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MARKER SYSTEM AND CONTROL METHOD

Abstract

A marker system relatively easily ensuring magnetic marker detection reliability is provided. In a marker system where magnetic markers are arranged as spaced along a path where a vehicle travels, in a combination of two magnetic markers adjacent to each other in a lateral direction and laid on a main road and a side road, respectively, the combination has a combination of different magnetic polarities when a space distance in the lateral direction is equal to or shorter than 0.3 meters, and the combination has a combination of same magnetic polarities when the space distance in the lateral direction exceeds 0.3 meters.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to Japanese application number 2024-021396 filed in the Japanese Patent Office on Feb. 15, 2024, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to a marker system in which magnetic markers are arranged on a traveling road so as to be detectable by a vehicle while traveling, and a vehicle control system.

[0003] Conventionally, a marker system in which magnetic markers are arranged along a traveling road so as to be detectable by a vehicle has been known (for example, refer to Japanese Unexamined Patent Application Publication No. 2017-199247). This marker system is targeted, for example, for a vehicle including a magnetic sensor unit including a detection area elongated in a vehicle-width direction. The vehicle detects a magnetic marker while traveling, and also measures a lateral deviation with respect to the detected magnetic marker. In the marker system, for example, a steered wheel is controlled so that the lateral deviation with respect to the magnetic marker is brought closer to zero, thereby achieving vehicle's automatic traveling along the traveling road.

SUMMARY OF THE INVENTION

[0004] However, the conventional marker system has the following problem. That is, for example, in a branch road or a merge road that runs oblique to a main road, there is a possibility that a magnetic marker arranged on the main road and a magnetic marker arranged on the branch road or the merge road may be laterally aligned and, due to magnetic mutual interference between adjacent magnetic markers, there is a possibility that processing load for reliably detecting magnetic markers increases and the processing load for vehicle control also increases.

[0005] The present invention was made in view of the conventional problem described above, and is to provide a marker system that can relatively easily ensure magnetic marker detection reliability and a control method for achieving highly-accurate vehicle control.

[0006] One aspect of the present invention is directed to a marker system comprising a plurality of magnetic markers arranged as spaced along a plurality of paths where a vehicle travels, wherein

[0007] in a combination of two magnetic markers of the plurality of magnetic markers laid on different paths of the plurality of paths and adjacent to each other in a lateral direction orthogonal to a path direction, a combination of magnetic polarities of the two magnetic markers varies in accordance with a distance between the two magnetic markers, and [0008] i) while the combination of the magnetic polarities of the two magnetic markers is a combination of different magnetic polarities when the distance between the two magnetic markers is equal to or shorter than the predetermined threshold value, the combination of the magnetic polarities of the two magnetic markers is a combination of same magnetic polarities when the distance between the two magnetic markers exceeds the predetermined threshold value, or [0009] ii) while the combination of the magnetic polarities of the two magnetic markers is the combination of different magnetic polarities when the distance between the two magnetic markers is below the predetermined threshold value, the combination of the magnetic polarities of the two magnetic markers is the combination of same magnetic polarities when the distance between the two magnetic markers is equal to or longer than the predetermined value.

[0010] The marker system according to the present invention has one technical feature in the combination of magnetic polarities of the two magnetic markers adjacent to each other and laid on different paths. In the above-described two magnetic markers, the combination of magnetic polarities varies in accordance with whether the distance between the two magnetic markers is equal to or shorter than or below the predetermined threshold value. i) While the combination of the magnetic polarities of the two magnetic markers is the combination of different magnetic polarities when the distance between the two magnetic markers is equal to or shorter than the predetermined threshold value, the combination of the magnetic polarities of the two magnetic markers is the combination of same magnetic polarities when the distance between the two magnetic markers exceeds the predetermined threshold value, or ii) while the combination of the magnetic polarities of the two magnetic markers is the combination of different magnetic polarities when the distance between the two magnetic markers is below the predetermined threshold value, the combination of the magnetic polarities of the two magnetic markers is the combination of same magnetic polarities when the distance between the two magnetic markers is equal to or longer than the predetermined value.

[0011] As the two magnetic markers adjacent to each other approach closer to each other, the possibility of occurrence of magnetic interference increases. If the magnetic polarities of these two magnetic markers are the same, the magnetic distribution becomes broad due to magnetic interference acted from two magnetic markers, and a possibility occurs in which peaks supposed to occur directly above magnetic markers are difficult to detect. On the other hand, if the magnetic polarities of the two magnetic markers adjacent to each other in the width direction of the path are different, detection of peaks in the magnetic distribution are easy even if magnetic interference occurs, and each magnetic marker can be detected with high reliability. If the magnetic marker can be detected with high reliability, it is possible to improve stability of vehicle control using the magnetic markers.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0012] FIG. **1** is a descriptive diagram of a marker system in a first embodiment;

[0013] FIG. **2** is a perspective view of a magnetic marker in the first embodiment;

[0014] FIG. **3** is a configuration diagram of a vehicle in the first embodiment;

[0015] FIG. **4** is a graph of an approximate curve representing a distribution of magnetic measurement values in a vehicle-width direction derived from one magnetic marker in the first embodiment;

[0016] FIG. **5** is a descriptive diagram of a mode of laying magnetic markers at a branching section in the first embodiment;

[0017] FIG. **6** is a descriptive diagram of a mode of laying magnetic markers at a merging section in the first embodiment;

[0018] FIG. **7** is a first graph of an approximate curve representing a distribution of magnetic measurement values in the vehicle-width direction derived from laterally-aligned two magnetic markers with same magnetic polarities in the first embodiment;

[0019] FIG. **8** is a second graph of an approximate curve representing a distribution of magnetic measurement values in the vehicle-width direction derived from laterally-aligned two magnetic markers with same magnetic polarities in the first embodiment;

[0020] FIG. **9** is a graph of an approximate curve representing a distribution of magnetic measurement values in the vehicle-width direction derived from laterally-aligned two magnetic markers with different magnetic polarities in the first embodiment;

[0021] FIG. **10** is a diagram describing a relation between a space between laterally-aligned two magnetic markers and a combination of magnetic polarities in the first embodiment;

[0022] FIG. **11** is a flow diagram depicting a flow of vehicle traveling control in the first

embodiment;
[0023] FIG. **12** is a descriptive diagram depicting a movement of the vehicle passing through the branching section in the first embodiment;
[0024] FIG. **13** is a descriptive diagram depicting a movement of the vehicle going to a branch road in the branching section in the first embodiment;
[0025] FIG. **14** is a descriptive diagram depicting a movement of the vehicle passing through the merging section while traveling a main road in the first embodiment;
[0026] FIG. **15** is a descriptive diagram depicting a movement of the vehicle merging to the main road in the merging section in the first embodiment;
[0027] FIG. **16** is a descriptive diagram depicting the structure of a traveling road in a second embodiment;
[0028] FIG. **17** is a perspective view of a magnetic marker with an RFID tag attached thereto in in the second embodiment;
[0029] FIG. **18** is a descriptive diagram of a mode of laying magnetic markers in the branching section in a third embodiment;
[0030] FIG. **19** is a descriptive diagram of a mode of laying magnetic markers in the merging section in the third embodiment; and
[0031] FIG. **20** is a flow diagram depicting a flow of vehicle traveling control in the third embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0032] Modes of the present invention are specifically described by using the following embodiments.

First Embodiment

[0033] The present embodiment is an example regarding marker system **1** in which magnetic markers **10** are arrayed along a plurality of paths, and a vehicle control method. Details of this are described by using FIG. **1** to FIG. **15**.
[0034] Marker system **1** (FIG. **1**) of the present embodiment is, for example, a system of magnetic markers **10** laid in traveling road **100** of vehicle **2**. Traveling road **100** is, for example, a traveling road configuring a BRT (bus rapid transit). On traveling road **100** to which marker system **1** is applied, vehicle **2** (bus vehicle) travels automatically as detecting magnetic markers **10**. Note that in FIG. **1**, not all magnetic markers **10** arrayed along traveling road **100** are depicted and they are partially omitted in the drawing.
[0035] Traveling road **100** is, for example, a one-way circular traveling road having a width of 3 meters. In traveling road **100**, magnetic markers **10** are laid as spaced in a forwarding direction. The present example is an example in which the space between magnetic markers **10** is set at 2 meters. Marker system **1** is used for vehicle **2** to circulate circular traveling road **100**. Traveling road **100** has a section where side road **120** is provided to main road **110**. Traveling road **100** forming main road **110** and side road **120** forms one example of a plurality of paths where vehicle **2** travels. Side road **120** forms one example of a path branching from a path forming main road **110** and one example of a path merging into a path forming main road **110**.
[0036] In traveling road **100** exemplarily depicted in FIG. **1**, there are two types of traveling route of vehicle **2**. A first traveling route is a traveling route of circulating over main road **110** not entering side road **120**. A second traveling route is a traveling route of circulating over main road **110** via side road **120**. Vehicle **2** traveling the first traveling route is controlled so as to go straight to pass through branching section **121** and not to go to side road **120**. Vehicle **2** traveling the second traveling route is controlled so as to branch to side road **120** in branching section **121** and then merge to main road **110** in merging section **123**.
[0037] Magnetic marker **10** (FIG. **2**) is a columnar-shaped magnet having a diameter of 30 millimeters and a height of 20 millimeters. Columnar-shaped magnetic marker **10** has one end face forming the N pole and the other end face forming the S pole. All magnetic markers **10** on main

road **110** are buried so as to take an attitude with the N-pole end face facing upward. Magnetic markers **10** on main road **110** are each detected on a vehicle **2** side as an N-pole magnet. Although details will be described further below, magnetic markers **10** on side road **120** except part of magnetic markers **10** in branching section **121** and merging section **123** are buried so as to take an attitude with the N-pole end face facing upward. In the following description, a magnetic marker with the N pole facing upward is denoted as **10**N and a magnetic marker with the S pole facing upward is denoted as **10**S.

[0038] Vehicle **2** (FIG. **3**) of the present embodiment is a bus vehicle having a length of 8 meters and a width of 2.3 meters. Vehicle **2** has operating systems such as a steering wheel, accelerator, and brake. Vehicle **2** includes a plurality of actuators (omitted in the drawing) for driving these operating systems and control unit **20** for controlling these actuators. Vehicle **2** can manually travel by a driver and also can travel automatically under control by control unit **20**.

[0039] Vehicle **2** is configured to be able to travel automatically by using magnetic markers **10** laid along traveling road **100**. Vehicle **2** includes magnetic sensor module **3** for detecting magnetic marker **10**. Magnetic sensor module **3** is attached to a front portion of vehicle **2**. Magnetic sensor module **3** performs process for detecting magnetic marker **10** in response to control by control unit **20** (marker detection process).

[0040] Magnetic sensor module **3** is one example of a magnetic detection circuit including a magnetic detection area elongated in the vehicle-width direction. Although not depicted in the drawing, magnetic sensor module **3** is a sensor unit including a plurality of magnetic sensors and a processing circuit that performs arithmetic process. In magnetic sensor module **3**, the plurality of magnetic sensors (omitted in the drawing) are attached to a rod-shaped frame as spaced. Magnetic sensor module **3** is attached to vehicle **2** so that its longitudinal direction is along the vehicle-width direction. The length of rod-shaped magnetic sensor module **3** is close to the length of the vehicle width of vehicle **2**. Magnetic sensor module **3** has a magnetic detection area elongated in the vehicle-width direction. According to magnetic sensor module **3**, it is possible to detect magnetic marker **10** with high reliability irrespective of the lateral deviation of vehicle **2** in traveling road **100**.

[0041] Each magnetic sensor of magnetic sensor module **3** is incorporated so as to be able to measure the magnitude of magnetism acting in a vertical direction. When magnetic sensor module **3** is positioned directly above magnetic marker **10**, a distribution of magnetic measurement values by a plurality of magnetic sensors arrayed in the vehicle-width direction is, for example, as depicted in FIG. **4**. Note that the drawing depicts the magnetic measurement values of each magnetic sensor by approximation by a curve. The horizontal axis in the drawing indicates the vehicle-width direction. As in the drawing, when magnetic sensor module **3** is positioned directly above magnetic marker **10**, the magnetic distribution has a mountain shape with a peak value directly above magnetic marker **10**.

[0042] The processing circuit of magnetic sensor module **3** applies marker detection process to the distribution formed by the magnetic measurement values of each magnetic sensor. In the marker detection process, when there is one peak exceeding a threshold value, for example, in an approximate curve in FIG. **4**, it is determined that one magnetic marker **10** has been detected.

[0043] In the marker detection process, in addition to whether magnetic marker **10** has been detected, the magnetic polarity of detected magnetic marker **10** is determined, and a lateral deviation of vehicle **2** with respect to detected magnetic marker **10** is measured. For example, as in the example of FIG. **4**, each magnetic sensor of magnetic sensor module **3** is configured to output a positive magnetic measurement value in accordance with magnetism acted from N-pole magnetic marker **10**N and output a negative magnetic measurement value in accordance with magnetism acted from S-pole magnetic marker **10**S. In the marker detection process, in accordance with the sign of the peak value when magnetic marker **10** is detected, the magnetic polarity of magnetic marker **10** is determined. Also, in the marker detection process, by identifying the position of the peak value in the vehicle-width direction, the lateral deviation of the vehicle with respect to magnetic marker **10** is identified (measured).

[0044] On performing the marker detection process, magnetic sensor module **3** outputs the process result. The process result includes information on whether magnetic marker **10** has been detected. Furthermore, the process result in the case in which magnetic marker **10** has been detected includes information on the magnetic polarity of detected magnetic marker **10** and information on the lateral deviation with respect to magnetic marker **10**.

[0045] Note that, as described above, magnetic sensor module **3** has the magnetic detection area elongated in the vehicle-width direction. When a plurality of magnetic markers **10** are provided to be aligned in the vehicle-width direction, there is a possibility that the plurality of magnetic markers **10** are included in the magnetic detection area of magnetic sensor module **3**. Magnetic sensor module **3** is configured to be able to output the magnetic polarity and the lateral deviation for each of the plurality of magnetic markers **10** belonging to the magnetic detection area.

[0046] Marker system **1** of the present embodiment has a technical feature in the laying mode of magnetic markers **10** in branching section **121** and merging section **123**. The control method for vehicle **2** of the present embodiment has a technical feature in branching control from main road **110** to side road **120** and merging control from side road **120** to main road **110**. Branching control and merging control of the present embodiment is control using the laying mode of magnetic markers **10** in branching section **121** or merging section **123**.

(Laying Modes of Magnetic Markers)

[0047] The laying mode of magnetic markers **10** in branching section **121** from main road **110** to side road **120** is a mode depicted in FIG. **5**. In branching section **121**, marker array line **124** where magnetic markers **10** are arrayed on side road **120** is obliquely branched from marker array line **114** where magnetic markers **10** are arrayed on main road **110**. In branching section **121**, a space between magnetic markers **10** on main road **110** and magnetic markers **10** on side road **120** in a lateral direction gradually expands toward the forwarding direction of traveling road **100**. Here, the lateral direction means a direction substantially orthogonal to a path direction of main road **110** and side road **120** forming one example of a plurality of paths.

[0048] The laying mode of magnetic markers **10** in merging section **123** from side road **120** to main road **110** is a mode depicted in FIG. **6**. In merging section **123**, marker array line **124** on side road **120** is obliquely connected to marker array line **114** on main road **110**. In merging section **123**, the space between magnetic markers **10** on main road **110** and magnetic markers **10** on side road **120** in the lateral direction gradually reduces toward the forwarding direction of traveling road **100**.

[0049] In branching section **121** and merging section **123**, the space between two magnetic markers **10** aligned in the lateral direction (distance between laterally-aligned magnetic markers **10**) is shorter as the space is closer to branching point **118** or merging point **119** between marker array line **114** on main road **110** and marker array line **124** on side road **120**.

[0050] Here, if the space between laterally-aligned two magnetic markers **10** is ensured to some extent, a distribution exemplarily depicted in FIG. **7** is acquired as the distribution of magnetic measurement values in the vehicle-width direction by magnetic sensor module **3**. With the magnetic distribution exemplarily depicted in this drawing, it is possible to distinguish the peak corresponding to each magnetic marker **10** and detect each magnetic marker **10**.

[0051] On the other hand, when the space between laterally-aligned two magnetic markers **10** is too narrow, as exemplarily depicted in FIG. **8**, the degree of difficulty of detection the peak corresponding to each magnetic marker **10** increases, because magnetic distributions derived from each magnetic marker **10** overlap to become integrated. In the case of the magnetic distribution exemplarily depicted in this drawing, while the presence of a magnetism generation source can be estimated, the degree of difficulty of detection by distinguishing each magnetic marker **10** increases.

[0052] When the space between laterally-aligned two magnetic markers **10** is too narrow, a combination of different magnetic polarities is preferably adopted. In this case, as exemplarily depicted as the distribution of magnetic measurement values in FIG. **9**, a positive peak value appears correspondingly to N-pole magnetic marker **10**N, and a negative peak value appears correspondingly to S-pole magnetic marker **10**S. In this manner, with the combination of magnetic markers **10**N and **10**S with different magnetic polarities, it is possible to relatively easily distinguish and detect each magnetic marker **10** even if the space between magnetic markers **10** adjacent to each other in the lateral direction is similar to that of FIG. **8**.

[0053] The inventors have acquired the following findings through verification experiments and simulations. That is, if the space between magnetic markers **10** adjacent to each other in the lateral direction exceeds 0.3 meters, it is possible to easily distinguish and detect each magnetic marker **10** even with a combination of same magnetic polarities. On the other hand, if the space between magnetic markers **10** adjacent to each other in the lateral direction equal to or shorter than 0.3 meters, in the case of the combination of same magnetic polarities, process load for distinguish and detect each magnetic marker **10** increases.

[0054] To address this, in the present embodiment, combinations of magnetic polarities of two magnetic markers are set as in FIG. **10** in accordance with the space in the lateral direction. The combination of different magnetic polarities is adopted when the space between two magnetic markers **10** is equal to or shorter than 0.3 meters, and the combination of same magnetic polarities is adopted when the space between two magnetic markers **10** exceeds 0.3 meters.

[0055] In the present embodiment, 0.3 meters is exemplarily set as one example of a predetermined threshold value for switching whether the combination of magnetic polarities of laterally-aligned two magnetic markers **10** is set as the combination of same magnetic polarities and the combination of different magnetic polarities. The predetermined threshold value is preferably changed as appropriate in consideration of detection performance of magnetic sensor module **3**, magnetic characteristics of magnetic marker **10**, an algorithm for detecting magnetic marker **10**, and so forth.

[0056] In the present embodiment, in branching section **121** and merging section **123**, two magnetic markers **10** are provided to be laterally aligned. As described above, in branching section **121**, the space between laterally-aligned two magnetic markers **10** gradually expands by taking branching point **118** as a starting point. In branching section **121**, the space between magnetic marker **10** on main road **110** and magnetic marker **10** on side road **120** is equal to or shorter than 0.3 meters at a position immediately after passing through branching point **118** between marker array line **114** on main road **110** and marker array line **124** on side road **120**. Thus, in branching section **121**, S-pole magnetic marker **10**S is laid at a position closest to branching point **118** on marker array line **124** on side road **120**.

[0057] In merging section **123**, as described above, the space between laterally-aligned two magnetic markers **10** gradually becomes narrow toward merging point **119**. In merging section **123**, the space between magnetic marker **10** on main road **110** and magnetic marker **10** on side road **120** is equal to or shorter than 0.3 meters at a position immediately before merging point **119** between marker array line **114** on main road **110** and marker array line **124** on side road **120**. Thus, in merging section **123**, S-pole magnetic marker **10**S is laid at a position immediately before merging point **119** on marker array line **124** on side road **120**.

(Branching Control and Merging Control)

[0058] Next, branching control and merging control, which are a method of controlling vehicle **2**, are described. Branching control is a control method using the laying mode (refer to FIG. **5**) of magnetic markers **10** in branching section **121**. Merging control is a control method using the laying mode (refer to FIG. **6**) of magnetic markers **10** in merging section **123**. Branching control and merging control are described with reference to a flow diagram of FIG. **11**.

[0059] While vehicle **2** is traveling road **100**, control unit **20** controls magnetic sensor module **3** so as to repeatedly perform marker detection process. The marker detection process is the process of, as described above, making an attempt of detecting magnetic marker **10**, while performing a determination of the magnetic polarity of detected magnetic marker **10** and a measurement of the lateral deviation of vehicle **2** with respect to magnetic marker **10**.

[0060] When acquiring the process result including the indication that magnetic marker **10** has been detected (S**101**: YES), control unit **20** first determines whether two magnetic markers **10** have been simultaneously detected (S**102**). In the case of not simultaneous detection of two magnetic markers **10** but single detection of one magnetic marker **10** (S**102**: NO), control unit **20** acquires the lateral deviation with respect to magnetic marker **10** from the process result of the marker detection process (S**137**). Vehicle **2** is subjected to steering control by taking the lateral deviation with respect to magnetic marker **10** as a controlled variable (S**108**).

[0061] If simultaneous detection of two magnetic markers **10** is determined at step S**102** described above (S**102**: YES), control unit **20** determines the combination of magnetic polarities of detected two magnetic markers **10** (S**103**). Note that the process result by magnetic sensor module **3** in the case in which two magnetic markers **10** have been simultaneously detected includes information about the magnetic polarity of each magnetic marker **10** and two lateral deviations with respect to respective magnetic markers **10**.

[0062] Here, as described above, in the laying mode of magnetic markers **10** of the present embodiment, among magnetic markers **10** on side road **120**, S-pole magnetic marker **10**S is laid at the position closest to branching point **118** or merging point **119**. The other magnetic markers **10** on side road **120** and all magnetic markers **10** on main road **110** are N-pole magnetic markers **10**N. On the vehicle **2** side, in accordance with simultaneous detection of any S-pole magnetic marker **10**S on side road **120** and any of laterally-aligned N-pole magnetic markers **10**N on main road **110**, arrival at branching section **121** (branching point **118**) or merging section **123** (merging point **119**) can be determined.

[0063] Note that when the vehicle enters merging section **123**, prior to simultaneous detection of two magnetic markers **10** with different magnetic polarities, simultaneous detection of two magnetic markers **10** with same magnetic polarities occurs. When simultaneous detection of two magnetic markers **10** with different magnetic polarities occurs subsequently to simultaneous detection of two magnetic markers **10** with same magnetic polarities, arrival at merging section **123** can be determined. On the other hand, when simultaneous detection of two magnetic markers **10** with different magnetic polarities occurs but simultaneous detection of two magnetic markers **10** with same magnetic polarities has not occurred previously, arrival at branching section **121** can be determined.

[0064] When the magnetic polarities of two magnetic markers **10** simultaneously detected are the same (S**102**: YES.fwdarw.S**103**: same), control unit **20** acquires, among two lateral deviations with respect to each magnetic marker **10**, the lateral deviation with a smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control) (S**127**). Selecting the lateral deviation as the controlled variable of steering control corresponds to selecting magnetic marker **10** as a target to be followed. For example, when vehicle **2** is traveling main road **110**, the lateral deviation with respect to magnetic marker **10** on main road **110** is acquired at step S**127**. For example, when vehicle **2** is traveling side road **120**, the lateral deviation with respect to magnetic marker **10** on side road **120** is acquired at step S**127**. With this, vehicle **2** is subjected to steering control so as to travel by maintaining traveling road **100** where vehicle **2** is now traveling (S**108**).

[0065] On the other hand, at step S**103** described above, when the combination of magnetic polarities of two magnetic markers **10** simultaneously detected is the combination of different magnetic polarities (S**103**: different), control unit **20** determines whether the type of traveling road where vehicle **2** is now traveling is main road **110** or side road **120** (S**104**). Control unit **20** identifies the magnetic polarity of magnetic marker **10** regarding the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic

marker detection (the controlled variable is the lateral deviation applied to the previous steering control) of two lateral deviations with respect to two magnetic markers **10**N and **10**S simultaneously detected. When the lateral deviation is the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110**, the type of traveling road **100** where the vehicle is now traveling can be determined as main road **110**. On the other hand, when the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control) is the lateral deviation with respect to S-pole magnetic marker **10**S, the type of traveling road **100** where the vehicle is now traveling can be determined as side road **120**.
[0066] When traveling side road **120** is determined at step S**104** described above (S**104**: side road), control unit **20** can immediately determine that laterally-aligned two magnetic markers **10** determined as having different magnetic polarities at step S**103** described above are laid on merging section **123**. In this case, control unit **20** acquires the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** among two lateral deviations with respect to laterally-aligned two magnetic markers **10** with different magnetic polarities (S**117**). Then, by applying the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** to steering control, merging control for merging from side road **120** to main road **110** starts (S**108**).
[0067] On the other hand, when traveling main road **110** is determined at step S**104** described above (S**104**: main road), control unit **20** determines whether the vehicle is in branching section **121** or merging section **123** (S**105**). As described above, it is possible to determine whether the vehicle is in branching section **121** or merging section **123** in accordance with whether simultaneous detection of two magnetic markers **10** with same magnetic polarities has occurred prior to simultaneous detection of two magnetic markers **10** with different magnetic polarities.
[0068] Next, control unit **20** makes a determination as to whether or not to branch (S**106**). For example, if merging section **123** is determined at step S**105** described above, the determination of not immediately branching can be made. When the determination of no branching is made (S**106**: NO), the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** is acquired (S**117**), and steering control is performed by taking this lateral deviation as the controlled variable (S**108**). With this, vehicle **2** travels straight along main road **110** to pass through merging section **123**.
[0069] For example, when branching section **121** is determined at step S**105** described above and the above-described second traveling route (traveling route via side road **120**) is set in vehicle **2**, branching can be determined at step S**106**. When vehicle **2** branches (S**106**: YES), the lateral deviation with respect to S-pole magnetic marker **10**S is acquired among two lateral deviations with respect to two magnetic markers **10** with different magnetic polarities simultaneously detected at step S**103** described above (S**107**). As described above, S-pole magnetic marker **10**S is laid on side road **120**. With this, branching control for vehicle **2** to branch to side road **120** starts (S**108**).
[0070] In the following, the flow of control is described for each traveling pattern.
(Traveling Pattern of Passing Through the Branching Section without Branching)
[0071] When vehicle **2** traveling main road **110** approaches branching section **121** and arrives at branching point **118** between marker array line **114** on main road **110** and marker array line **124** on side road **120** (sign **2***a* in FIG. **12**), simultaneous detection of two magnetic markers **10** with different magnetic polarities next occurs (sign **2***b* in FIG. **12**).
[0072] When the traveling route set in vehicle **2** is the above-described first traveling route not via side road **120**, control unit **20** performs steering control by taking the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** as the controlled variable. When vehicle **2** further proceeds (sign **2***c* in FIG. **12**) and simultaneous detection of two magnetic markers **10** occurs irrespective of the combination of magnetic polarities, steering control by taking the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** as the controlled variable continues. With this, vehicle **2** is steered so as to travel main road **110** without entering side road

120.
[0073] Note that in the laying mode of FIG. **5** of the present embodiment, only one laying point of laterally-aligned two magnetic markers **10** with different magnetic polarities is provided in branching section **121**. In place of this, a plurality of laying points of laterally-aligned two magnetic markers **10** with different magnetic polarities may be provided in branching section **121**. In this case, simultaneous detection of two magnetic markers **10** with different magnetic polarities continuously occurs. In this case, steering control is performed by taking the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** as the controlled variable.
[0074] When vehicle **2** passes through branching point **118** to further travel, simultaneous detection of two magnetic markers **10** with same magnetic polarities occurs once or a plurality of times (sign **2**_c_ in FIG. **12**). Among the lateral deviations of these two magnetic markers **10**, control unit **20** selects the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control). With this, as with the previous steering control, magnetic marker **10**N on main road **110** is selected as the target to be followed, and vehicle **2** travels straight along main road **110**.
(Branching Traveling Pattern)
[0075] When vehicle **2** traveling main road **110** approaches branching section **121** and arrives at branching point **118** between marker array line **114** on main road **110** and marker array line **124** on side road **120** (sign **2**_a_ in FIG. **13**), simultaneous detection of two magnetic markers **10** with different magnetic polarities occurs next (sign **2**_b_ in FIG. **13**).
[0076] When the traveling route set in vehicle **2** is the above-described second traveling route via side road **120**, control unit **20** performs steering control by taking the lateral deviation with respect to S-pole magnetic marker **10**S on side road **120** as the controlled variable. With this, vehicle **2** is steered so as to branch from main road **110** to enter side road **120** (branching control).
[0077] Note that, in place of the laying mode of FIG. **5** of the present embodiment, a plurality of laying points of laterally-aligned two magnetic markers **10** with different magnetic polarities may be provided in branching section **121**. In this case, simultaneous detection of two magnetic markers **10** with different magnetic polarities continuously occurs. In this case, steering control is performed by taking the lateral deviation with respect to S-pole magnetic marker **10**S on side road **120** as the controlled variable. Vehicle **2** is steered so as to follow S-pole magnetic markers **10**S on side road **120**.
[0078] When vehicle **2** passes through branching point **118** to further travel, simultaneous detection of two magnetic markers **10** with same magnetic polarities occurs once or a plurality of times (sign **2**_c_ in FIG. **13**). Among the lateral deviations with respect to these two magnetic markers **10**, control unit **20** selects a lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control). With this, magnetic marker **10**N on side road **120** is selected as the target to be followed, and vehicle **2** is steered so as to directly enter side road **120**.
(Traveling Pattern in which the Vehicle on the Main Road Passes Through the Merging Section)
[0079] When vehicle **2** traveling main road **110** approaches merging section **123** and approaches merging point **119** between marker array line **114** on main road **110** and marker array line **124** on side road **120** (sign **2**_a_ in FIG. **14**), simultaneous detection of two magnetic markers **10** with same magnetic polarities first occurs.
[0080] Among the lateral deviations with respect to these two magnetic markers **10** simultaneously detected, control unit **20** selects the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control). With this, as with the previous steering control, magnetic marker **10**N on main road **110** is selected as the target to be followed,

and vehicle **2** is steered so as to travel straight along main road **110**. In this manner, during a time when simultaneous detection of two magnetic markers **10** with same magnetic polarities occurs once or a plurality of times, vehicle **2** travels straight along main road **110**.
[0081] When vehicle **2** further approaches merging point **119** (sign **2***b* in FIG. **14**), simultaneous detection of two magnetic markers **10** with different magnetic polarities occurs. Control unit **20** refers to the traveling route set in vehicle **2** in response to the occurrence of simultaneous detection of two magnetic markers **10** with different magnetic polarities. When the traveling route set in vehicle **2** is the above-described first traveling route not via side road **120**, control unit **20** performs steering control by taking the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** as the controlled variable. With this, vehicle **2** is steered so as to travel straight on main road **110** to pass through merging section **123**.
[0082] Note that in the laying mode of FIG. **6** of the present embodiment, only one laying point of laterally-aligned two magnetic markers **10** with different magnetic polarities is provided in merging section **123**. In place of this, a plurality of laying points of laterally-aligned two magnetic markers **10** with different magnetic polarities may be provided in merging section **123**. In this case, simultaneous detection of two magnetic markers **10** with different magnetic polarities continuously occurs. In this case, steering control is performed by taking the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** as the controlled variable. Vehicle **2** is steered so as to follow N-pole magnetic marker **10**N on main road **110**.
(Traveling Pattern in which the Vehicle on the Side Road Merges to the Main Road)
[0083] When vehicle **2** traveling side road **120** approaches merging section **123** and approaches merging point **119** between marker array line **114** on main road **110** and marker array line **124** on side road **120** (sign **2***a* in FIG. **15**), simultaneous detection of two magnetic markers **10** with same magnetic polarities first occurs.
[0084] Among the lateral deviations with respect to these two magnetic markers **10** simultaneously detected, control unit **20** selects the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control). With this, as with the previous steering control, magnetic marker **10**N on side road **120** is selected as the target to be followed, and vehicle **2** is steered so as to travel along side road **120**. In this manner, during a time when simultaneous detection of two magnetic markers **10** with same magnetic polarities occurs once or a plurality of times, vehicle **2** is steered so as to travel straight along side road **120**.
[0085] When vehicle **2** further approaches merging point **119** (sign **2***b* in FIG. **15**), simultaneous detection of two magnetic markers **10** with different magnetic polarities occurs. Control unit **20** determines that the vehicle has arrived at merging section **123** via side road **120**, and starts merging control by switching the target to be followed to N-pole magnetic marker **10**N on main road **110**.
[0086] Note that, in place of the laying mode of FIG. **6** of the present embodiment, a plurality of laying points of laterally-aligned two magnetic markers **10** with different magnetic polarities may be provided in merging section **123**. In this case, simultaneous detection of two magnetic markers **10** with different magnetic polarities continuously occurs. In this case, steering control is performed by taking the lateral deviation with respect to N-pole magnetic marker **10**N on main road **110** as the controlled variable. Vehicle **2** is steered so as to follow N-pole magnetic marker **10**N on main road **110**.
[0087] When vehicle **2** arrives at merging point **119** (sign **2***c* in FIG. **15**), simultaneous detection of two magnetic markers **10** ends, and only one magnetic marker **10** on main road **110** is detected. Control unit **20** performs steering control by taking the lateral deviation with respect to this magnetic marker **10** as the controlled variable. With this, vehicle **2** can follow and travel main road **110**.
[0088] As described above, marker system **1** of the present embodiment has a technical feature in the combination of magnetic polarities of laterally-aligned two magnetic markers **10** laid on

different paths of the plurality of paths. In laterally-aligned two magnetic markers **10**, the combination of magnetic polarities varies in accordance with whether a distance between the two magnetic markers **10** is equal to or shorter than the predetermined threshold value. While the combination of the magnetic polarities is a combination of different magnetic polarities when the distance between the two magnetic markers **10** is equal to or shorter than the predetermined threshold value, the combination of the magnetic polarities is a combination of same magnetic polarities when the distance between the two magnetic markers **10** exceeds the predetermined threshold value. Note, in laterally-aligned two magnetic markers **10**, the combination of magnetic polarities may varies in accordance with whether the distance between the two magnetic markers **10** is below the predetermined threshold value or not.

[0089] As laterally-aligned two magnetic markers **10** approach closer to each other, the possibility of occurrence of magnetic interference increases. If the magnetic polarities of these two magnetic markers **10** are the same, the magnetic distribution becomes broad due to magnetic interference acted from two magnetic markers **10**, and a possibility occurs in which the peak supposed to appear directly above magnetic marker **10** is difficult to detect. On the other hand, if the magnetic polarities of laterally-aligned two magnetic markers **10** are different, detection of the peak in the magnetic distribution is easy even if magnetic interference occurs, and each magnetic marker **10** can be detected with high reliability.

[0090] The control method of the present embodiment is the control method of causing vehicle **2** to enter side road **120** (one example of a path) branching from the path forming main road **110** with an impetus of simultaneous detection of two magnetic markers **10** with different magnetic polarities when vehicle **2** is branched from the path forming main road **110**. Also, the control method of the present embodiment is the control method of causing vehicle **2** to enter the path forming main road **110** from side road **120** with the impetus of simultaneous detection of two magnetic markers **10** with different magnetic polarities when vehicle **2** is merged to the path forming main road **110**.

[0091] In the configuration of the present embodiment, N-pole magnetic markers **10**N are laid on traveling road **100** except for branching section **121** and merging section **123**. Thus, S-pole magnetic marker **10**S laid on branching section **121** or merging section **123** can serve as the impetus for starting branching control or merging control. By using S-pole magnetic marker **10**S laid in branching section **121** and merging section **123** on side road **120**, it is possible for control unit **20** to start branching control or merging control at extremely appropriate timing.

[0092] Magnetic markers **10** with different magnetic polarities laid in branching section **121** and merging section **123** indicate, with high accuracy, the position of a connecting point (branching point **118**, merging point **119**) between marker array line **114** on main road **110** and marker array line **124** on side road **120**. On the vehicle **2** side, by detecting magnetic markers **10** with different magnetic polarities, it is possible to grasp, without delay, arrival at the connecting point between marker array line **114** on main road **110** and marker array line **124** on side road **120** and perform branching control or merging control at almost optimal timing.

Second Embodiment

[0093] The present embodiment is an example of marker system **1** based on the marker system of the first embodiment and is applied to traveling road **100** with a complex path structure. Details of this are described with reference to FIG. **16** and FIG. **17**.

[0094] Traveling road **100** (FIG. **16**) of the present embodiment is a traveling road where a plurality of branching sections **121** and merging sections **123** are set. Marker system **1** applied to this traveling road **100** is configured to include a server device that can be accessed by vehicle **2** via wireless communication.

[0095] In the server device, a database having attribute information of at least specific magnetic marker **10** recorded thereon is constructed. Specific magnetic marker **10** is a magnetic marker with a magnetic polarity different from laterally-aligned magnetic marker **10** in branching section **121** and merging section **123**. In the database, attribute information of the corresponding magnetic marker **10** is recorded as having identification information of magnetic marker **10** linked thereto. The attribute information is, for example, information indicating the kind such as branching section **121**, merging section **123**, or the like, information indicating the position of branching section **121** or merging section **123**, or the like. By referring to the database by using the identification information of magnetic markers **10**, it is possible to identify branching section **121** or merging section **123**.

[0096] Any of two magnetic markers **10** with different magnetic polarities laterally aligned is specific magnetic marker **10** described above. At least either one of these two magnetic markers **10** is a magnetic marker with RFID tag **10**T affixed to an end face (FIG. **17**). Tag information to be outputted from RFID tag **10**T is information that can uniquely identify corresponding magnetic marker **10**, and can be used as identification information of that magnetic marker **10**.

[0097] Vehicle **2** of the present embodiment includes, although not depicted in the drawings, a tag reader for reading the tag information from RFID tag **10**T and a wireless communication circuit for accessing the database of the server device. Furthermore, vehicle **2** includes a storage device that stores information about a path set in advance. The information about the path includes information for specifying branching section **121** to be passed through, branching section **121** to be branched, merging section **123** to be passed through, and merging section **123** to be merged.

[0098] When arriving at branching section **121** or merging section **123**, vehicle **2** reads tag information from RFID tag **10**T attached to the above-described specific magnetic marker **10**. By using this tag information, which is identification information of magnetic marker **10**, vehicle **2** accesses the server device and acquires attribute information to which this tag information (identification information) is linked. As described above, this attribute information is, for example, information indicating the kind such as branching section **121**, merging section **123**, or the like, information indicating the position of branching section **121** or merging section **123**, or the like.

[0099] Vehicle **2** determines, based on information about the traveling route set in advance, whether to branch or merge in branching section **121** or merging section **123** where magnetic marker **10** corresponding to the acquired attribute information is located. In vehicle **2**, in accordance with the determination result, branching control or merging control is performed as appropriate.

[0100] Note that other configurations and operations and effects are similar to those in the first embodiment.

Third Embodiment

[0101] The present embodiment is based on the marker system of the first embodiment, and is an embodiment in which polarities of magnetic markers **10** laid in traveling road **100** are changed. Details of this are described with reference to FIG. **18** to FIG. **20**. In marker system **1** of the present embodiment, the magnetic polarities of magnetic markers **10** are random except for those at part of marker laying positions **10**D (FIG. **18** and FIG. **19**) belonging to branching section **121** and merging section **123**.

[0102] Part of marker laying positions **10**D are laying positions of magnetic markers **10** with a possibility of being detected simultaneously with any of other laterally-aligned magnetic markers **10**. In the present embodiment, the laying position of magnetic marker **10** with a space with other laterally-aligned magnetic marker **10** being equal to or shorter than 2.3 meters, which is the width of vehicle **2**, is specified as marker laying position **10**D. Marker laying position **10**D is a position where the magnetic polarity of laid magnetic marker **10** is controlled.

[0103] Furthermore, among marker laying positions **10**D, marker laying position **10**D with the space with other laterally-aligned marker laying position **10**D being equal to or shorter than 0.3 meters is a position where magnetic marker **10** with a magnetic polarity different from that of other laterally-aligned magnetic marker **10** is to be laid. Note that any of magnetic markers **10** laid on main road **110** and side road **120** is not required to be specified as having the N pole or the S pole. It is only required that the magnetic polarities of laterally-aligned these two magnetic markers **10**

be different.
[0104] Among marker laying positions **10**D, marker laying position **10**D with the space with other laterally-aligned marker laying position **10**D being longer than 0.3 meters and equal to or shorter than 2.3 meters is a position where magnetic marker **10** with the same magnetic polarity as that of other laterally-aligned magnetic marker **10** is to be laid. Note that the magnetic polarities of laterally-aligned these two magnetic markers **10** are any and it is only required that the magnetic polarities of these two magnetic markers **10** be the same.
[0105] In FIG. **18** exemplarily depicting branching section **121**, marker laying position **10**D on main road **110** and marker laying position **10**D on side road **120** immediately after passage through branching point **118** are positions each at which magnetic marker **10** with the magnetic polarity different from that of laterally-aligned magnetic marker **10** is to be laid. Second to fourth marker laying positions **10**D on main road **110** and second to fourth marker laying positions **10**D on side road **120** after passage through branching point **118** are positions each at which magnetic marker **10** with the same magnetic polarity as that of other laterally-aligned magnetic marker **10** is to be laid.
[0106] In FIG. **19** exemplarily depicting merging section **123**, marker laying position **10**D on main road **110** and marker laying position **10**D on side road **120** immediately before merging point **119** are positions each at which magnetic marker **10** with the magnetic polarity different from that of other laterally-aligned magnetic marker **10** is to be laid. Second to fourth marker laying positions **10**D on main road **110** and second to fourth marker laying positions **10**D on side road **120** immediately before merging point **119** are positions each at which magnetic marker **10** with the same magnetic polarity as that of other laterally-aligned magnetic marker **10** is to be laid.
[0107] The control by marker system **1** of the present embodiment is described with reference to a flow diagram of FIG. **20**. When acquiring the process result indicating that magnetic marker **10** has been detected (S**201**: YES), control unit **20** first determines whether two magnetic markers **10** have been simultaneously detected (S**202**). In the case of not simultaneous detection of two magnetic markers **10** but single detection of one magnetic marker **10** (S**202**: NO), control unit **20** acquires the lateral deviation with respect to magnetic marker **10** from the process result of the marker detection process (S**236**). Vehicle **2** travels by steering control by taking the lateral deviation acquired as described above as the controlled variable (S**209**).
[0108] In this manner, control of vehicle **2** traveling main road **110** or side road **120** other than branching section **121** and merging section **123** is exactly identical to that of the first embodiment. However, in the process of the present embodiment, step S**237** of resetting flag A and flag B to zero is added subsequently to step S**236** described above.
[0109] Flag A is a control flag indicating an occurrence of simultaneous detection of two magnetic markers **10** with same magnetic polarities. In the configuration of the present embodiment, when two magnetic markers **10** with different magnetic polarities are simultaneously detected, flag A is used to determine whether these two magnetic markers **10** are in branching section **121** or merging section **123**. Flag B is a control flag indicating that branching control or merging control has started. Flags A and B are reset to zero after passage through branching section **121** or merging section **123**. Before vehicle **2** enters branching section **121** or merging section **123**, flags A and B are both in a state of being reset to zero.
[0110] When two magnetic markers **10** have been simultaneously detected (S**202**: YES), the value of flag B indicating that branching control or merging control has started is first determined (S**203**). When flag B indicates 1, that is, if branching control or merging control has started (S**203**: 1), step S**216** is performed. At this step S**216**, among two lateral deviations with respect to two magnetic markers **10** simultaneously detected, the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control) is acquired. The process at step S**216** is performed irrespective of the combination of magnetic polarities of two magnetic markers **10** simultaneously detected. Then, vehicle **2** is subjected to steering control by

taking the lateral deviation acquired as described above as the controlled variable (S**209**).

[0111] On the other hand, when flag B indicates zero at step S**203**, that is, if neither branching control nor merging control has not started (S**203**: 0), the combination of magnetic polarities of two magnetic markers **10** simultaneously detected is determined (S**204**). When the magnetic polarities of two magnetic markers **10** simultaneously detected are the same (S**202**: YES.fwdarw.S**203**: 0.fwdarw.S**204**: same), step S**226** is performed. At this step S**226**, among two lateral deviations with respect to two magnetic markers **10** simultaneously detected, the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control) is acquired.

[0112] The process at step S**226** is identical to the above-described process at step S**216**. However, step S**227** of substituting **1** for flag A comes subsequently to step S**226**. After 1 is substituted for flag A (S**227**), vehicle **2** is subjected to steering control by taking the lateral deviation acquired at step S**226** as the controlled variable (S**209**).

[0113] On the other hand, when the magnetic polarities of two magnetic markers **10** simultaneously detected before the start of branching control and merging control are different (S**202**: YES.fwdarw.S**203**: 0.fwdarw.S**204**: different), control unit **20** first determines the value of flag A (S**205**). Flag A indicates whether simultaneous detection of two magnetic markers **10** with same magnetic polarities has occurred in advance. If simultaneous detection of two magnetic markers **10** with same magnetic polarities has occurred in advance, that is, at the time of entering merging section **123**, **1** has been substituted for flag A at step S**227** described above. On the other hand, at the time of entering branching section **121**, prior to simultaneous detection of two magnetic markers **10** with different magnetic polarities, no simultaneous detection of two magnetic markers **10** with same magnetic polarities occurs, and therefore flag A stays at zero.

[0114] Therefore, when flag A indicates zero (S**205**: 0), entering not merging section **123** but branching section **121** can be determined. In response to entering branching section **121**, control unit **20** makes a determination as to whether to branch (S**206**). When the second traveling route (traveling route via side road **120**) is set in vehicle **2**, control unit **20** determines to branch.

[0115] When the traveling route of vehicle **2** is to branch (S**206**: YES), control unit **20** starts branching control by performing replacement of magnetic marker **10** as the target to be followed at step S**207**. At step S**207**, from two lateral deviations with respect to two magnetic markers **10** simultaneously detected, the lateral deviation with a larger difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control) is acquired. With this, magnetic marker **10** as the target to be followed is replaced from magnetic marker **10** on main road **110** to magnetic marker **10** on side road **120**. Then, in response to this replacement of magnetic marker **10** as the target to be followed, branching control is started, and 1 is substituted for flag B (step S**208**).

[0116] When this branching control is started and then simultaneous detection of two magnetic markers **10** with different magnetic polarities occurs, since flag B indicates 1, step S**207** described above is not performed again. In this case, based on the determination at step S**203**, step S**216** described above is immediately performed. At this step S**216**, among two lateral deviations with respect to two magnetic markers **10** simultaneously detected, the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation acquired at the previous step S**207** and applied to steering control) is acquired. That is, magnetic marker **10** on side road **120** set as the target to be followed in response to the start of branching control at the previous step S**207** is maintained as it is as the target to be followed.

[0117] When no branching is determined at step S**206** described above (S**206**: NO), the process proceeds to step S**216**, at which, among two lateral deviations with respect to two magnetic markers **10** simultaneously detected, the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation acquired at the previous step S**207** and applied to steering control) is acquired. That is, magnetic marker **10** on main road **110** is maintained as it is as the target to be followed.

[0118] If the vehicle passes through branching section **121**, simultaneous detection of magnetic markers **10** with same magnetic polarities occurs (S**201**.fwdarw.S**202**: YES). In this case, branching control is not started, and therefore flag B indicates zero. In the case of simultaneous detection of two magnetic markers **10** with same magnetic polarities (S**204**: same), the process proceeds to step S**226**, at which a state of following magnetic markers **10** on main road **110** is maintained. Then, at the subsequent step S**227**, **1** is substituted for flag A. In branching section **121**, marker array line **114** on main road **110** and marker array line **124** on side road **120** form a V shape. Therefore, after step S**227** is performed and during passage through branching section **121**, simultaneous detection of two magnetic markers **10** with different magnetic polarities does not occur, and processes following “step S**204**: different” are not performed. Therefore, vehicle **2** travels along main road **110** and can pass through branching section **121**.

[0119] On the other hand, at step S**205** to be performed in response to simultaneous detection of two magnetic markers **10** with different magnetic polarities prior to the start of branching control and merging control, when flag A indicates 1, that is, in the case of entering merging section **123** (S**205**: 1), control unit **20** determines whether to merge at step S**215**. When the second traveling route is set in vehicle **2**, control unit **20** determines as merging.

[0120] When the traveling route of vehicle **2** requires merging (S**215**: YES), control unit **20** performs replacement of magnetic marker **10** as the target to be followed at step S**207**, thereby starting merging control. Specifically, among two lateral deviations with respect to two magnetic markers with different magnetic polarities simultaneously detected, the lateral deviation with the larger difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control) is acquired. With this, magnetic marker **10** as the target to be followed is replaced from magnetic marker **10** on side road **120** to magnetic marker **10** on main road **110**. Then, merging control is started in response to replacement of magnetic marker **10** as the target to be followed, and 1 is substituted for flag B (S**208**).

[0121] If this merging control is started and then simultaneous detection of two magnetic markers **10** with different magnetic polarities occurs, since flag B indicates 1, step S**207** described above is not performed again. In this case, based on the determination at step S**203**, step S**216** described above is immediately performed. At this step S**216**, among two lateral deviations with respect to two magnetic markers **10** simultaneously detected, the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation acquired at the previous step S**207** and applied to steering control) is acquired. That is, magnetic marker **10** on main road **110** set as the target to be followed in response to the start of merging control at the previous step S**207** is maintained as it is as the target to be followed.

[0122] On the other hand, no merging is determined at step S**215** described above (S**215**: NO), among two lateral deviations with respect to two magnetic markers **10** with different magnetic polarities simultaneously detected, the lateral deviation with the smaller difference from the controlled variable at the time of the immediately-previous magnetic marker detection (the controlled variable is the lateral deviation applied to the previous steering control) is acquired (S**216**), and steering control is performed (S**208**). That is, the state of vehicle **2** traveling along main road **110** is maintained as it is.

[0123] Note that other configurations and operations and effects are similar to those in the first embodiment.

[0124] In the foregoing, while specific examples of the present invention are described in detail as in the embodiments, these specific examples merely disclose examples of technology included in the scope of the claims. Needless to say, the scope of the claims should not be restrictively construed based on the configuration, numerical values, and so forth of the specific examples. The scope of the claims includes technologies acquired by variously modifying, changing, or combining as appropriate the above-described specific examples by using known technologies, knowledge of a person skilled in the art, and so forth.

Claims

1. A marker system comprising a plurality of magnetic markers arranged as spaced along a plurality of paths where a vehicle travels, wherein in a combination of two magnetic markers of the plurality of magnetic markers laid on different paths of the plurality of paths and adjacent to each other in a lateral direction orthogonal to a path direction, a combination of magnetic polarities of the two magnetic markers varies in accordance with a distance between the two magnetic markers, and i) while the combination of the magnetic polarities of the two magnetic markers is a combination of different magnetic polarities when the distance between the two magnetic markers is equal to or shorter than the predetermined threshold value, the combination of the magnetic polarities of the two magnetic markers is a combination of same magnetic polarities when the distance between the two magnetic markers exceeds the predetermined threshold value, or ii) while the combination of the magnetic polarities of the two magnetic markers is the combination of different magnetic polarities when the distance between the two magnetic markers is below the predetermined threshold value, the combination of the magnetic polarities of the two magnetic markers is the combination of same magnetic polarities when the distance between the two magnetic markers is equal to or longer than the predetermined value.
2. The marker system in claim 1, further comprising a database recording attribute information of the plurality of magnetic markers laid on the plurality of paths, wherein the combination of the two magnetic markers includes a combination of a magnetic marker laid on a path forming a main road and a magnetic marker laid on a path branching from the path forming the main road, the combination of the two magnetic markers with a spaced distance therebetween being equal to or shorter than the predetermined threshold value or below the predetermined threshold value, and in the database, at least one of the two magnetic markers has the attribute information indicating a branching section recorded thereon.
3. The marker system in claim 1, further comprising a database recording attribute information of the plurality of magnetic markers laid on the plurality of paths, wherein the combination of the two magnetic markers includes a combination of a magnetic marker laid on a path forming a main road and a magnetic marker laid on a path merging to the path forming the main road, the combination of the two magnetic markers with a spaced distance therebetween being equal to or shorter than the predetermined threshold value or below the predetermined threshold value, and in the database, at least one of the two magnetic markers has the attribute information indicating a merging section recorded thereon.
4. A control method for causing a vehicle to travel along a plurality of paths by using the marker system in claim 2, the vehicle including a magnetic detection area elongated in a vehicle-width direction and a magnetic detection circuit simultaneously detecting the two magnetic markers adjacent to each other in the lateral direction, the method comprising: when the vehicle is caused to branch from the path forming the main road, starting control of causing the vehicle to enter a path branching from the path forming the main road with simultaneous detection of the two magnetic markers with different magnetic polarities as a trigger.
5. The control method in claim 4, further comprising, every time any of the plurality of magnetic markers is detected, controlling steering by taking a lateral deviation of the vehicle with respect to the detected magnetic marker as a controlled variable, when the vehicle is caused to branch from

the path forming the main road and the simultaneous detection of the two magnetic markers with different magnetic polarities occurs, the controlling steering is performed in which, from two lateral deviations with respect to the two magnetic markers, a lateral deviation with a larger difference from a lateral deviation as a controlled variable at immediately-previous magnetic marker detection is taken as the controlled variable, thereby starting the control of causing the vehicle to enter the path branching from the path forming the main road, and after starting the control, when the simultaneous detection of the two magnetic markers occurs irrespective of whether the magnetic polarities are same or different, the controlling steering is performed in which a lateral deviation with a smaller difference from the lateral deviation as the controlled variable at the immediately-previous magnetic marker detection is taken as the controlled variable.

6. A control method for causing a vehicle to travel along a plurality of paths by using the marker system in claim 1, the combination of the two magnetic markers including a combination of a magnetic marker laid on a path forming a main road and a magnetic marker laid on a path merging to the path forming the main road, the combination of the two magnetic markers with a spaced distance therebetween being equal to or shorter than the predetermined threshold value or below the predetermined threshold value, and the vehicle including a magnetic detection area elongated in a vehicle-width direction and a magnetic detection circuit simultaneously detecting the two magnetic markers adjacent to each other in the lateral direction, the method comprising: when the vehicle is caused to merge from the merging path to the path forming the main road, starting control of causing the vehicle to merge from the path merging to the path forming the main road with simultaneous detection of the two magnetic markers with different magnetic polarities as a trigger.

7. The control method in claim 6, further comprising, every time any of the plurality of magnetic markers is detected, controlling steering by taking a lateral deviation of the vehicle with respect to the detected magnetic marker as a controlled variable, when the vehicle is caused to merge from the path merging to the path forming the main road and the simultaneous detection of the two magnetic markers with different magnetic polarities occurs, the controlling steering is performed in which, from two lateral deviations with respect to the two magnetic markers, a lateral deviation with a larger difference from a lateral deviation as a controlled variable at immediately-previous magnetic marker detection is taken as the controlled variable, thereby starting the control of causing the vehicle to merge from the path merging to the path forming the main road, and after starting the control, when the simultaneous detection of the two magnetic markers occurs irrespective of whether the magnetic polarities are same or different, the controlling steering is performed in which a lateral deviation with a smaller difference from the lateral deviation as the controlled variable at the immediately-previous magnetic marker detection is taken as the controlled variable.