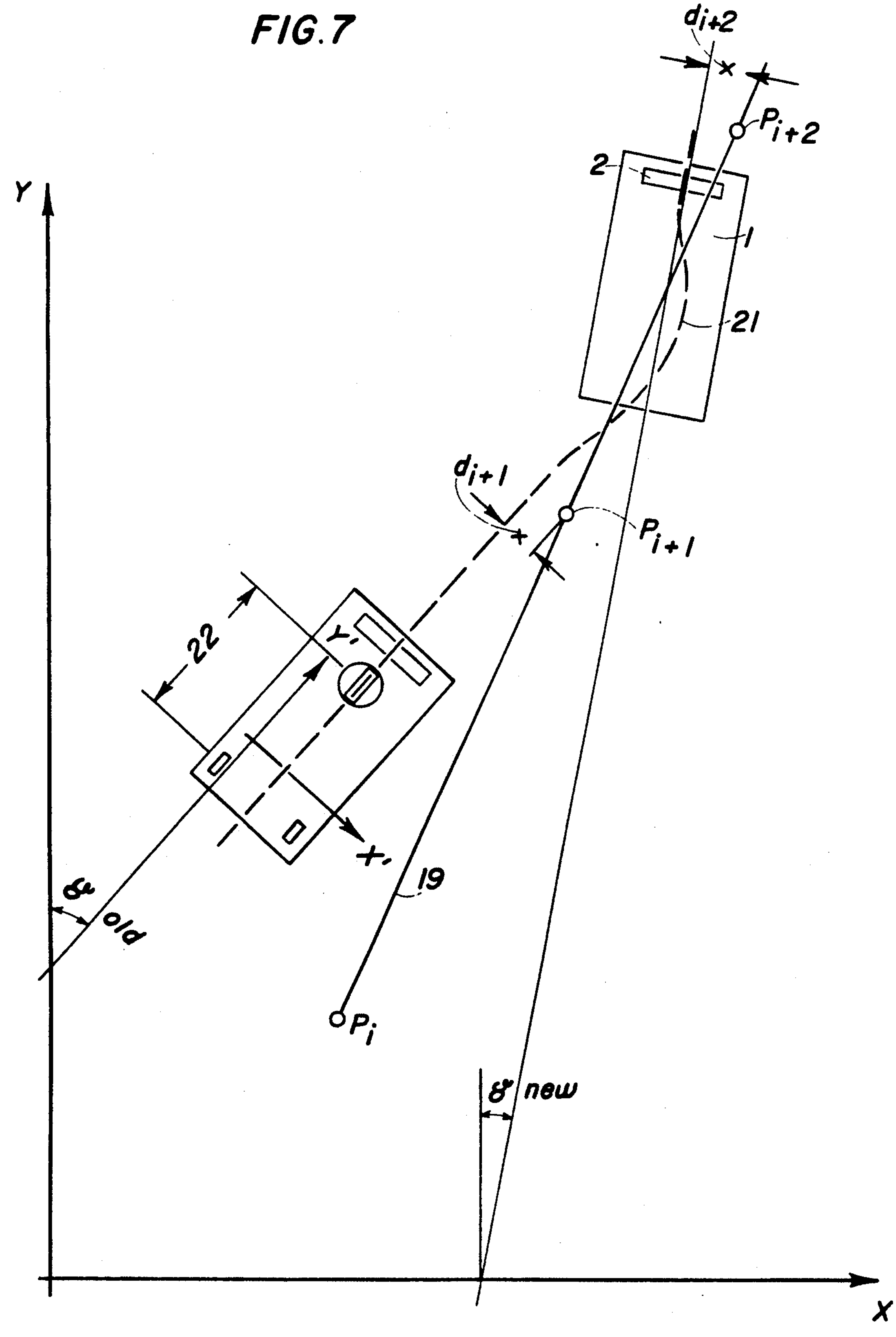


FIG. 6

FIG. 7



NAVIGATION SYSTEM AND PROCESS FOR GUIDING UNMANNED INDUSTRIAL TRUCKS WITHOUT GUIDE WIRE

FIELD AND BACKGROUND OF THE INVENTION

The present invention pertains to a navigation system and process for self-guiding unmanned industrial trucks with any desired wheel configuration without a guide wire, for free movement on paths and in curves along a virtual reference. The path having at least one straight and/or curved section, wherein floor-installed discrete elements are provided which are in operative connection with the vehicle's internal control device via the vehicle's internal sensory analysis system.

It has been known for many years that the traffic lanes of unmanned industrial trucks can be marked by current-carrying wires in the traveled floor surface and that these wires can be inductively scanned by means of the vehicle's internal sensors or coils for finding the lane. This technology, called "inductive guiding", has the particular disadvantage that construction of the traveled sections requires expensive mechanical and electrical preparation of the floor, e.g., the milling of grooves, laying of wires, pouring out and grinding of the grooves, etc., in order to install the inductive lane loops in the floor surface. Fully aside from the often undesired damage to new shop floors which occurs in this connection, the time and cost involved are in many cases unacceptable.

Another method for guiding unmanned industrial trucks on predetermined guide paths, known as dead reckoning navigation, consists of composing the paths of a plurality of short, straight section elements which, placed next to each other, represent a polygonal course. Steering is influenced such that each section element is traveled through with the industrial truck having a defined steering angle. By establishing a mathematical or trigonometric connection between the speed traveled and the aetual steering angle values α, it is possible to calculate the change in the spatial position of the industrial truck. It has been clearly established in practice, as an essential disadvantage of this principle of guiding, that the calculation of the spatial position of the industrial truck based on a starting point according to dead reckoning navigation is subject to an inaccuracy which increases over the entire travel section and is caused by a plurality of parameters that are not taken into account, e.g., unevennesses of the floor, vehicle tolerances, inexactitude of the angle and displacement measurements, etc. Since it is usually impossible in practice to accurately determine all the parameters which cause the error because of the costs and apparatuses which such measurements would require, free travel sections without guiding medium can be realized according to this principle of dead reckoning navigation only over short lengths ranging from 5 to a maximum of 10 m.

Experience showing that navigation along longer sections requires measurement of the ambient conditions is based on the above. In consideration of these relationships, distance sensors based on ultrasound or laser beams for scanning room walls or spatial distance marks, or optical sensors, for example, laser scanners, for scanning guide beams or bar codes arranged in space, have been suggested. These methods require that the actual measuring sections between the industrial truck and the room walls or the spatial marks be always free, and they must not be disturbed and consequently interrupted by persons, other vehicles, objects, or merchandise. Therefore, the conditions occurring in production and material handling facilities permit the use of this method in very few cases only.

The discovery that this disadvantage can be avoided by scanning floor marks was already taken into account in European Patent Application No. 0,193,985. It was suggested in this application that the floor serving as a travel surface be provided in the area of the traffic lanes with a geometric surface grid of marking elements which are scanned by means of a sensory analysis system arranged in the front part of the vehicle, and the values thus determined are trigonometrically linked for steering correction and guiding of the industrial truck. The relatively short grid distance between the individual marking elements, which approximately corresponds to the width of the vehicle, ensures independence of the path to be traveled from the geometric marking grid, as a result of which the path may extend in any preselectable pattern. However, the stationary floor installation of the marking points of the geometric surface grid, whose number may reach several hundred, depending on the existing space conditions and the length of the course to be traveled, represents an absolute maximum of expenditure in terms of means and cost, which is acceptable only in individual cases in which continuously varying travel courses are required. However, this undoubtedly represents an exception, because the trucks usually have to travel on fixed travel courses between existing production facilities and machines. Aside from this, due to the geometric surface pattern of the grid points with absolutely equal distances between them, which pattern is to be strictly maintained, and the absolutely perpendicular arrangement of the vertical and horizontal lines formed by the individual grid points in the surface, the floor installation of the marking elements requires utmost precision and care on the part of the installers, which is ultimately reflected in its enormous costs.

SUMMARY AND OBJECT OF THE INVENTION

Based on this state of the art, it is an object of the present invention to provide—on the smallest possible floor space, using the smallest possible amount of materials and at the lowest possible cost—a navigation system and process for determining and changing the travel course of self-guided industrial trucks, which system and process are not susceptible to malfunction under external effects, wherein the system is based exclusively on the floor without requiring continuous guiding lanes or multidimensional geometric guide patterns (surface pattern), and permits free travel with linear and/or curved movements along any mathematically or geometrically definable path with relatively close lane tolerances, and in which the travel course can be preset, expanded, and changed on the site with a minimum amount of mechanical work in connection with the tracing of the travel course with the simplest possible means, and in the shortest possible time.

According to the present invention, the above-described task is accomplished by means of a navigation system including a plurality of floor-installed discrete elements which are in operative connection with an internal path control device of the vehicle. The discrete elements for course correction are arranged at spaced locations exclusively along the area of the reference path forming a linear chain defining a plurality of reference points. The distance between the navigation reference points is either regular or irregular and relatively great and equal to a multiple of the wheel base of the vehicle. An outboard sensory analysis system is provided which exclusively determines distances for measuring the distance between the longitudinal axis of the truck and the navigation reference point. Data or coordinate values of the nominal reference path are fed into a path guiding computer along with navigation reference points by means of wireless or wire-type meter data coupling via at least one external computer.

The method of the invention includes the storage of nominal path curves in the vehicle and coordinates of navigation reference points relative to a spacially fixed system of coordinates x,y as a set of geometric data. The absolute angular position gamma (γ) is determined for the truck in the plane by measuring the distance between the longitudinal axis of the industrial truck and the center point of a navigation reference point p at two consecutive navigation reference points P_i and P_{i+1}. The geometric data is transformed on board into correction paths by means of the deviation d_i between the longitudinal axis of the industrial truck and the center of the navigation reference point P and the angle gamma. These are measured at a navigation reference point P_i, with the correction path exactly meeting the next navigation reference point P_{i+1}. The vehicle-related nominal values $S_{nominal}$ and $\alpha_{nominal}$ are calculated from the correction paths and at least one steering motor and/or drive motor are programmed with the axis nominal values $S_{nominal}$ and α for travelling to the next navigation reference point P_{i+1}. Additional feedback in the space control loop is provided simultaneously with the axis control by the transformation of the axis actual values S_{actual} and α_{actual} into space coordinates x,y, gamma and controlling at least one steering motor and/or drive motor of the industrial truck in the space coordinates. The procedures are continuous during the further travel of the industrial truck.

The design according to the present invention offers the following advantages over the state of the art:

no optical scanning of the floor is performed, which ensures insensitivity to soiling or mechanical stress of the floor;

no walls are scanned, as a result of which application of the present invention is also possible in places where there are no walls (outside use) or where walls cannot be scanned because of obstacles, e.g., other vehicles;

there are no rotating precision parts in the path sensor, as a result of which application is possible even under the hardest conditions;

there are no optical sensors, as a result of which application is possible even in dusty and dirty air;

there are only a few navigation reference points in the floor, and a navigation module in the industrial truck, and these units are very inexpensive.

Further advantageous embodiments and further improvements of the object of the invention will become apparent from the claims and the description.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its uses, reference is made to the accompanying drawings and descriptive matter in which a preferred embodiment of the invention is illustrated.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a schematic diagram of an industrial truck with the association of the vehicle's internal sensory analysis system with a navigation reference point according to the present invention;

FIG. **2** is a schematic representation of a vehicle's internal ultrasonic distance sensor;

FIG. **3** is a block diagram of the control unit of an industrial truck according to FIG. **1**;

FIG. **4** is a diagram defining the parameters of a travel course geometry, which are to be preset by the user;

FIG. **5** is a schematic representation of the floor structure of a travel section with a nominal path (reference path) and a correction path with schematic indication of an industrial truck with three-wheel configuration to be moved;

FIG. **6** is a schematic diagram of an industrial truck according to FIG. **1**, which is to be moved on the correction path, with angular deviation between an actual path and a nominal path;

FIG. **7** is a schematic diagram of a compensating movement of an industrial truck according to FIG. **1** between two navigation reference points on an actual curve for course correction with representation of fixed space coordinates and offset space coordinates.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An industrial truck or any self-guided vehicle **1** shown schematically in FIG. **1** is equipped with at least one steering motor and at least one drive motor in the known manner, which is therefore not shown and described in greater detail. The number of steering motors and drive motors used depends on the chassis configuration and the wheel arrangement(s). The lower side of the industrial truck **1** is equipped—preferably in its front area—with a distance-detecting sensory analysis system **2**.

As is indicated in FIG. **1**, said sensory analysis system **2** is associated with navigation reference points P embedded in the floor **3** for measurement purposes. The reference points form a linear formation chain and are embedded in the floor at spaced locations, so that their surface is flush with the floor surface or is slightly lower. Permanent magnets—preferably in a size of up to 1 cm in diameter—as well as active and/or passive data storage media of an identification system (also called plaquettes, transponders or code carriers) may be used as said navigation reference points P. Said navigation reference points P preferably consist of materials that can be scanned inductively.

The sensory analysis system shown in the embodiment according to FIG. **2** is preferably designed as ultrasonic distance sensors **2** operating on a magnetostrictive basis. This system operates by utilizing the magnetostrictive effect which is evaluated by ultrasonic travel time measurement for determining the position as will be described below.

Said ultrasonic distance sensor **2** consists of a rod **5** which is arranged at right angles to the vehicle's longitudinal axis **4** and in which a tensioned wire **6** is located. A current impulse is sent to said wire **6** by an impulse generator arranged in a schematically indicated sensor control device 7. On passing over a navigation reference point P, which is designed, for example, as a permanent magnet, a magnetostrictive effect appears at the point of the wire 6 which is located above said navigation reference point P. This results in an ultrasound impulse which propagates to the ends of the wire. The travel time of this ultrasound impulse is measured by an evaluating electronic unit incorporated in the sensor control device 7 and represents an indicator of the lateral distance between the vehicle's longitudinal axis 4 and the center of said navigation reference point P. It is thus possible to determine the lateral offset with which the actual navigation reference point P is traversed by said industrial truck 1 in a simple manner.

Even though the principle of the physical measuring effect of such a sensor is known, the discovery that this can surprisingly be used for the free navigation of an industrial truck represents an absolute novelty. The use of other distance-determining sensors, e.g., linear arrays, etc., with the width of the greatest side tolerance to be determined, for distance measurement is, of course, also within the scope of the present invention. However, these are very expensive compared with said ultrasonic distance sensor 2 and require more sophisticated measuring circuits.

According to the block diagram shown in FIG. 3, the control device of said industrial truck consists essentially of a path guiding computer 8, an onboard computer 9, as well as the above-mentioned steering motors and drive motors with their power end stages, which are indicated only schematically with the reference numeral 10. Said path guiding computer 8 is equipped with a microprocessor bus 11 to which a data storage unit 12, a program register 13, at least one serial interface 14 and one parallel interface 15, a microprocessor 16, at least one angle control unit 17, and one speed control unit 18 are connected. Said speed control unit 18 is data-coupled to the power end stages of said drive motors 10 for transmitting measured and control speed values s_{actual} and $s_{nominal}$. The angle control unit 17 is data-coupled to said power end stages of said steering motors 10 for transmitting the measured and control values α_{actual} and $\alpha_{nominal}$. Said ultrasonic distance sensor 2 is connected to said microprocessor 16 via a microprocessor bus 11 for transmitting its measured values via said parallel interface 15 and said onboard computer 9 at the serial interface 14 for entering and acknowledging travel instructions.

Said onboard computer 9 can be coupled with at least one external computer 20 for wireless and/or wire-bound data transmission for presetting and storing data and/or coordinate values of said navigation reference points P and/or at least one nominal reference path 19. Said external computer 20 is preferably designed as a laptop PC with CAD. This makes it possible for the user of said industrial trucks 1 himself to generate the travel section or expansions and/or changes of said travel sections and to store them in the data storage unit 12 of said path guiding computer 8.

FIG. 4 shows a greatly simplified travel course geometry with a definition of the user-defined parameters. This travel course consists of a straight section with length 1 extending between the navigation reference points P_i and P_{i+1} and a curved section extending between the navigation reference points P_{i+1} and P_{i+2}, designed as a curved path with radius r.

FIG. 5 shows schematically the floor structure of a travel section with a nominal reference path 19 defined by the navigation reference points P_1–P_{i+3} as well as a correction path 21 to the navigation reference point P_{i+2}, which is traveled by said industrial truck 1 based on a detected deviation from said nominal reference path 19. It is particularly clearly visible here that said navigation reference points P are arranged, in the area of said planned nominal reference path 19, along said reference path in a linear chain-shaped formation. The distances between said individual navigation reference points P may be selected as regular and/or irregular distances and may be relatively great, which was not possible before. They usually equal a multiple of—preferably 4 to 15 times—the wheelbase 22 of said industrial truck 1 and are in the range of between 8 and 30 m.

The linear formation chain of said navigation reference points P may, of course, be formed by a plurality of individual sections which are designed as straight sections and/or mathematically or geometrically definable curves that may have any desired curvature, e.g., elliptical segments, parabolic segments, etc.

The schematic diagram shown in FIG. 6 shows, for example, an industrial truck 1 with a three-wheel configuration and a front steered wheel 24. The industrial truck 1 travels on an actual path 25 with the angular deviation 26 from the nominal reference path 19 formed by the three navigation reference points P_i through P_{i+2} in the direction of the second navigation reference point P_{i+1}, which it crosses with a lateral distance d_{i+1} between the vehicle's longitudinal axis 4 and said navigation reference point P_{i+1}. The steering angle alpha is indicated as an example by a position of said steered wheel 24 that deviates from the direction of said actual path 25. The position of said steered wheel 24 must, of course, be located in the direction of said actual path 25 traveled, which is indicated in dash-dotted line.

FIG. 7 illustrates the principle of a compensating movement of an industrial truck 1 between said navigation reference points P_{i+1} and P_{i+2}, wherein a lateral distance of d_{i+1} is measured on passing over the second navigation reference point P_{i+1} and a lateral distance of d_{i+2} is measured on passing over the third navigation element P_{i+2}. Starting from the origin of the space coordinates x, y, said navigation reference point P_{i+1} is passed over in space with the vehicle in the angular position γ_{old}, and a new correction path 21 is generated on the basis of the new distance value d_{i+1} now measured. Said industrial truck 1 performs a compensating movement on this correction path 21, and said correction path 21 traveled should meet the next navigation reference point P_{i+2} as accurately as possible. However, nonmeasurable deviations caused by interfering effects which again lead to a lateral deviation d_{i+2}, appear during this travel.

The mode of action of the navigation system and process according to the present invention will be explained in greater detail below.

The nominal path curves 19 for said unmanned industrial trucks 1 are generated via a CAD system of the external computer 20, and said nominal path curves are stored as a set of geometric data (Geo) in space coordinates in the memory 13 of said path guiding computer 8, and they form the nominal values for controlling the vehicle. The set of geometric data also contains the coordinates of said navigation reference points P.

These nominal values of the path are first converted into correction paths 21 rather than being immediately converted into vehicle-related nominal values $S_{nominal}$ and $\alpha_{nominal}$. Said correction paths 21 are formed on the basis of the deviations d_i at a reference point P_i so that said correction path **21** exactly meets said navigation reference point P_{i+1}. The axis nominal values $S_{nominal}$ and $\alpha_{nominal}$ of said industrial truck **1** are calculated from said correction paths **21** in said path guiding computer **8**, and they are sent to the subordinate elements, i.e., steering motors and/or drive motors **10**, and used for control.

During the travel from P_i to P_{i+1}, there is feedback in the space control loop by converting the actual values S_{actual} and alpha$_{actual}$ into space coordinates x, y, γ, and controlling the steering motors and/or drive motors in space coordinates, in addition to the axis regulation. At the next reference point element P_{i+1}, a lateral deviation d_{i+1} occurs as a consequence of the inevitable path deviations. A section S_{max} is present for each navigation reference point P as a safety function, after which emergency stopping of said industrial truck **1** is induced if said navigation reference point P is not detected.

Knowledge of the actual dihedral angle γ is needed to determine said correction path **21**. This angle can be determined as follows:

Relative to the system of coordinates x, y, which is fixed in space, a system of coordinates x', y' of the vehicle, which is rotated through the angle α_{old} compared with x, y, is formed during the passage over a navigation reference point P_i. As was explained above, the distance d_i is measured by means of said distance sensor **2**.

During the travel from P_i to P_{i+1}, the components of the distance traveled s in the x' direction and the y' direction are formed. These are designated by $\Delta x'$ and $\Delta y'$. These values are formed by performing a coordinate transformation

$$x' = f(s, \alpha)$$

$$y' = f(s, \alpha)$$

$$\gamma' = f(s, \alpha)$$

adapted to the kinematics of the vehicle, wherein the distance traveled s and the steering angle α in the vehicle are measurable. The following equations are now used for a three-wheel vehicle with a point guided in the center of said steered wheel **24**:

$$X' = X_o' - \int_o^t \dot{s} \cdot \sin(\gamma + \alpha)dt$$

$$Y' = Y_o' + \int_o^t \dot{s} \cdot \cos(\gamma + \alpha)dt$$

$$\gamma' = \gamma_o' + \int_o^t (1/l) \cdot \dot{s} \cdot \sin\alpha dt$$

The distance d_{i+1} is again measured by means of said distance sensor **2** when passing over point P_{i+1}. Both γ_{new} and γ_{old} can be determined from these values as follows:

$$\gamma_{new} = f(d_1, d_2, \Delta x', y', \gamma')$$

$$\gamma_{old} = f(d_1, d_2, \Delta x', \Delta y', \Delta\gamma').$$

The process described makes it possible to calculate the position of said industrial truck **1** in the space coordinates, i.e., the actual values of x, y, and γ in said path guiding computer **8** by measuring the section traveled s, the steering angle α, and the distance values d of said distance sensor **2**.

The present invention is clearly not limited to the embodiments shown in the figures and described in the description. Numerous modifications, expansions, and refinements of process steps, as well as design embodiments are evidently also within the scope of the present invention. For example, installing two path sensors in said industrial truck **1** one behind the other, as a result of which greater accuracy of angle measurements are achieved, is conceivable. Arranging two navigation reference points P at relatively closely spaced locations one behind the other in the floor, which substantially simplifies the calculation of the angle, is also within the realm of technical expertise. Finally, using other physical effects by selecting navigation reference points P made of other materials and sensors corresponding to these for the measurement, e.g., sensors operating according to the optoelectronic principle, is also conceivable.

A very particular effect of the navigation system and process according to the present invention is that the user is able to select the floor-embedded arrangement of the navigation reference points perfectly freely by selecting any desired straight and/or nonstraight paths and arbitrarily great distances. Thus, he can install them by taking into account all the machines present and the travel path conditions, e.g., travel path marks, covers for lines and chip canals or chip conveyors, gulleys, etc., without being bound to a defined laying pattern with permanently predetermined distances.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A navigation system for guiding unmanned industrial trucks having any desired wheel configuration with a wheel base, the system providing free movement on paths without wires along at least one of a curved path and a straight path, comprising: a plurality of floor-installed discrete elements positioned at individually variable spaced locations along a reference path forming navigation reference points, P distances between any two of said navigation reference points being independent of any distance between any two other of said navigation reference points, an on-board sensory analysis system in operative connection with said discrete elements for determining distance travelled by said industrial truck and for measuring the distance between the longitudinal axis of the industrial truck and one of said navigation reference points; and, vehicle internal control means for receiving signals from said internal sensor analysis system and for generating signals for correcting the course of the industrial truck.

2. A navigation system according to claim **1**, wherein said on-board vehicle internal sensory analysis system is an ultrasonic path sensor and said ultrasonic path sensor operating according to the magnetostrictive principle.

3. A navigation system according to claim **1**, wherein the distance between said navigation reference points P is at least four time and no greater than 15 times the wheel base of the industrial truck.

4. A navigation system according to claim 1, wherein the distance between said navigation reference points P is at least eight meters and no more than 30 meters.

5. A navigation system according to claim 1, wherein said navigation reference points P are designed as permanent magnets.

6. A navigation system according to claim 5, wherein said navigation reference points P are of a cylindrical shape having a diameter less than or equal to 1 cm.

7. The navigation system according to claim 1, wherein said navigation reference points P are designed as data storage media of an identification system.

8. A navigation system according to claim 1, wherein said navigation reference points P are formed of materials that can be scanned inductively.

9. A navigation system according to claim 1, wherein said navigation reference points P are imbedded in the floor positioned to not project over a surface of the floor.

10. A navigation system according to claim 1, wherein said vehicle internal path control means includes at least one path guiding computer data coupled with said sensory analysis system to generate a correction path signal for leading said vehicle to a next one of said navigation reference point P.

11. A navigation system according to claim 1, wherein data or coordinate values of said reference path and said navigation reference points P are fed to a guiding computer associated with said vehicle internal path control means, said data or coordinate values and said navigation reference points P being fed into said path guiding computer by one of a wireless and wire media coupling via at least one external computer.

12. A navigation system according to claim 1, wherein each of said navigation reference points P include a safety section S_{max} for inducing emergency stopping of the industrial truck or for protection by the distance-determining sensor analysis system.

13. A navigation system in accordance with claim 1, wherein:

said vehicle internal control means further generates a present position and a present direction of the industrial truck from said signals from said on board sensory analysis system, said generated present position and present direction of the industrial truck being used to generate said signals for correcting the course of the industrial truck.

14. A navigation system comprising:

a reference path;

discrete reference points positioned at individually variable separate locations on said reference path, distances between any two of said discrete reference points being independent of any distance between any two other of said discrete reference points;

a self-guided vehicle;

a sensory analysis system for detecting distance between said discrete reference points and said self-guided vehicle;

a speed control means for measuring and controlling speed and distance travelled by said self-guided vehicle;

angle control means for measuring and controlling a steering angle of said self-guided vehicle; and

on-board computer means for determining said reference path from external data and for commanding said speed control means and said angle control means in order to move said self-guided vehicle along said reference path to a next of said reference points, said on-board computer means analyzing said measured speed and distance, said measured steering angle and said distance detected by said sensor analysis system to form a correction path to said next reference point is said self-guided vehicle moves away from said reference path.

15. A navigation system in accordance with claim 14, wherein:

said on board computer means further analyzes said measured speed and distance, said measured steering angle and said distance detected by said sensor analysis system to calculate a present position and present direction of the industrial truck, said present position and present direction of the industrial truck being used to form said correction path to said next reference point.

16. A navigation system for guiding unmanned industrial trucks having any desired configuration with a wheel base, the system providing absolutely free movement between a determined starting point and a determined destination point without wires and patterns along at least one of a curved path and a straight path, the navigation system comprising:

a limited number of floor installed discreet elements positioned at spaced locations exclusively in a direction of a reference path to form a linear formation chain of navigation reference points, distances between said navigation reference points being at a function of local disturbance variables of floor surfaces, said distances between said navigation points not being required to be substantially identical, and said distances being of substantially equal or non-equal lengths, a remainder of said floor surfaces being absolutely free of any reference points; on-board sensor analysis system in operative connection with said discreet elements for determining a distance traveled by the industrial truck and for measuring a distance between the longitudinal axes of the industrial truck and one of said navigation reference points; and, vehicle internal control means for receiving signals from said internal sensor analysis system and guiding computer data means coupled with said sensory analysis system for generating signals, and for determining and correcting a position as well as a direction of the industrial truck in space.

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