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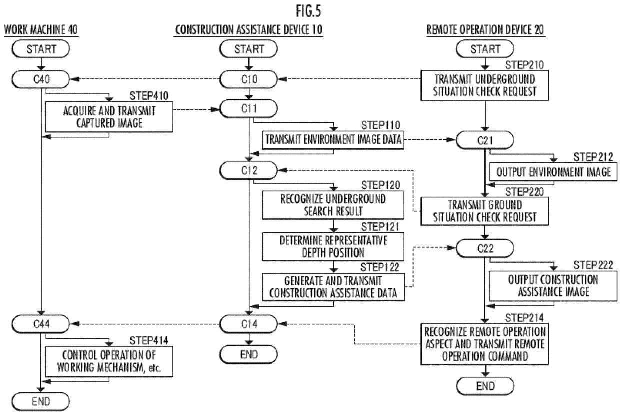
(54) CONSTRUCTION ASSISTANCE DEVICE AND CONSTRUCTION ASSISTANCE METHOD

(57) There is provided a device, etc. that generates construction assistance data that can be used for generating an image that allows a user to easily understand a position and posture of an underground buried object, and for controlling operation of a construction machine to avoid contact with the buried object, while reducing data amount for construction assistance data for representing the buried object. In at least part of a plurality of underground search areas $S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}$, underground search points $P_1, ...P_{i-1}, P_i, P_{i+1}, ...P_{n-1}, P_n$ of the underground buried objects each have a depth position from the ground surface, measured by an underground search machine 60, and the depth positions are consolidated into a representative depth position. Then, construction assistance image data is generated that represents a three-dimensional image including closed surfaces m_1, m_2 as objects each representing the representative depth position arranged at each of the plurality of underground search areas $S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}$.

FIG.5



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Description

Technical Field

[0001] The present invention relates to a technology for preventing accidental damage to underground buried objects during excavation of the ground with a work machine.

Background Art

[0002] A technology has been proposed that can prevent breakage of buried objects and efficiently perform excavation work in excavation of soil around the buried objects, buried in the underground near the ground surface, with a hydraulic excavator (see, for example, Patent Literature 1). Specifically, the relationship between the absolute position of the buried pipe and the absolute position of the bucket blade tip is determined, and the excavation position and excavation depth of the bucket are determined based on this relationship. Displaying the determined excavation position and excavation depth, for example, on a monitor allows the operator to operate the hydraulic excavator reliably and quickly while preventing breakage of buried objects while watching the monitor display.

[0003] A technology has been proposed that can improve the accuracy and efficiency of excavation performed by a work machine (see, for example, Patent Literature 2). Specifically, an allowable depth and an excavation position where the work device performs excavation work are displayed on a map, based on: an allowable depth, which is a depth at which the radar can perform exploration from the ground surface with a predetermined accuracy; and the exploration position where the radar has performed the exploration. For example, in a mesh-type work site map in which a single work site is divided into a plurality of underground search areas, a plurality of groups (a plurality of ranks) indicating the exploration results and allowable depth are assigned to the divided data corresponding to each underground search area. In the work site map, the groups (ranks) are displayed with colors, numbers, letters, etc. so that the groups (ranks), which are previously assigned to each underground search area Qn, can be identified.

Citation List

Patent Literature

[0004]

Patent Literature 1: Japanese Patent Laid-Open No. 2003-056010
Patent Literature 2: Japanese Patent Laid-Open No. 2021-189127

Summary of Invention

Technical Problem

[0005] In order to allow a user to understand the position and posture of an underground buried object, a three-dimensional image is preferable to a two-dimensional image, but the construction assistance image data tends to have an excessive data amount due to its rich information amount.

[0006] The present invention aims to provide a device or the like that generates construction assistance data that can be used for generating an image that allows a user to easily understand the position and posture of an underground buried object and for controlling operation of a construction machine to avoid contact with the buried object, while reducing a data amount of the construction assistance data for representing the buried object.

Solution to Problem

[0007] The construction assistance device of the present invention includes an underground search machine, wherein the underground search machine measures a depth position from a ground surface in each of a plurality of underground search areas, and construction assistance data is generated that includes a plurality of objects each representing a depth position from a ground surface, the objects each being arranged in its individual area in the plurality of underground search areas.

[0008] According to the construction assistance device of this configuration, construction assistance data is generated in which the depth positions from the ground surface each in its individual area in the plurality of underground search areas are represented by the arrangement aspects of the objects each in its individual area in the plurality of underground search areas, the depth positions being measured by the underground search machine. This reduces the data amount in the construction assistance data compared to a case in which the construction assistance data is generated without consolidating all the underground search results, made by the underground search machine, into one in the underground search area.

Brief Description of the Drawings

[0009]

FIG. 1 is an explanatory diagram of a configuration of a construction assistance device.
FIG. 2 is an explanatory diagram of a configuration of a remote operation device.
FIG. 3 is an explanatory diagram of a configuration of a work machine.
FIG. 4 is an explanatory diagram of a configuration of an underground search machine.
FIG. 5 is an explanatory diagram relating to functions

of the construction assistance device (construction assistance system).

FIG. 6 is an explanatory diagram relating to a work environment image and a construction assistance image.

FIG. 7A is an explanatory diagram relating to fixed arrangement aspects of a plurality of underground search areas.

FIG. 7B is an explanatory diagram relating to dynamic arrangement aspects of a plurality of underground search areas.

FIG. 8A is an explanatory diagram relating to a processing method for underground search areas whose overlap degree is equal to or greater than a threshold value.

FIG. 8B is an explanatory diagram relating to a first processing method for underground search areas whose overlap degree is less than the threshold value.

FIG. 8C is an explanatory diagram relating to a second processing method for underground search areas whose overlap degree is less than the threshold value.

FIG. 9 is an explanatory diagram relating to a method for determining representative coordinate values.

FIG. 10 is an explanatory diagram relating to another embodiment of a construction assistance image.

Description of Embodiments

(Configuration of construction assistance device)

[0010] A construction assistance system shown in FIG. 1 is configured of a construction assistance device 10 as one embodiment of the present invention, a remote operation device 20, and a work machine 40 and an underground search machine 60, which are configured to be able to mutually communicate with the construction assistance device 10 via a network. The construction assistance device may be configured of the construction assistance device 10, the remote operation device 20, and one or two of the work machine 40 and the underground search machine 60. The intercommunication network of the construction assistance device 10 and the remote operation device 20, the intercommunication network of the construction assistance device 10 and the work machine 40, and the intercommunication network of the construction assistance device 10 and the underground search machine 60 may be the same or different.

(Configuration of construction assistance device)

[0011] The construction assistance device 10 is configured of one or more computers or server computers. As shown in FIG. 1, the construction assistance device 10 comprises a database 102, an underground search result recognition element 120, a representative depth position determination element 121, and a construction assistance image data generation element 122. The database 102 stores captured image data as well as search results of underground buried objects in the construction target area and the like. The database 102 may be configured of a database server separate from the construction assistance device 10. Each component of the construction assistance device 10 is configured of a calculation processing device (a single-core processor, or a multi-core processor or a processor core constituting the same), reads necessary data and software from a storage device such as a memory, and executes the calculation processing, described below, on the data according to the software.

[0012] That the component of the present invention "recognizes" information (or data) is a concept that includes all processing that prepares the information in a form that can be used in executing subsequent calculation processing, such as: acquiring the information by receiving, reading, or searching; and executing calculation processing on the underlying data or signal to determine, measure, identify, estimate, and predict the information.

(Configuration of remote operation device)

[0013] As shown in FIG. 1, the remote operation device 20 comprises a remote control device 200, a remote input interface 210, and a remote output interface 220. The remote control device 200 is configured of a calculation processing device (a single-core processor, or a multi-core processor or a processor core constituting the same). The remote control device 200 reads necessary data and software from the storage device such as a memory, and executes calculation processing on the data according to the software.

[0014] The remote input interface 210 comprises a remote operation mechanism 211. The remote output interface 220 comprises a remote image output device 221, a remote audio output device 222, and a remote wireless communication device 224.

[0015] The remote operation mechanism 211 includes a travel operation device, a revolving operation device, a boom operation device, an arm operation device, and a bucket operation device. Each operation device has an operation lever that receives a turning operation. The operation lever of the travel operation device (travel lever) is operated to move the lower traveling body 41 of the work machine 40. The travel lever may also serve as a travel pedal. For example, there may be provided a travel pedal fixed to the base portion or lower end portion of the travel lever. The operation lever of the revolving operation device (revolving lever) is operated to drive the hydraulic swing motor constituting the revolving mechanism 43 of the work machine 40. The operation lever of the boom operation device (boom lever) is operated to operate the boom cylinder 442 of the work machine 40. The operation lever of the arm operation device (arm lever) is operated to operate an arm cylinder 444 of the work machine 40. The operation lever of the bucket operation device (bucket lever) is operated to operate the bucket cylinder 446 of the work machine 40.

[0016] The operation levers constituting the remote operation mechanism 211 are disposed around the seat St on which the operator sits, for example, as shown in FIG. 2. The seat St is in a form of a high-back chair with armrests. However, the seat St may be in a form of a low-back chair without a headrest, or in a form of a chair without a backrest, or in any other form on which the operator can sit.

[0017] Left and right travel levers 2110 corresponding to the left and right crawlers are disposed left and right side by side in front of the seat St. One operation lever may serve as a plurality of operation levers. For example, the left operation lever 2111, provided in front of the left frame of the seat St shown in FIG. 2, may function as an arm lever when operated in the forward and backward directions, and may function as a revolving lever when operated in the left and right directions. Similarly, the right operation lever 2112, provided in front of the right frame of the seat St shown in FIG. 2, may function as a boom lever when operated in the forward and backward directions, and may function as a bucket lever when operated in the left and right directions. The lever pattern may be changed freely according to the operation instruction of the operator.

[0018] As shown in FIG. 2, the remote image output device 221 is configured of a central remote image output device 2210, a left remote image output device 2211, and a right remote image output device 2212, each having a substantially rectangular screen, which are respectively disposed in front of, diagonally forward left of, and diagonally forward right of the seat St, for example. The screens (image display areas) of the central remote image output device 2210, the left remote image output device 2211, and the right remote image output device 2212 may be the same or different in shape and size. The remote image output device 221 may be configured of a single bent or bendable image output device, or two or four or more image output devices disposed so as to surround the front of the seat St.

[0019] As shown in FIG. 2, the right edge of the left remote image output device 2211 is adjacent to the left edge of the central remote image output device 2210 so that the screens of the central remote image output device 2210 and the left remote image output device 2211 form an inclination angle $\theta 1$ (e.g., $120° \leq \theta 1 \leq 150°$). As shown in FIG. 2, the left edge of the right remote image output device 2212 is adjacent to the right edge of the central remote image output device 2210 so that the screens of the central remote image output device 2210 and the right remote image output device 2212 form an inclination angle $\theta 2$ (e.g., $120° \leq \theta 2 \leq 150°$). The inclination angles $\theta 1$ and $\theta 2$ may be the same or different.

[0020] The screens of the central remote image output device 2210, the left remote image output device 2211, and the right remote image output device 2212 may be parallel to the vertical direction or inclined to the vertical direction. At least one image output device of the central remote image output device 2210, the left remote image output device 2211, and the right remote image output device 2212 may be configured of a plurality of divided image output devices. For example, the central remote image output device 2210 may be configured of vertically adjacent image output devices each having a substantially rectangular screen.

[0021] The remote audio output device 222 is configured of one or more speakers. For example, the remote audio output device 222 is configured of a central audio output device 2220, a left audio output device 2221, and a right audio output device 2222, which are disposed behind the seat St, the rear of the left armrest, and the rear of the right armrest, respectively, as shown in FIG. 2. The specifications of the central audio output device 2220, the left audio output device 2221, and the right audio output device 2222 may be the same or different.

(Configuration of work machine)

[0022] As shown in FIG. 1, the work machine 40 comprises an actual machine control device 400, an actual machine input interface 410, an actual machine output interface 420, and an actual machine wireless communication device 422. Each of the components of the actual machine control device 400 is configured of a calculation processing device (a single-core processor, or a multicore processor or a processor core constituting the same). Each of the components of the actual machine control device 400 reads necessary data and software from the storage device such as a memory, and executes calculation processing on the data according to the software.

[0023] The work machine 40 is, for example, a crawler excavator (construction machine), and comprises a crawler-type lower traveling body 41 and an upper revolving body 42 that is mounted on the lower traveling body 41 so as to be revolvable via a revolving mechanism 43, as shown in FIG. 3. A cab 42C (operation room) is provided on the front left side of the upper revolving body 42. A working mechanism 44 is provided in the front center of the upper revolving body 42.

[0024] The actual machine input interface 410 comprises an actual machine operation mechanism 411, an actual machine imaging device 412, and an actual machine positioning device 414. The actual machine operation mechanism 411 comprises a plurality of operation levers disposed around a seat disposed inside the cab 42C in the same manner as the remote operation mechanism 211. The cab 42C is provided with a drive mechanism or robot that receives a signal corresponding to the operation aspect of the remote operation lever and moves the actual machine operation lever based on the received signal. The actual machine imaging device 412 is installed, for example, inside the cab 42C, and images the environment including at least part of the working mechanism 44 through the front window and the left and right side windows. The front window and the side windows may be omitted in part or in whole. The actual machine positioning device 414 is configured of a GPS or GNSS and, if necessary, a gyro sensor, etc., and measures the position (latitude and longitude) of the work machine 40.

[0025] As shown in FIG. 3, the working mechanism 44 comprises a boom 441 that is mounted on the upper revolving body 42 so as to be capable of hoisting and lowering, an arm 443 that is turnably connected to the front end of the boom 441, and a bucket 445 that is turnably connected to the front end of the arm 443. The working mechanism 44 is equipped with a boom cylinder 442, an arm cylinder 444, and a bucket cylinder 446 that are composed of extendible hydraulic cylinders.

[0026] The boom cylinder 442 is interposed between the boom 441 and the upper revolving body 42 so as to extend and retract when supplied with hydraulic oil, thereby turning the boom 441 in the hoisting and lowering direction. The arm cylinder 444 is interposed between the arm 443 and the boom 441 so as to extend and retract when supplied with hydraulic oil, thereby turning the arm 443 around the horizontal axis relative to the boom 441. The bucket cylinder 446 is interposed between the bucket 445 and the arm 443 so as to extend and retract when supplied with hydraulic oil, thereby turning the bucket 445 around the horizontal axis relative to the arm 443.

(Configuration of underground search machine)

[0027] As shown in FIG. 1, the underground search machine 60 comprises a search control device 600, a search storage device 602, a depth position measurement element 611, a search position measurement element 612, and a search wireless communication device 624.

[0028] The depth position measurement element 611 is configured of an underground radar device and measures the depth position of an underground buried object from the ground surface. For example, as shown in FIG. 4, a plurality of depth position measurement elements 611 may be mounted at different positions on one underground search machine 60. The search position measurement element 612 is configured of a GPS or GNSS and, if necessary, a gyro sensor, etc., and measures the two-dimensional position (latitude and longitude) of the underground search machine 60.

[0029] The search storage device 602 stores the depth position measured by the depth position measurement element 611 and the horizontal position measured by the search position measurement element 612, as the underground search results. The search storage device 602 may also store the coordinate values of the underground radar device in a search coordinate system (a coordinate system in which the position and posture are fixed relative to the underground search machine 60). The search wireless communication device 624 is configured to transmit the underground search results stored in the search storage device 602 to the construction assistance device 10 (or database server) via the network. The underground search results are accumulated or saved in the database 102.

(Functions)

[0030] The following describes the functions of the construction assistance device and the imaging function control system configured as described above, using the flowchart shown in FIG. 5. In the flowchart, a block "C•" is used for the sake of simplicity of description. The block "C•" means transmission and/or reception of the data, and means a conditional branch in which processing in the branch direction is executed on the condition that the data is transmitted and/or received.

[0031] In the remote operation device 20, the remote control device 200 transmits a ground situation check request to the construction assistance device 10 through the remote wireless communication device 224 (FIG. 5/STEP 210). The operator may determine whether there is a first designation operation through the remote input interface 210, and if the determination result is positive, he/she may transmit a ground situation check request. The "first designation operation" is, for example, an operation such as tapping on the remote input interface 210 for the operator to designate the work machine 40 that he/she intends to remotely operate.

[0032] When the construction assistance device 10 receives a ground situation check request, the construction assistance device 10 transmits the ground situation check request to the corresponding work machine 40 (FIG. 5/C10).

[0033] When the work machine 40 receives the ground situation check request through the actual machine wireless communication device 424 (FIG. 5/C40), the actual machine control device 400 transmits captured image data to the construction assistance device 10, the captured image data representing a captured image (which may have been subjected to appropriate image processing) acquired through the actual machine imaging device 412 (FIG. 5/STEP 410).

[0034] When the construction assistance device 10 receives captured image data (FIG. 5/C11), the construction assistance device 10 transmits environment image data corresponding to the captured image to the remote operation device 20 (FIG. 5/STEP 110). The environment image data is not only the captured image data itself, but also image data representing a simulated environment image generated based on the captured image.

[0035] When the remote operation device 20 receives the environment image data through the remote wireless communication device 224 (FIG. 5/C21), the remote control device 200 outputs an environment image corresponding to the environment image data to the remote image output device 221 (FIG. 5/STEP 212).

[0036] This outputs an environment image to the remote image output device 221. The environment image reflects, for example, the ground spreading in front of the cab 42C, as well as the boom 441 and arm 443 that are part of the working mechanism 44, and piles of rubble or earth and sand in the construction target area (the work target of the bucket 445), as shown in FIG. 6.

[0037] In the remote operation device 20, the remote control device 200 transmits an underground situation check request to the construction assistance device 10 through the remote wireless communication device 224 (FIG. 5/STEP 220). The operator may determine whether there is a second designation operation through the remote input interface 210, and if the determination result is positive, he/she may transmit an underground situation check request. The "second designation operation" is, for example, an operation such as tapping on the remote input interface 210 for the operator to designate the work machine 40 that he/she intends to remotely operate. The second designation operation may be the same as or different from the first designation operation. The underground situation check request signal (see FIG. 5/STEP 210) and the underground situation check request (see FIG. 5/STEP 220) may be transmitted simultaneously by the remote control device 200 through the remote wireless communication device 224.

[0038] When the construction assistance device 10 receives an underground situation check request (FIG. 5/C12), the underground search result recognition element 120 recognizes (searches, from the database 102,) the underground search result made by the underground search machine 60 in the construction target area related to the underground situation check request (FIG. 5/STEP 120).

[0039] The construction target area is identified, for example, by a set of horizontal coordinate values (X (longitude), Y (latitude)) of the world coordinate system that represent its boundary. The construction target area is recognized by searching the database 102 based on communication between the construction assistance device 10 and the remote operation device 20 or the work machine 40 that is the target of operation, for example, based on an identifier for identifying the remote operation device 20 and/or the work machine 40.

[0040] In each of a plurality of underground search areas in the construction target area, the depth position (Z (depth)) from the ground surface of an underground buried object such as a pipe is recognized as the underground search result, the depth position being measured by the underground search machine 60. Each underground search area is identified, for example, by a set of horizontal coordinate values (X (longitude), Y (latitude)) of the world coordinate system that represent boundary of the underground search area. The plurality of underground search areas may be defined adjacently to or continuously with each other, but are preferably defined to be spaced apart from each other. The shapes, or the shapes and sizes, of the plurality of underground search areas may be the same or different.

[0041] The plurality of underground search areas may be fixedly defined. For example, as shown in FIG. 7A, a plurality of substantially rectangular or square underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} that are regularly arranged at a distance from each other (in a form of square lattice or a triangular lattice) may be defined as a plurality of underground search areas. The plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} may be regularly arranged adjacently to or continuously with each other. In this case, as shown by a dashed arrow in FIG. 7A, when the underground search machine 60 is passively or actively displaced, the underground search results in the underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} are registered in the database 102 and can be recognized by the underground search result recognition element 120. The shape of the underground search area may be various shapes such as a triangle, a trapezoid, a parallelogram, a regular polygon (regular hexagon, regular octagon, regular dodecagon, etc.), a circle, or an ellipse.

[0042] The plurality of underground search areas may be dynamically defined according to the search results by the underground search machine 60. For example, as shown by a dashed arrow in FIG. 7B, assume that: there are locations that are represented by a black circles (•) in FIG. 7B at predetermined intervals in the process of the underground search machine 60 being passively or actively displaced; and the locations are underground search points, in each of which a depth position from the ground surface of the buried object is measured. In this case, a plurality of substantially rectangular or square underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} that each has its center or center of gravity at the underground search point (defined by two-dimensional coordinate values (X (latitude), Y (longitude))) and that are irregularly arranged at a distance from each other may be defined as a plurality of underground search area. When there are a plurality of underground search points in one predetermined period, their center of gravity may be defined as the center or center of gravity of the underground search area S_{ik} (k = 1, 2, ..., m, m+1). The size and shape of the underground search area S_{ik} may be changed in various ways, but are preferably defined in advance. The size of the underground search area S_{ik} may be determined according to the displacement speed and the predetermined period (time interval) of the underground search machine 60.

[0043] A plurality of underground search areas may be dynamically defined according to the displacement aspect of the underground search machine 60. For example, in the process in which the underground search machine 60 is passively or actively displaced, a plurality of substantially rectangular or square underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} that each has its center or center of gravity at the position of the center of gravity of the underground search machine 60 for each predetermined period (defined by two-dimensional coordinate values) and that are arranged at a distance from each other may be defined as a plurality of underground search areas. The posture of the underground search area S_{ik} (e.g., the orientation of the long side or short side) may be defined so as to be aligned with the displacement direction of the underground search machine 60.

[0044] Here, processing will be described when a plurality of underground search areas overlap. For example, when the overlap degree of two substantially rectangular underground search areas S_1 and S_2, shown on the left side of FIG. 8A, is equal to or greater than a threshold value, one underground search area S_2 remaining as a result of deleting (thinning) the other underground search area S_1 is defined as a single underground search area S_{-} shown on the right side of FIG. 8A. Of the plurality of overlapping underground search areas, the underground search areas may be deleted that are the other areas than one underground search area where the depth position has the maximum (or minimum) distance or average distance from the ground surface, the depth position being measured by the underground search machine 60. When the underground search areas are deleted, which are other than the one having the minimum distance or average distance from the ground surface, construction assistance data can be generated that maintains a sufficient distance to the buried object, contributing to the efficiency of work that prioritizes the protection of the buried object.

[0045] Of the plurality of overlapping underground search areas, underground search areas may be deleted that are other than the one underground search area with the greatest (or least) number of measurement of depth positions performed by the underground search machine 60. When the underground search areas are deleted, which are other than the one underground search area with the greatest number of measurement of depth positions, construction assistance data can be generated that has information about the depth at which buried objects are likely to be located, contributing to improving work efficiency.

[0046] On the other hand, when the overlap degree of the two substantially rectangular underground search areas S_1 and S_2 shown on the left side of FIG. 8B is less than a threshold value, a single underground search area S+ is defined in which the two underground search areas S_1 and S_2 are combined, as shown on the right side of FIG. 8B. When the overlap degree of the two substantially rectangular underground search areas S_1 and S_2 shown on the left side of FIG. 8C is less than a threshold value, two underground search areas S_1' and S_2' may be defined in which the two underground search areas S_1 and S_2 are displaced so as to be spaced apart from each other, as shown on the right side of FIG. 8C.

[0047] Then, the representative depth position determination element 121 determines the representative position of the depth position groups consisting of one or more depth positions in each of the plurality of underground search areas (FIG. 5/STEP 121).

[0048] For example, as schematically shown in FIG. 9 by a black circle (•), consider a case in which: there is an underground search point group in one underground search area; and the underground search point group consists of a plurality of underground search points P_1, ...P_{i-1}, P_i, P_{i+1}, ...P_{n-1}, P_n for an underground buried object each having a depth position from the ground surface measured by the underground search machine 60. In this case, the depth position of the underground search point P_+ closest to the ground surface or the underground search point P_1 farthest from the ground surface may be determined as the representative depth position of the underground search point group. The average depth position (see dash-dot line in FIG. 9), or the central depth position or the most frequent depth position (see dot line in FIG. 9) of the plurality of underground search points P_1, ...P_{i-1}, P_i, P_{i+1}, ...P_{n-1}, P_n may be determined as the representative depth position of the underground search point group.

[0049] Then, the construction assistance image data generation element 122 generates construction assistance image data as "construction assistance data" and transmits it to the remote operation device 20 (FIG. 5/STEP 122). The construction assistance image data is three-dimensional image data representing a three-dimensional image including a plurality of objects each arranged in its individual area in a plurality of underground search areas so as to represent the representative depth position of the underground search point group. In addition, the construction assistance image data may be, for example, two-dimensional image data representing a two-dimensional image including a plurality of objects in a cross-sectional view parallel to a vertical plane, such as a topographical cross-sectional view.

[0050] As shown in FIG. 6, each object has a shape and size such that an underground search area of a substantially rectangular or substantially square shape is projected in the vertical direction or depth direction. The objects are closed surfaces m_1 and m_2 parallel to a horizontal plane. When the shapes (e.g., substantially rectangular or substantially square) and sizes of the plurality of underground search areas are the same, the shapes and sizes of the plurality of closed surfaces as the objects are also the same. When the shapes of a plurality of underground search areas are the same, the shapes of the plurality of the closed surfaces as the objects are also the same and similar.

[0051] The closed surface may be defined as a curved surface defined by a plurality of control points, such as a Bezier curved surface and/or a NURBS (non-uniform rational B-spline) curved surface. The curved surface may be defined as a curved surface having continuity (G1 continuity, G2 continuity, or G3 continuity). For example, when the closed surface is defined by Bezier triangular curved surfaces, the closed surface is defined such that: the domain of the control net of the Bezier triangular curved surfaces is defined by a triangular mesh stretched over a horizontal plane; the underground search points are set as control points; and continuity of the triangular patches are ensured.

[0052] When the remote operation device 20 receives construction assistance image data through the remote wireless communication device 224 (FIG. 5/C22), the remote control device 200 outputs a construction assistance image corresponding to the construction assistance information to the remote image output device 221 (FIG. 5/STEP 222).

[0053] As a result, for example, as shown in FIG. 6, a construction assistance image including a plurality of closed surfaces m_1 and m_2 is output to the remote image output device 221 so as to be superimposed on the environment image. Each of closed surfaces m_1 and m_2 is arranged at the representative depth position of the underground search point group in the individual area in the plurality of underground search areas included in the construction target area. The designs (e.g., colors) of the plurality of closed surfaces m_1 constituting the first object group M_1 and the plurality of closed surfaces m_2 constituting the second object group M_2 shown in FIG. 6 are differentiated so as to be identifiable depending on the depth position of the closed surfaces m_1 and m_2. As shown in FIG. 6, the vertical line segment extending from each closed surface m_1, m_2 to the ground surface may form part of the object, but the vertical line segment may be omitted.

[0054] Since the spatial occupancy aspects of the objects in the construction assistance data (or construction assistance image data) are defined in the world coordinate system, the arrangement aspects of the objects are subjected to coordinate conversion into the environment image coordinate system. For this coordinate conversion, the coordinate value in the world coordinate system of the work machine 40 may be measured using a GPS or the like, and the actual machine coordinate system (a coordinate system in which the position and posture are fixed with respect to the upper revolving body 42) of the actual machine imaging device 412 may be stored and held in the storage device and/or database 102 constituting the remote control device 200. The operator can operate the operation lever constituting the remote operation mechanism 211 to move the bucket 445 while viewing the environment image output to the remote image output device 221 and the construction assistance image superimposed on the environment image.

[0055] The real spatial position (latitude, longitude, and altitude) of each point on the ground surface is measured by a ranging device (such as LiDAR or a stereo camera) constituting the actual machine input interface 410. Then, based on the result of converting the measurement result into the environment image coordinate system, aspects are determined that are: each arrangement aspect of the underground search area in the captured image coordinate system; and each spatial occupancy aspect of the object representing the representative depth position from the ground surface of the underground search point group in the underground search area.

[0056] Otherwise, the construction assistance image may be output to the remote image output device 221 alone without being superimposed on the environment image. In this case, a three-dimensional model image is output, as the construction assistance image, to the remote image output device 221 separately from the environment image, in which the three-dimensional model image represents the spatial occupancy aspects of: the work machine 40 on the ground surface; and each object arranged to represent the depth position from the ground surface of the underground buried object, in the three-dimensional virtual space. Since the arrangement aspects of the closed surfaces represented by the construction assistance information are defined in the world coordinate system, the coordinate value in the world coordinate system of the work machine 40 may be measured using a GPS or the like and stored in the storage device and/or database 102 constituting the remote control device 200.

[0057] In the remote operation device 20, the remote control device 200 recognizes the operation aspect of the remote operation mechanism 211, and transmits a remote operation command corresponding to the operation aspect to the construction assistance device 10 through the remote wireless communication device 224 (FIG. 5/STEP 214).

[0058] When the construction assistance device 10 receives a remote operation command, the remote operation command is transmitted to the work machine 40 (FIG. 5/C14).

[0059] When the actual machine control device 400 receives an operation command through the actual machine wireless communication device 422 (FIG. 5/C44) in the work machine 40, the operation of the working mechanism 44 and the like is controlled (FIG. 5/STEP 414). For example, work is performed in which soil is dug and shoveled by the bucket 445 in the construction target area in front of the work machine 40, the upper revolving body 42 is revolved, and the soil is dumped from the bucket 445 outside the work area.

(Effects)

[0060] According to the construction assistance device 10 that performs the above-mentioned functions, in at least some underground search areas of the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} (see Figs. 7A and 7B), the underground search points P_1, ...P_{i-1}, P_i, P_{i+1}, ...P_{n-1}, P_n of the underground buried objects each have a depth position from the ground surface, measured by the underground search machine 60, and the depth positions are consolidated into a representative depth position (Fig. 5/STEP 121, see Fig. 9). Then, construction assistance image data is generated that represents a three-dimensional image including closed surfaces m_1, m_2, as objects representing the representative depth positions, each arranged in its individual area in the plurality of underground search areas $S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}$ (see Fig. 5/STEP 122, see Fig. 5).

[0061] This reduces the data amount in the construction assistance image data compared to a case in which the underground search machine 60 generates the construction assistance image data that includes a plurality of objects representing the depth positions of all the underground search points $P_1, ...P_{i-1}, P_i, P_{i+1}, ...P_{n-1}, P_n$. This allows the user or operator who is in contact with the remote image output device 221 to understand the spatial occupancy aspects of the underground buried objects in the three-dimensional real space through the spatial occupancy aspects of the closed surfaces m_1, m_2, as the plurality of objects in the construction assistance image (see FIG. 5), output to the remote image output device 221 constituting the remote output interface 220.

[0062] Furthermore, the closed surfaces m_1, m_2 as the objects only need to be arranged separately and independently so as to represent the corresponding representative depth positions, and the relative positions and postures between the plurality of objects do not need to be adjusted. Accordingly, the calculation processing load is reduced that is required for the generation processing of the construction assistance image data.

(Other embodiments of the present invention)

[0063] In the above embodiment, the construction assistance device 10 is configured of a computer separate from the remote operation device 20, the work machine 40, and the underground search machine 60. However, in another embodiment, the construction assistance device 10 may be equipped with the remote operation device 20, and the work machine 40 or the underground search machine 60.

[0064] In the above embodiment, the work machine 40 is remotely operated by the operator through the remote operation device 20. However, in another embodiment, the work machine 40 may be operated as an actual machine by the operator on board the work machine 40. In this case, construction assistance image data may be transmitted from the construction assistance device 10 to the work machine 40 (see FIG. 5/STEP 122), thereby outputting a construction assistance image corresponding to the data to an actual machine image output device constituting the actual machine output interface 420 (see FIG. 5).

[0065] The construction assistance image generated by the construction assistance device 10 may be output to a communication terminal having a display device such as a smartphone or tablet held by a worker or a construction manager. If the communication terminal is equipped with an imaging device and is configured to be able to acquire information about position of the terminal with GNSS or the like and the information about direction and angle, toward which the terminal is directed, with a direction sensor, tilt sensor, or the like, the communication terminal can superimpose a construction assistance image on a captured image of the surroundings as in the above embodiment, allowing for understanding the spatial occupancy aspects of the underground buried objects in the three-dimensional real space.

[0066] As an object arranged in the underground search area, construction assistance image data may be generated that represents a three-dimensional image that includes a three-dimensional object extending from the ground surface of the underground search area to a representative depth position of the underground search point group. For example, as shown in FIG. 10, construction assistance image data may be generated that represents a three-dimensional image that includes, as the objects, a plurality of inverted cones m_1, m_2 each having a bottom arranged on the ground surface and an apex arranged at the representative depth position in the underground search area. As in the example shown in FIG. 5, the plurality of inverted cones m_1 constituting the first object group M_1 and the plurality of inverted cones m_2 constituting the second object group M_2 have differentiated designs (e.g., colors) so as to be identifiable depending on the depth positions of the closed surfaces m_1 and m_2.

[0067] The surface of the three-dimensional object may be defined as a curved surface defined by a plurality of control points, such as a Bezier curved surface and/or a NURBS (non-uniform rational B-spline) curved surface. The curved surface may be defined as a curved surface having continuity (G1 continuity, G2 continuity, or G3 continuity). The three-dimensional object may be of various shapes different from an inverted cone, such as an inverted pyramid such as an inverted square pyramid, an inverted frustum, a cylinder, a sphere, or an ellipsoidal sphere.

[0068] In the above embodiment, the construction assistance image data, which is three-dimensional image data or two-dimensional image data, is generated as the construction assistance data. In another embodiment, the control data, including a plurality of objects each arranged in its individual area in the plurality of underground search areas so as to represent the representative depth position of the underground search point group in each of the plurality of underground search areas, may be generated as the construction assistance data.

[0069] In this case, the operation of the work machine 40 and the working mechanism 44 in its turn may be restricted or controlled so that: the construction assistance data is transmitted from the construction assistance device 10 to the work machine 40 and/or the remote operation device 20; and the actual machine control device 400 stops the depth position of the bucket 445 above the representative depth position related to the arrangement aspect of each of a plurality of objects included in the construction support data in a certain underground search area.

[0070] In addition, the work machine to which the control for restricting the operation is applied by the control data generated from the construction assistance data may have a configuration such that the operator on board the actual machine operates the work machine or a configuration such that the operator operates the work machine through remote control. The work machine can also be applied to a work machine operated by automatic operation.

[0071] In the above embodiment, the depth positions of the plurality of underground search points in each underground search area are measured by the underground search machine 60. However, another embodiment may be such that: the depth position of a single underground search point in each underground search area is measured by the underground search machine 60; and construction assistance data or construction assistance image data is generated that includes an object arranged in the underground search area so as to represent the depth position.

[0072] The construction assistance device having the above configuration is preferably such that construction assistance data is generated such that each of the depth positions represents a representative depth position of an underground search point group consisting of one or more underground search points P_1, ...P_{i-1}, P_i, P_{i+1}, ...P_{n-1}, P_n of a measured underground buried object.

[0073] According to the construction assistance device of this configuration, in at least some underground search areas of the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}, the depth positions from the ground surface of the underground search points of the underground buried object are consolidated into a representative depth position, the depth positions being measured by the underground search machine 60. The "plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}" may be predetermined underground search areas, such as a plurality of mesh-shaped underground search areas spaced apart from each other, or may be underground search areas occupied by the underground search machine 60 at a predetermined time interval or distance. Then, construction assistance data is generated that includes objects each arranged in its individual area in the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}, the objects each representing the representative depth position.

[0074] This reduces the data amount in the construction assistance data compared to a case in which the underground search machine 60 generates the construction assistance data that includes a plurality of objects representing the depth positions of all the underground search points.

[0075] Furthermore, the objects only need to be arranged separately and independently so as to represent the corresponding representative depth positions, and the relative positions and postures between the plurality of objects do not need to be adjusted. Accordingly, the calculation processing load is reduced that is required for the generation processing of the construction assistance data.

[0076] The construction assistance device having the above configuration is preferably such that construction assistance image data is generated as the construction assistance data, the construction assistance image data representing an image including the plurality of objects.

[0077] According to the construction assistance device of this configuration, construction assistance image data is generated as the construction assistance data, the construction assistance image data representing an image (three-dimensional image or two-dimensional image) that includes objects each arranged in its individual area in the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}, the objects each representing the representative depth position.

[0078] This reduces the data amount in the construction assistance image data compared to a case in which the underground search machine 60 generates the construction assistance image data that includes a plurality of objects representing the depth positions of all the underground search points. A plurality of objects in a construction assistance image corresponding to the construction assistance image data are output to the output interface (e.g., the remote output interface 220 or a remote image output device 221 constituting the same). The spatial occupancy aspects of the objects allow the user who is in contact with the output interface to understand the spatial occupancy aspects of the underground buried objects in real space.

[0079] The construction assistance device having the above configuration is preferably such that the construction assistance image data is generated that represents an image including a plurality of closed surfaces as the plurality of objects, the plurality of closed surfaces each being arranged at the representative depth position in its individual area in the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}.

[0080] According to the construction assistance device having the above configuration, the objects included in the construction assistance image data are closed surfaces, thus the data amount in the construction assistance image data is reduced. The "closed surface" is a concept that includes planes and curved surfaces surrounded by a closed curve. In particular, when the closed surface is a plane, the data amount in the construction assistance image data can be further reduced. An image (three-dimensional image or two-dimensional image) is output to the output interface (e.g., the remote output interface 220 or a remote image output device 221 constituting the same). The image (three-dimensional image or two-dimensional image) includes a plurality of closed surfaces each in its individual area in the plurality of underground search areas in a virtual space. The arrangement aspects of the closed surfaces allow the user who is in contact with the output interface to understand the spatial occupancy aspects, including the depth positions from the ground surface, of the underground buried object, in the real space.

[0081] The construction assistance device having the above configuration is preferably such that the construction assistance image data is generated that represents an image including a single closed surface as part of the plurality of objects, the single closed surface corresponding to a result of synthesizing a plurality of the closed surfaces each in its individual area in overlapping the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} among the plurality of underground search areas.

[0082] According to the construction assistance device having this configuration, the plurality of closed surfaces are consolidated into the single closed surface, the plurality of closed surfaces each corresponding to its individual area in the plurality of overlapping underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}. Accordingly, the data amount of the construction assistance image data is reduced. For example, a plurality of horizontal closed surfaces, each of which has the same or nearly the same depth position from the ground surface in its individual area in the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}, are output to an output interface (e.g., the remote output interface 220 or the remote image output device 221 constituting the same), as a horizontal or nearly horizontal single plane that covers the plurality of underground search areas and that has the same or nearly the same depth position as the plurality of closed surfaces. Furthermore, a plurality of horizontal closed surfaces, each of which has different depth positions from the ground surface in the individual area in the plurality of underground search areas, are output to the output interface, as a single plane that inclines with respect to the horizontal depending on the difference in the depth position and that covers the plurality of underground search areas.

[0083] The construction assistance device having the above configuration is preferably such that the construction assistance image data is generated that represents an image including the plurality of closed surfaces having the same shape.

[0084] According to the construction assistance device of this configuration, the plurality of closed surfaces have a common shape (the closed surfaces limited to be the same or similar in shape), so that the representation of the plurality of closed surfaces is simplified, and the data amount of the construction assistance image data is reduced accordingly.

[0085] The construction assistance device having the above configuration is preferably such that: the plurality of objects are classified into a plurality of object groups depending on a relative arrangement aspect of each of the plurality of objects; and the construction assistance image data is generated that represents an image in which each of the plurality of objects m_1, m_2 is identifiable by a design corresponding to one object group to which the object belongs.

[0086] According to the construction assistance device of this configuration, the plurality of objects m_1 constitute a common object group, and the plurality of objects m_2 constitute another common object group, among the plurality of object groups. The objects m_1 have a common design, and objects m_2 have another common design. Accordingly, the data amount of the construction assistance image data is reduced. The "design" means a color, a shape (including size), a pattern, or any combination of these, and is a concept that includes dynamic designs as well as static designs.

[0087] The construction assistance device having the above configuration is preferably such that the construction assistance image data is generated that represents an image including a plurality of three-dimensional objects as the plurality of objects m_1, m_2, the plurality of three-dimensional objects each extending from the ground surface to the representative depth position in its individual area in the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}.

[0088] According to the construction assistance device of this configuration, the plurality of three-dimensional objects have a common rule of extending from the ground surface to the representative depth position in the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}. Accordingly, the data amount of the construction assistance image data is reduced compared to a case in which the objects m_1, m_2 without such a common rule are included.

[0089] The construction assistance device having the above configuration is preferably such that the construction assistance image data is generated that represents an image including the plurality of three-dimensional objects each having the same shape or the same shape resulting from projecting the three-dimensional object onto a horizontal plane.

[0090] According to the construction assistance device of this configuration, the plurality of three-dimensional objects have a common shape or a common shape resulting from projecting a three-dimensional object onto a horizontal plane (or the ground surface) (the three-dimensional objects or the closed surfaces resulting from projecting the three-dimensional objects onto a horizontal plane are the same or similar in shape). This simplifies the representation of the shape and posture of the plurality of three-dimensional objects, and accordingly reduces the data amount of the construction assistance image data.

[0091] The construction assistance device having the above configuration is preferably such that the plurality of underground search areas S_{i1}, S_{i2}, ..., S_{im}, S_{im+1} are spaced apart from each other.

[0092] According to the construction assistance device of this configuration, misidentification of the plurality of objects m_1, m2 can be avoided when they are processed, in which the misidentification is caused by the fact such that: the objects m1, m2 are each arranged in its individual area in the plurality of underground search areas Si1, Si2, ..., Sim, Sim+1 adjacent to each other via a boundary line; and at least part of data representing the boundary line is common.

Reference Signs List

[0093]

10: construction assistance device
102: database
120: underground search result recognition element
121: representative depth position determination element
122: construction assistance image data generation element
20: remote operation device
200: remote control device
210: remote input interface
211: remote operation mechanism
220: remote output interface
221: remote image output device
222: remote audio output device
224: remote wireless communication device
40: work machine
41: lower traveling body
42: upper revolving body
42C: cab (operation room)
44: working mechanism
445: bucket
400: actual machine control device
410: actual machine input interface
420: actual machine output interface
60: underground search machine
600: search control device
602: search storage device
611: depth position measurement element
612: search position measurement element
624: search wireless communication device
m_1, m_2: object (closed surface, three-dimensional object)
P_1, ...P_{i-1}, P_i, P_{i+1}, ...P_{n-1}, P_n: underground search point
S_{i1}, S_{i2}, ..., S_{im}, S_{im+1}: underground search area.

Claims

1. A construction assistance device, comprising an underground search machine, wherein

the underground search machine measures a depth position from a ground surface in each of a plurality of underground search areas, and
construction assistance data is generated that includes a plurality of objects each representing the depth position from the ground surface, the objects each being arranged in each of the plurality of underground search areas.

2. The construction assistance device according to claim 1, wherein construction assistance data is generated such that each of the depth positions represents a representative depth position of an underground search point group consisting of one or more underground search points of a measured underground buried object.

3. The construction assistance device according to claim 2, wherein construction assistance image data is generated as the construction assistance data, the construction assistance image data representing an image including the plurality of objects.

4. The construction assistance device according to claim 3, wherein the construction assistance image data is generated that represents an image including a plurality of closed surfaces as the plurality of objects, the plurality of closed surfaces each being arranged at the representative depth position in each of the plurality of underground search areas.

5. The construction assistance device according to claim 4, wherein the construction assistance image data is generated that represents an image including a single closed surface as part of the plurality of obj ects, the single closed surface corresponding to a result of synthesizing a plurality of the closed surfaces in each of overlapping underground search areas among the plurality of underground search areas.

6. The construction assistance device according to claim 4, wherein the construction assistance image data is generated that represents an image including the plurality of closed surfaces having the same shape.

7. The construction assistance device according to claim 3, wherein the plurality of objects are classified into a plurality of object groups depending on a relative arrangement aspect of each of the plurality of objects, and the construction assistance image data is generated that represents an image in which each of the plurality of objects is identifiable by a design corresponding to one object group to which the object belongs.

8. The construction assistance device according to claim 3, wherein the construction assistance image data is generated that represents an image including a plurality of three-dimensional objects as the plurality of objects, the plurality of three-dimensional objects each extending from a ground surface to the representative depth position in each of the plurality of underground search areas.

9. The construction assistance device according to claim 8, wherein the construction assistance image data is generated that represents an image including the plurality of three-dimensional objects having a same shape or a same shape resulting from projecting the three-dimensional object onto a horizontal plane.

10. The construction assistance device according to claim 1, wherein the plurality of underground search areas are spaced apart from each other.

11. A construction assistance method comprising:

a step of determining a representative depth position of an underground search point group in each of a plurality of underground search areas, the underground search point group composed of one or more underground search points of an underground buried object having one or more depth positions from a ground surface measured by an underground search machine; and

a step of generating construction assistance data including a plurality of objects each arranged in each of the plurality of underground search areas so as to represent the representative depth position.

FIG.1

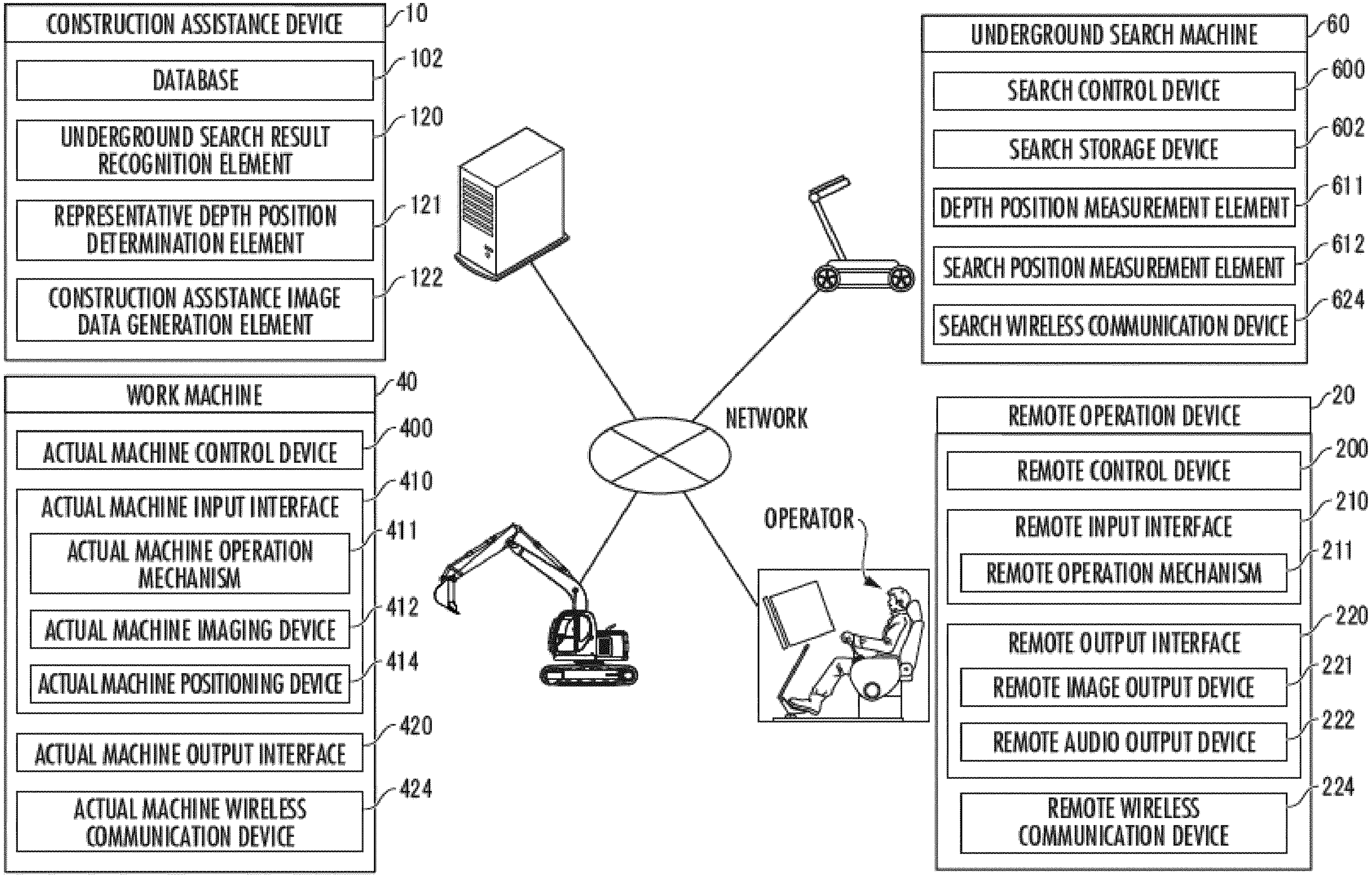

CONSTRUCTION ASSISTANCE DEVICE
10
DATABASE
102
UNDERGROUND SEARCH RESULT RECOGNITION ELEMENT
120
REPRESENTATIVE DEPTH POSITION DETERMINATION ELEMENT
121
CONSTRUCTION ASSISTANCE IMAGE DATA GENERATION ELEMENT
122
WORK MACHINE
40
ACTUAL MACHINE CONTROL DEVICE
400
ACTUAL MACHINE INPUT INTERFACE
410
ACTUAL MACHINE OPERATION MECHANISM
411
ACTUAL MACHINE IMAGING DEVICE
412
ACTUAL MACHINE POSITIONING DEVICE
414
ACTUAL MACHINE OUTPUT INTERFACE
420
ACTUAL MACHINE WIRELESS COMMUNICATION DEVICE
424
NETWORK
OPERATOR
UNDERGROUND SEARCH MACHINE
60
SEARCH CONTROL DEVICE
600
SEARCH STORAGE DEVICE
602
DEPTH POSITION MEASUREMENT ELEMENT
611
SEARCH POSITION MEASUREMENT ELEMENT
612
SEARCH WIRELESS COMMUNICATION DEVICE
624
REMOTE OPERATION DEVICE
20
REMOTE CONTROL DEVICE
200
REMOTE INPUT INTERFACE
210
REMOTE OPERATION MECHANISM
211
REMOTE OUTPUT INTERFACE
220
REMOTE IMAGE OUTPUT DEVICE
221
REMOTE AUDIO OUTPUT DEVICE
222
REMOTE WIRELESS COMMUNICATION DEVICE
224

FIG.2

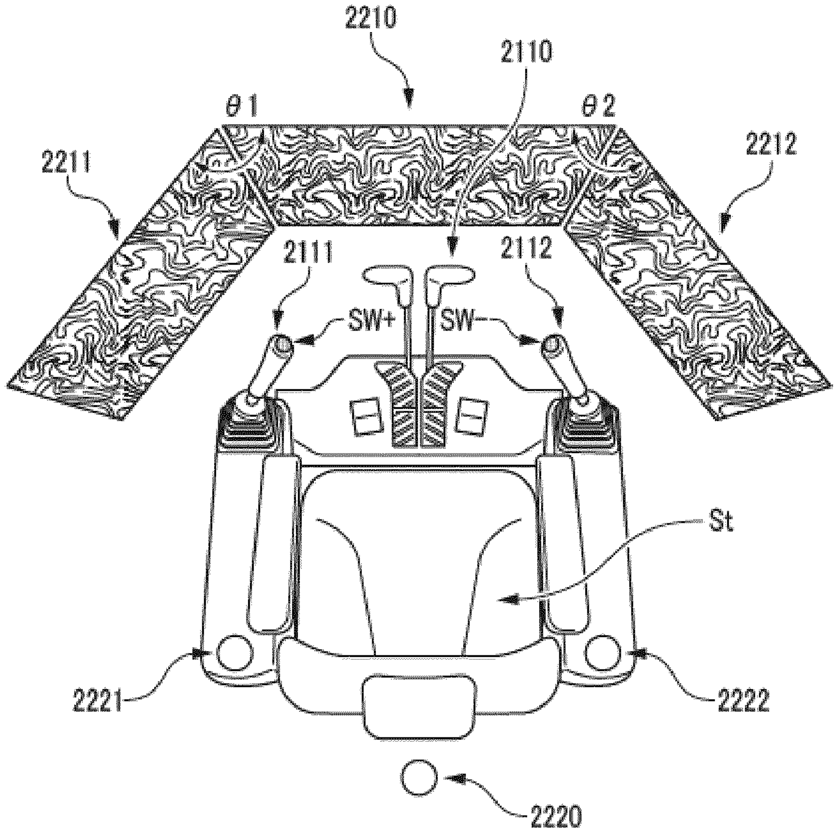


FIG.3

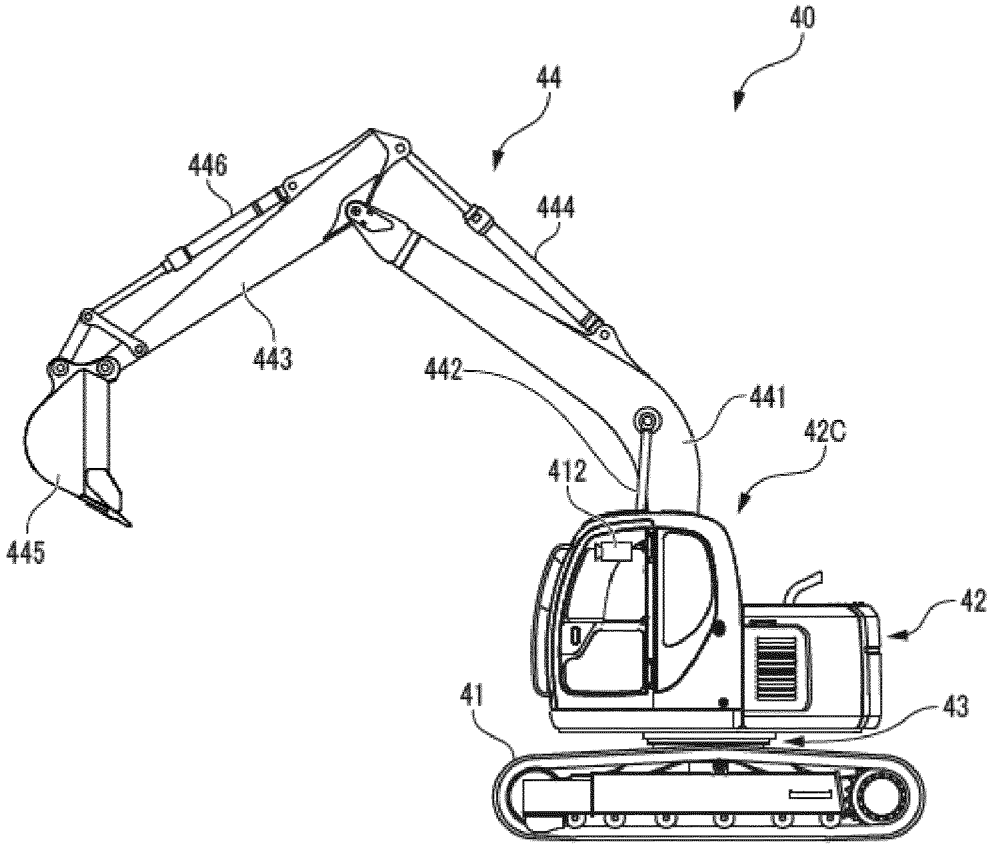

40
44
446
444
443
442
441
42C
412
445
42
41
43

FIG.4

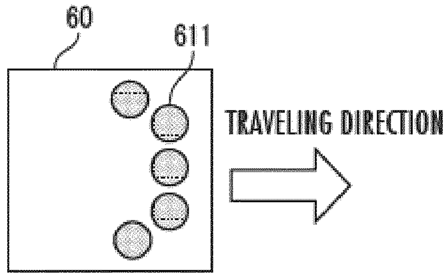

60
611
TRAVELING DIRECTION

FIG.5

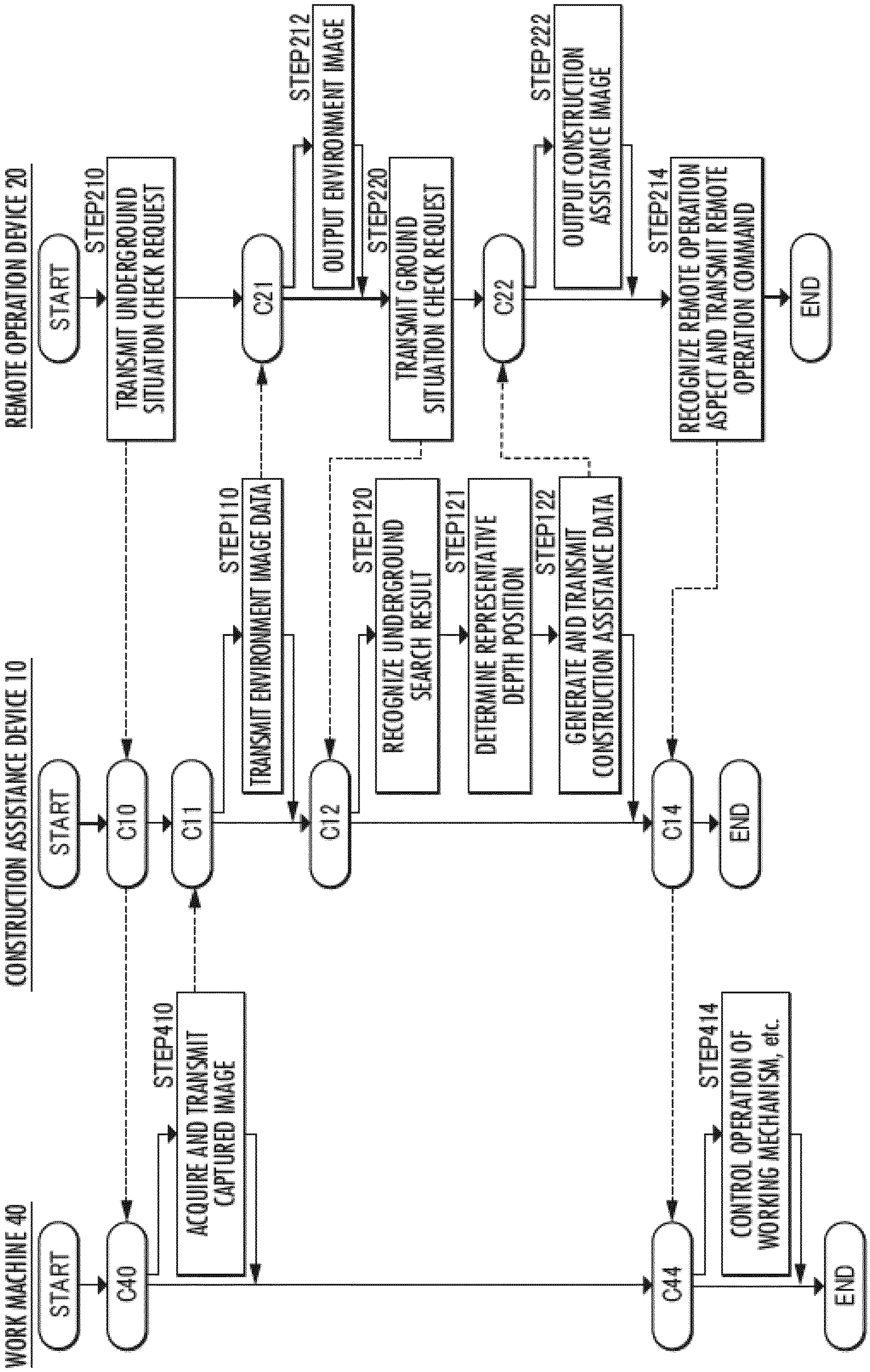

WORK MACHINE 40
START
C40
STEP410
ACQUIRE AND TRANSMIT CAPTURED IMAGE
C44
STEP414
CONTROL OPERATION OF WORKING MECHANISM, etc.
END
CONSTRUCTION ASSISTANCE DEVICE 10
START
C10
C11
STEP110
TRANSMIT ENVIRONMENT IMAGE DATA
C12
STEP120
RECOGNIZE UNDERGROUND SEARCH RESULT
STEP121
DETERMINE REPRESENTATIVE DEPTH POSITION
STEP122
GENERATE AND TRANSMIT CONSTRUCTION ASSISTANCE DATA
C14
END
REMOTE OPERATION DEVICE 20
START
STEP210
TRANSMIT UNDERGROUND SITUATION CHECK REQUEST
C21
STEP212
OUTPUT ENVIRONMENT IMAGE
STEP220
TRANSMIT GROUND SITUATION CHECK REQUEST
C22
STEP222
OUTPUT CONSTRUCTION ASSISTANCE IMAGE
STEP214
RECOGNIZE REMOTE OPERATION ASPECT AND TRANSMIT REMOTE OPERATION COMMAND
END

FIG.6

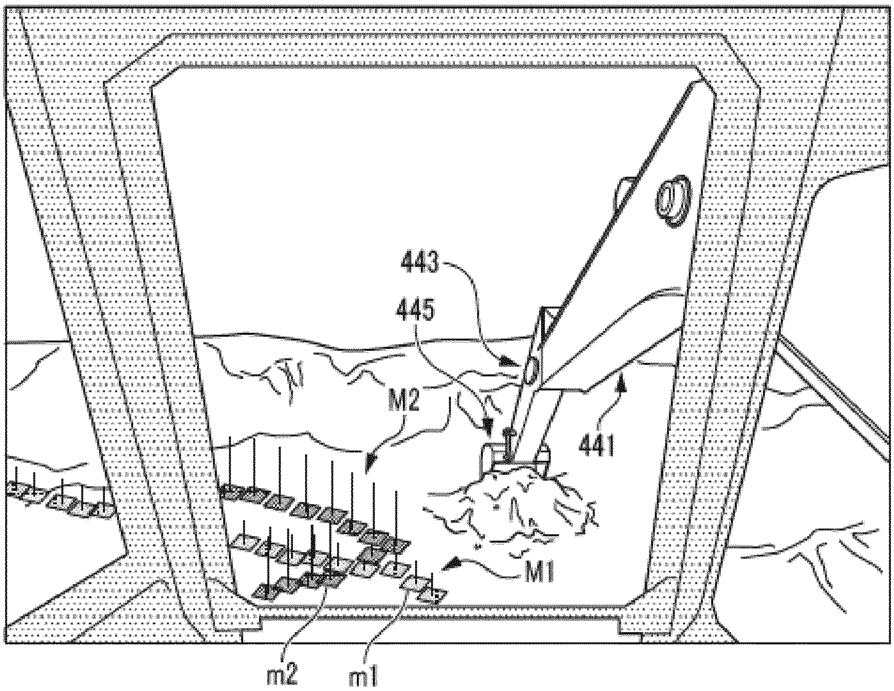


FIG.7A

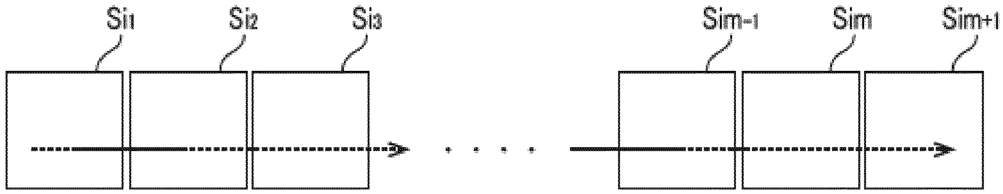


FIG.7B

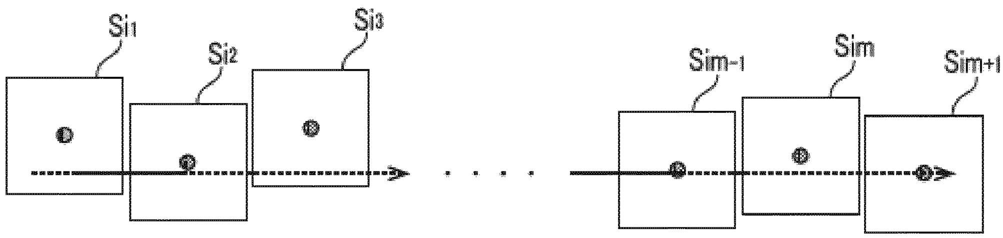


FIG.8A

FIG.8B

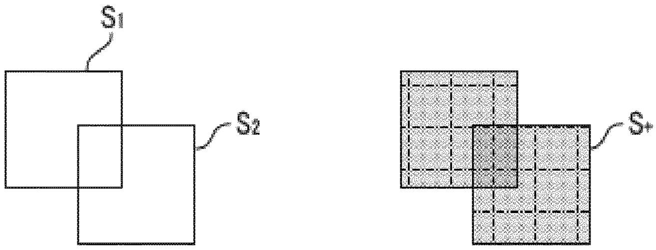


FIG.8C

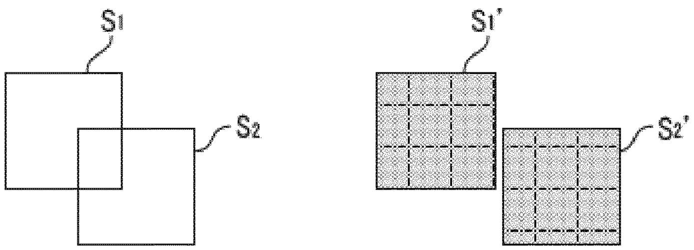


FIG.9

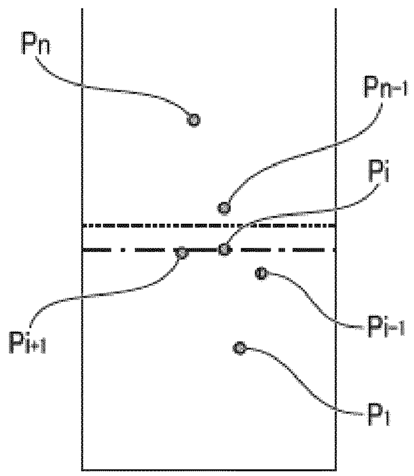
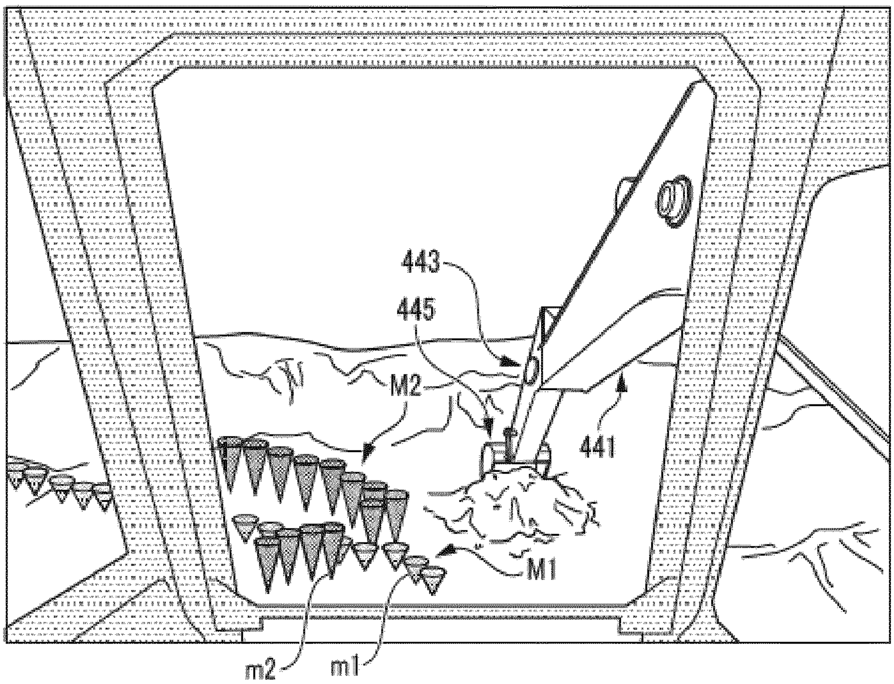


FIG.10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/027785

A. CLASSIFICATION OF SUBJECT MATTER

E02F 9/20(2006.01)i; ***G06T 19/00***(2011.01)i
FI: E02F9/20 C; G06T19/00 600; E02F9/20 N

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F3/42-3/43, E02F3/84-3/85, E02F9/00-9/28, G06T19/00, G01V1/00-99/00, F41H11/13

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2016-57235 A (OSAKA GAS CO., LTD.) 21 April 2016 (2016-04-21) paragraphs [0001], [0025]-[0071], fig. 1-3	1-4, 6-7, 10-11
A	paragraphs [0001], [0025]-[0071], fig. 1-3	5, 8-9
X	JP 2004-109084 A (NTT INFRANET CO., LTD.) 08 April 2004 (2004-04-08) paragraphs [0001], [0015]-[0028], fig. 1-9	1-3, 10-11
X	JP 2021-189127 A (KUBOTA CORP.) 13 December 2021 (2021-12-13) paragraphs [0001], [0008]-[0079], fig. 1-7	1-3, 7, 11
A	JP 2005-134015 A (HITACHI CONSTR. MACH. CO., LTD.) 26 May 2005 (2005-05-26) paragraphs [0036]-[0045], fig. 3	1-11

☐ Further documents are listed in the continuation of Box C.   ☑ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2023	**26 September 2023**

Name and mailing address of the ISA/JP	Authorized officer
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INTERNATIONAL SEARCH REPORT
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Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2016-57235 A	21 April 2016	(Family: none)	
JP 2004-109084 A	08 April 2004	US 2004/0059539 A1 paragraphs [0089]-[0116], fig. 1-9	
JP 2021-189127 A	13 December 2021	(Family: none)	
JP 2005-134015 A	26 May 2005	(Family: none)	

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Patent documents cited in the description

- JP 2003056010 A **[0004]**
- JP 2021189127 A **[0004]**