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(54) **Title:** VARIABLE DENSITY DEPTHPMAP

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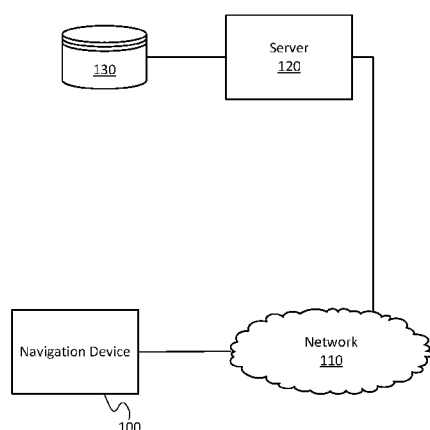


FIG. 1

(57) **Abstract:** One or more systems, devices, and/or methods for organizing spatial data are disclosed. For example, a method includes receiving a location data point from a navigation device. A controller compares the distance from each of a plurality of data points to the location data point. In constructing a depthmap that associates each of the data points with the distance from the location data point, the controller assign data points within a minimum distance from the location data point into a first cell and data points greater than the minimum distance from the location data point into a second cell. The second cell is larger than the first cell and corresponds to a larger geographic area than the first cell. The depthmap may be configured to position points of interest in a panoramic or street level view image.

VARIABLE DENSITY DEPTHMAP

BACKGROUND OF THE INVENTION

The present invention relates to maps and/or navigation and, more particularly, to method(s) and system(s) for constructing depthmaps for use in maps and/or navigation.

An example depthmap is a two-dimensional array including two-dimensional location information along with the array's element values as depth values. In other words, each point in a depthmap may have three coordinates. Two coordinates correspond to the location in the two-dimensional array, and the third is the depth at that location. A depthmap may resemble a gray scale image with the intensity values replaced by depth values.

Depthmaps may be used for a variety of image processing techniques. For example, the background of an image may be identified and removed to isolate the foreground image or to insert a new background. In addition, depthmaps may be used to add effects to an image such as fog or shadows. Depthmaps may also be used to add information to images.

SUMMARY OF THE INVENTION

According to one aspect, organizing spatial data is performed remotely by a server or locally by a navigation device. A controller receives a location data point from the navigation device and identifies a plurality of data points indexed by a distance from the location data point. The distance from each of the plurality of data points to the location data point are compared to a minimum distance. At least one data point within the minimum distance from the location data point is assigned to a first cell, and at least one data point greater than the minimum distance from the location data point is assigned to a second cell. The controller constructs a depthmap including the first cell and the second cell, wherein the second cell is larger than the first cell and/or covers a greater geographical area than the first cell. The depthmap is sent for display by the navigation device.

The present invention is defined by the following claims, and nothing in this section should be taken as a limitation on those claims. Further aspects and

1 advantages of the invention are discussed below in conjunction with the preferred
2 embodiments.

3 4 BRIEF DESCRIPTION OF THE DRAWINGS

5 Figure 1 illustrates an example embodiment of a navigation system.

6 Figure 2 illustrates a graphical view of a variable density depthmap.

7 Figure 3 illustrates a partial view of the variable density depthmap of Figure 2.

8 Figure 4 illustrates a comparison of a constant density depthmap and a
9 variable density depthmap.

10 Figure 5 illustrates another graphical view of a variable density depthmap.

11 Figure 6 illustrates a detailed view of the server of Figure 1.

12 Figure 7 illustrates a detailed view of navigation the device of Figure 1.

13 Figure 8 illustrates a panoramic image incorporating a variable density
14 depthmap.

15 Figure 9 illustrates a flowchart for constructing a variable density depthmap.

16 17 DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED 18 EMBODIMENTS

19 Depthmaps of variable density include a higher density of depth values nearer
20 a center location, which may correspond to the location of a user, and progressively
21 lower density of depth values as the distance from the center increases. The variable
22 density depthmaps may include two or more densities of depth values. The densities
23 may be determined based on the distance of a particular location in the depth map to
24 the user or based on an amount of information associated with a particular location in
25 the depth map. Because fewer depthmap values are used, less data is required to store
26 the depthmap. Therefore, the variable density reduces the amount of time, processing
27 power, storage space, bandwidth for transmission, time for transmission, and/or time
28 for decoding required to utilize depthmaps.

29 Depthmaps may be constructed from light detection and ranging (LIDAR)
30 data. LIDAR, which may also be referred to as three dimensional laser scanning,
31 employs one or more lasers or “cameras” to collect data points representing a
32 surrounding area, such as an area about a road or walkway. A LIDAR device collects
33 and gathers data points in a point cloud in which each data point corresponds to a
34 local coordinate, such as (x, y, z), and is either on or off. Alternatively, the LIDAR

1 data may be a grayscale point cloud including an intensity for each data point, ranging
2 from 0 for black to 255 for white or vice versa. The point cloud may be stored in
3 ASCII or LIDAR exchange format. The one or more lasers may be in a near infrared
4 spectrum (such as about 700nm to about 5000nm or about 800nm to about 2500nm)
5 or other light spectrum.

6 In one example algorithm for construction of a depthmap from LIDAR data,
7 the LIDAR data may be rendered into a cube of any size. The center of the cube
8 corresponds to the location of the LIDAR device when collecting the LIDAR data. A
9 depthmap is derived from each face of the cube. The depthmap allows objects to be
10 accurately placed on the images that correspond to views associated with the
11 particular face of the cube. The object may be a point of interest tag such as label
12 describing an address, a building, a landmark, a business, or other object visible in the
13 image. Alternatively, the object may be an advertisement, a speed limit, a street name,
14 or a landmark identifier. The images may be combined in a panoramic imagery such
15 as that found in a street level navigation application or an augmented reality
16 application. While the following description places the origin of the depthmap, street
17 level navigation image, or augmented reality image as the location of a user or
18 navigation device, the origin may also be a simulated location used to provide a
19 perspective in a mapping application without the navigation device or the user
20 actually being located at the origin.

21 In panoramic imagery some objects that are close to the center of the image or
22 in the foreground of the image, which corresponds to locations near the user's
23 location, are displayed to the user at a larger scale. These foreground objects are
24 relatively farther apart and may be positioned precisely with respect to the objects'
25 geographic locations. However, objects that are relatively distant from the center of
26 the image or in the background of the image, are displayed to the user at a smaller
27 scale. In other words, based on perspective, the foreground of the image includes less
28 geographical area than the background of the image. Therefore, less precision is
29 needed in placing objects in the background of the image. Accordingly, a less detailed
30 depthmap is needed to store the location of objects closer to the background of the
31 image. A variable density depthmap allows the locations of objects in one area of the
32 image to be stored in a low resolution area of the depthmap and the locations of

1 objects in another area of the image to be stored in a high resolution area of the
2 depthmap.

3 Figure 1 illustrates a navigation system 150 for constructing and displaying
4 variable density depthmaps. The navigation system 150 includes a navigation device
5 100, a network 110, a server 120, and a database 130. The navigation device 100 may
6 be a cellular telephone (smart phone), a personal digital assistant (“PDA”), a tablet
7 computer, a laptop, a personal navigation device (“PND”), or any portable device.

8 The navigation device 100 or mobile device generates a location according to
9 the geographic location of the navigation device 100. The location may be generated
10 using positioning circuitry including one or more of a global navigation satellite
11 system based on a satellite signal, a triangulation system that utilizes one or more
12 terrestrial communication signals, a inertial position system based on sensors such as
13 gyroscopes or accelerometers, and/or a or dead reckoning system based on a
14 previously known position. The positioning circuitry may also determine an
15 orientation using any of the above systems and/or a magnetic sensor such as a
16 compass. The orientation and the location allow the appropriate variable density
17 depthmap to be selected based on the perspective of the user at the current geographic
18 location of the navigation device 100.

19 The database 130 stores depthmap data. The depthmap data comprises
20 geographic coordinates paired with objects. The navigation device 100 communicates
21 the location, which may include a single location data point, to the server 120 via
22 network 110. The server 120 accesses the depthmap data from the database 130 to
23 identifying a plurality of data points. The data points may be indexed by a distance
24 from the location data point or the distance from the location data point may be
25 calculated from the coordinates of the data points and the location data point.

26 The variable density depthmap is organized in a plurality of cells. The cells
27 vary in size with respect to the geographic area that the cells represent. The server 120
28 compares the distance from each of the plurality of data points to the location data
29 point to construct the variable density depthmap. The server 120 constructs the
30 variable density depthmap by assigning or binning at least one of the plurality of data
31 points within a minimum distance from the location data point into a first cell and
32 assigning or binning a at least one of the plurality of data points greater than the
33 minimum distance from the location data point into a second cell. The second cell is

larger than the first cell, which means the second cell covers a greater geographic area than the geographic area covered by the first cell. The second cell may include a subset of the plurality of data points separated by a distance greater than that of the first cell. The server 120 sends the depthmap to the navigation device 100.

The depthmap constructed from the first cell and the second cell includes a low density region, which includes the second cell, and a high density region, which includes the first cell. The low density region includes fewer possible data points in the depthmap than in the high density region. The density of the cells, which directly determines the size of the cell, may be selected by a user of the server 120. For example, the server 120 may define the variable density depthmap such that for the first 10 meters from the reference location, cells are 1 meter by 1 meter, and for 10 meters to 100 meters from the reference location, cells are 5 meters by 5 meters. When objects are loaded into the depthmap, there are 100 possible coordinates (cells) in the depth map for the first 10 meter interval, and 396 possible coordinates for the interval from 10 meters to 100 meters, which totals 496 values to store in the depthmap. A conventional constant density depth map using 1 meter by 1 meter cells for the entire depthmap involves 10,000 values to store in the depthmap. In this simple example, variable density depthmaps involve reduction in storage and processing resources by a factor of 20.

The variable density depthmap provides a link between the panoramic or street level view image and points of interest associated with the plurality of data points so that the points of interest can be combined with the panoramic or street view image and displayed on the navigation device 100. The points of interest may be combined with the panoramic or street view image by the navigation device 100 or on the server 120. Alternatively, the variable density depthmap may be overlaid on the image.

The network 110 may include any combination of a cellular network, the Internet, or a local computer network. For example, the navigation device 100 may communicate with the network 110 wirelessly through protocols known as Wi-Fi, the protocols defined by the IEEE 802.11 standards, the protocols defined by the Bluetooth standards, or other protocols. Alternatively or in addition, the navigation device 100 may communicate with the network 110 wirelessly as a cellular network such as a Global System for Mobile Communication (GSM) or other third generation (3G) or fourth generation (4G) networks.

Figure 2 illustrates a graphical view of a variable density depthmap 200. The variable density depthmap 200 is shown against an example layout of buildings 201. The buildings 201 are not part of the variable density depthmap 200. The buildings 201 are shown for illustrative purposes only. The variable density depthmap 200 is constructed from the perspective of a user or navigation device 100 located at point 203. The variable density depthmap 200 includes a plurality of cells. The cells may be sized based on a distance from the point 203.

Figure 3 illustrates a partial view of the variable density depthmap 200 of Figure 2. The cells closest to point 203, which are shown as a first level of cells 305, are within a first predefined distance from the point 203. The second level of cells 303 encircle or surround the first level of cells 305. The second level of cells 303 are greater than the first predefined distance from the point 203 but less than a second predefined distance from the point 203. The third level of cells 301 encircle or surround the second level of cells 303. The third level of cells 301 is greater than the second predefined distance from the point 203. The third level of cells 301 is less dense than the second level of cells 303, which is less dense than the first level of cells 305.

As illustrated by Figures 2 and 3, cells 303 are larger than cells 305 with respect to geographic area. Points of interests that correspond to geographic locations are associated with a cell. In the first level of cells 305, most buildings span across multiple cells. Points of interest in the same building may be associated with different cells, and accordingly, displayed on navigation device 100 at different locations on the screen. In the second level of cells 303, some buildings may span multiple cells but most are limited to a single cell. Points of interest in the same building are less likely to be associated with different cells, and accordingly, may be displayed on the navigation device 100 at the same or nearby locations on the screen even though they are geographically spaced apart. In the third level of cells 301, some buildings share a single cell. Points of interest in different buildings may be associated with a single cell, and displayed at a single location by navigation device 100.

The relative relationship between buildings 201 and the variable density depthmap 200 shown in Figure 2 is just one example. The first level of cells 305 may be smaller. For example, each cell may be a size suitable to distinguish between adjacent store fronts (e.g., 1 ft, 1 m., 10 ft). The third level of cells 301 may be a

1 larger scale. For example, each cell may be city blocks (e.g., 2 blocks, 10 blocks) or
 2 miles (e.g., 1 mile, 10 mile) across.

3 The variable density depthmap 200 may also be used in indoor maps of indoor
 4 environments (e.g., shopping mall, convention center, etc.) or in a hybrid outdoor and
 5 indoor environment (e.g., fairgrounds, amusement park, etc.). Each of the first level of
 6 cells 305, the second level of cells 303, and the third level of cells 301 may be
 7 associated with locations and objects in the indoor environment. For example, in a
 8 shopping mall, the stores closest to the navigation device 100 may be associated with
 9 the first level of cells 305 to provide precise placement of objects on the navigation
 10 device 100, while the more distant stores or even out of line of sight stores may be
 11 associated with the second level of cells 303 or the third level of cells 301.

12 Alternately, the first level of cells 305 may be associated with the indoor environment
 13 and the second level of cells 303 and/or third level of cells 301 may be associated
 14 with an adjacent outdoor environment.

15 In another example, the variable density depthmap 200 may be constructed
 16 according to a linear relationship. The size of a cell may be selected as a function of
 17 the distance from the location of the navigation device 100. The function may be a
 18 stepwise function so that the size of the cells changes in proportional intervals moving
 19 away from the location of the navigation device 100, as shown by the following
 20 example:

$$21 \quad \text{Size} = 2^{\text{floor}((d + \frac{N}{2})/N)} \quad [\text{EQ1}]$$

22 where d is the distance from the center, N is the distance across each level of cells in a
 23 direction from the center (In the example of Figures 2 and 3, N=12. EQ1 also assumes
 24 a minimum cell size of 1 unit, which could be adjusted with the addition of a constant.
 25 The center may be the location of the navigation device 100. The floor function,
 26 which also may be referred to as a truncation, maps the input to the largest integer not
 27 greater than the input. Equations EQ1 is based on square cells; however, the cells may
 28 be rectangular, circular, a circular segment, a circular sector, or any other shape.

29 In an alternative embodiment, the relative sizes of cells of the variable density
 30 depthmap 200 may be based on the number of objects or data points associated with
 31 the particular cell. The cells are sized larger in areas with relatively few objects and
 32 smaller in areas with relatively numerous objects. For example, each cell may include
 33 a predetermined number of objects. The objects may be sorted according to the

1 location of the center point and new cells are created concentrically around the center
2 point every predetermined number of objects. The cells may be cylindrically shaped
3 in this manner or further divided over a predetermined angular range to approximate
4 rectangular cells.

5 The variable density depthmap 200 may be created by indexing depth values
6 using a spatial data structure, such as a k -dimensional (k -d) tree, quadtree, or any
7 binary tree or other data tree structure. The spatial data structure partitions a two or
8 three dimensional space by recursively subdividing the space into regions. For
9 example, the k -d tree is a binary tree in which every node is a k -dimensional point.
10 The k -d tree iteratively bisects the search space into two regions containing half of the
11 points of the parent region. This subdivision stops when a predetermined cell size is
12 reached. The k -d tree allows an efficient and quick look up to find a location in the
13 depthmap. The spatial data structure tree defines the cells which are used to process
14 the points when creating the depthmap. In this case, the spatial data structure tree is
15 built by subdividing the region from the center 203 to the maximum distance into
16 cells each half the size of the parent. At each level of recursion, the distance from the
17 cell's center to the depthmap center 203 is checked. When the distance equals the
18 minimum for that distance to the depthmap center 203, the division stops.

19 In another alternative embodiment, the variable density depthmap 200 may be
20 created by processing all LIDAR points less than a maximum distance from the center
21 point. A point is inserted into the variable density depthmap 200 into a large cell. If
22 another point is added that falls within the cell, the cell is divided into two cells.
23 Additional points are inserted or discarded based on the distance from the center point
24 and the population of particular cell. For example, all points less than the maximum
25 distance from the depthmap center 203 are processed using a spatial data structure.
26 The spatial data structure classifies the point to determine what cell the point is to be
27 inserted into. The level of the cell may be 0 (corresponding to the first level of cells
28 305), 1 (corresponding to the second level of cells 303), 2 (corresponding to the third
29 level of cells 301), and so on. If the level of the cell is 0, then the point is inserted into
30 the depthmap in the first level of cells. If the level is greater than 0, then the point is
31 inserted if the cell contains less than the maximum number of points for each cell at
32 that level. If the number of points in the cell is greater than the maximum, the point is
33 not added to the depthmap.

1 In addition, the variable density depthmap 200 may vary over time by
2 progressive refinement. For example, one depth value per cell may be used initially.
3 As time progresses, the additional depth values are added to provide a higher
4 resolution to the depthmap. This allows the navigation device 100 to quickly load the
5 variable density depthmap 200 with one or more low resolution portions and update
6 the variable density depthmap 200 with more accurate depth values as the resources
7 become available or as time passes.

8 Figure 4 illustrates a comparison of a constant density depthmap 350 and a
9 variable density depthmap 351. In the constant density depthmap 350, each cell is the
10 same size. That is, each cell includes the same number of data points, which may be
11 labels, points of interest, or other objects, in relation to the two or three dimensional
12 geographic area. However, in the variable density depthmap 351 some cells include a
13 different number of data points. For example, Label 3, which corresponds to location
14 (X3, Y3, Z3), and Label 4, which corresponds to location (X4, Y4, Z4), are binned to
15 single cell in the variable density depthmap 351, which, in this example may be
16 displayed near (X4, Y4, Z4), which may or may not be the same as the locations
17 corresponding to Labels 3 and Label 4 in the constant density depthmap. In another
18 example, Labels 6, 7, and 8, corresponding to three different locations, are binned to a
19 single cell. The labels are displayed at location (X6, Y7, Z8), which does not precisely
20 match the actual location associated with any of the labels but is an estimated location
21 suitable for Labels 6, 7, and 8 based on the distances from the actual locations and the
22 user or navigation device 100. Even when only one label is included in a particular
23 cell in the variable density depthmap 351, the cell location may not precisely match
24 the actual location associated with the label. For example, Label 9 corresponds to a
25 location (X9, Y9, Z9), which may be displayed at estimated location (X9, Y9, Z10).

26 Figure 5 illustrates another graphical view of a variable density depthmap 400.
27 In one example the variable density depthmap 400 may be a zoomed in view of the
28 variable depthmap 200 shown in Figure 2. The variable density depthmap 400 is
29 shown against an example layout of buildings 401 for illustrative purposes. The
30 buildings 201 are not part of the depthmap 400. The variable density depthmap 400
31 includes a plurality of data points 402, which may be objects, labels, or points of
32 interest that correspond to the buildings 401.

1 The first level of cells 411 is within a first distance from a center point 403,
2 which corresponds to the location of the navigation device 100. In the example shown
3 in Figure 5, the first level of cells 411 is sized such that no more than one data point
4 403 is associated with each cell. When displayed by the navigation device 100, the
5 data points 403 in the first level of cells 411, are shown precisely at the respective
6 geographic location associated with the data points 403.

7 The second level of cells 413 is positioned at a distance greater than the first
8 distance from the center point 403 and less than a second distance from the center
9 point 403. Each cell in the second level of cells 413 covers a greater area than each of
10 the first level of cells 411. When more than one of the plurality of data points 402 are
11 within the increased area of the second level of cells, one cell includes the more than
12 one data points 402, which would not occur if the second level of cells 413 were sized
13 similarly to the first level of cells 411. Likewise, the third level of cells 415 is
14 positioned at a distance greater than the second distance from the center point 403 and
15 less than a maximum distance from the center point 403 to be included in the variable
16 density depthmap 400. As shown in Figure 5, the cells in the third level of cells 415
17 may include as many as four or five data points 402 or more.

18 Figure 6 illustrates a detailed view of server 120. The server 120 is an
19 apparatus for organizing spatial data. The server 120 includes a server controller 500,
20 a memory 501, and a communication interface 505. The database 130 may be external
21 or internal to the server 120. The memory 501 and/or database 130 is configured to
22 store a plurality of objects. The objects may be labels identifying points of interests
23 such as businesses, street names, buildings, landmarks, etc. More specifically, the
24 objects may identify types of businesses or types of locations such as gasoline
25 stations, office locations, indoor locations, hotels, restaurants, museums, stadiums,
26 offices, automobile dealerships, auto repair shops, stores, parks, etc. The objects may
27 include data identifying broader locations such as states, cities, towns, counties or
28 other communities. The objects may identify geographic features, such as bodies of
29 water, mountain ranges, etc. Each of the objects are associated with a two dimensional
30 coordinate system (latitude and longitude) or a three dimensional coordinate system
31 (latitude, longitude, and altitude) to index the objects by location.

32 The database 130 may be maintained by a map developer, such as NAVTEQ
33 North America, LLC located in Chicago, Illinois. The map developer may collect

1 geographic data to generate and enhance the database 130. The database 130 may be
2 stored in an Oracle spatial format or other spatial format, such as for development or
3 production purposes. The Oracle spatial format or development/production database
4 may be compiled into a delivery format, such as a geographical data format (GDF)
5 format or a physical storage format (PSF).

6 The communication interface 505 is configured to receive a location data point
7 from a mobile device such as navigation device 100. The server controller 120
8 calculates a distance from each of the plurality of objects to the location data point
9 using either the two dimensional coordinate system or the three dimensional
10 coordinate system. The server controller 120 constructs the variable density depthmap
11 200 by associating each of the plurality of objects with one of a plurality of cells of
12 the variable density depthmap according to the distance.

13 The memory 501 stores one or more predetermined distances to define the
14 variable density depthmap 200. The server controller 120 compares the distance of
15 each of the plurality of objects with a first predetermined distance. Each of the
16 plurality of objects less than the first predetermined distance from the location data
17 point is associated with a first type of cell, which may be one of the cells of the first
18 level of cells 305. Each of the plurality of objects greater than the first predetermined
19 distance is associated with a second type of cell, which may be one of the cells of the
20 second level of cells 303. The second type of cell corresponds to a larger geographic
21 area than the first type of cell.

22 The server controller 120 may be configured to utilize any number of cutoff
23 distances. For example, as shown in Figure 2 and 5, a first predetermined distance and
24 a second predetermined distance are used. The server controller 120 compares the
25 distance of each of the plurality of objects with a first predetermined distance. Each of
26 the plurality of objects less than the first predetermined distance from the location
27 data point is associated with a first type of cell, which may be one of the cells of the
28 first level of cells 305. The server controller 120 compares the distance of each
29 remaining plurality of objects with a second predetermined distance. Each of the
30 plurality of objects greater than the first predetermined distance and smaller than the
31 second predetermined distance is associated with a second type of cell, which may be
32 one of the cells of the second level of cells 303. Each of the plurality of objects
33 greater than the second predetermined distance is associated with a third type of cell,

1 which may be one of the cells of the third level of cells 301. The third type of cell is
2 larger than the second type of cell, which means the third type of cell corresponds to a
3 larger geographic area than the second type of cell. The server controller 120 may
4 also compare the distances of the plurality of objects to a preliminary distance to
5 determine whether the object is associated with the variable density depthmap 200 at
6 all or is out of range of the navigation device 100 at the current location.

7 Figure 7 illustrates a detailed view of navigation device 100. The navigation
8 device 100 is an apparatus for organizing spatial data. The navigation device 100
9 includes a navigation controller 600, a memory 601, a communication interface 605,
10 and position circuitry 607. The navigation device 100 may also include a user input
11 device 603, a media input device 609, and a display 611.

12 In the server-based embodiment above, the position circuitry 607 determines a
13 current geographic position of the navigation device 100 and the communication
14 interface 605 sends the current geographic position to the server 120. The server 120
15 constructs the variable density depthmap 200 and connects the variable density
16 depthmap with a panoramic image based on the current geographic position of the
17 navigation device 100 to appropriately position objects on the panoramic image,
18 which is sent to the navigation device 100 for display.

19 In an alternative, user device-based embodiment, the navigation device 100
20 constructs the variable density depthmap 200. The position circuitry 607 determines
21 location data including the position and/or the orientation of the navigation device
22 100. The location data may be generated using one or more of a global navigation
23 satellite system based on a satellite signal (such as Global Positioning System (GPS),
24 the Russian GLONASS or European Galileo), a triangulation system that utilizes one
25 or more terrestrial communication signals, a inertial position system based on relative
26 position sensors such as gyroscopes, accelerometers, and altimeters, and/or a or dead
27 reckoning system based on a previously known position. The orientation may be
28 determined using any of the above systems and/or a magnetic sensor such as a
29 compass or a three dimensional magnetic sensor array. Magnetic sensors determine
30 the direction and or strength of a magnetic field and can be used to determine heading
31 or orientation. Inertial sensors such as accelerometers and gyroscopes measure
32 acceleration, which can be used to calculate position, orientation, and velocity
33 (direction and speed of movement) of the navigation device 100.

1 The location data is sent to the navigation controller 600, which constructs the
2 variable density depthmap 200. The navigation controller 600 identifies a plurality of
3 data points indexed by a distance from the location data point determined by the
4 position circuitry 607. The navigation controller 600 compares the distance from each
5 of the plurality of data points to the location data point. Data points within a minimum
6 distance from the location data point are binned in one of a plurality of high resolution
7 cells and data points greater than the minimum distance from the location data point
8 are binned into one of a plurality of low resolution cells. The variable density
9 depthmap 200 is constructed from the plurality of low resolution cells and the
10 plurality of high resolution cells.

11 In the user device-based embodiment, the memory 601 stores depthmap data.
12 The depthmap data comprises geographic coordinates paired with objects. The
13 navigation controller 600 accesses the location, which may include a single location
14 data point, from the memory 601. Alternatively, the geographic coordinates paired
15 with objects may be received through media input device 209 via an external storage
16 medium or wired or wireless communication through the communication interface
17 605.

18 The navigation controller 600 selects a street view image or street view level
19 map based on the location data. The street view image is combined with the variable
20 position depthmap 200 in order to position objects or points of interest within the
21 street view image. Objects far from the navigation device 100 are less accurately
22 positioned than objects near the navigation device 100 because the depthmap cells in
23 the background of the street view image have a lower resolution than the depthmap
24 cells in the foreground of the street view image. The navigation controller 600 sends
25 the variable density depthmap 200 or the street view image combined with the
26 variable density depthmap to the display 611.

27 The user input device 603 receives a command from a user to turn on the
28 navigation device 100 or to activate the algorithm for organizing spatial data by
29 constructing variable density depthmap. The user input device 603 includes one or
30 more buttons, keypad, keyboard, mouse, stylist pen, trackball, rocker switch, touch
31 pad, voice recognition circuit, or other device or component for inputting data to the
32 navigation device 100. The user input device 603 and the display 611 may be
33 combined as a touch screen, which may be capacitive or resistive. The display 611

1 may be a liquid crystal display (LCD) panel, light emitting diode (LED) screen, thin
2 film transistor screen, or another type of display.

3 The navigation controller 600 or server controller 500 may include a general
4 processor, digital signal processor, an application specific integrated circuit (ASIC),
5 field programmable gate array, analog circuit, digital circuit, combinations thereof, or
6 other now known or later developed processor. The navigation controller 600 or
7 server controller 500 may be a single device or combinations of devices, such as
8 associated with a network, distributed processing, or cloud computing.

9 The memories 501, 601 may be a volatile memory or a non-volatile memory.
10 The memory 501, 601 may include one or more of a read only memory (ROM),
11 random access memory (RAM), a flash memory, an electronic erasable program read
12 only memory (EEPROM), or other type of memory. The memory 501, 601 may be
13 removable from the navigation device 100, such as a secure digital (SD) memory
14 card.

15 The communication interfaces 505, 605 may include any operable connection.
16 An operable connection may be one in which signals, physical communications,
17 and/or logical communications may be sent and/or received. An operable connection
18 may include a physical interface, an electrical interface, and/or a data interface. The
19 communication interfaces 505, 605 provides for wireless and/or wired
20 communications in any now known or later developed format.

21 In an alternative embodiment, the navigation device 100 may omit the position
22 circuitry 607 or use of the position circuitry 607. In this alternative embodiment, the
23 navigation device 100 may be a personal computer, which encompasses desktops,
24 laptops, and other computer processing platforms. Instead of a location determined by
25 the position circuitry 607, the depthmap is constructed based on a location data point
26 (focal geographical point) selected within a navigation application such as a street
27 view application. The user may select the point using the user input device 603. The
28 navigation controller 600 receives the location data point from the navigation
29 application. The navigation controller 600 may also receive an orientation from the
30 navigation application. The navigation controller 600 constructs the variable density
31 depthmap according to the location data point and optionally the orientation in a
32 manner similar to the other embodiments discussed herein.

1 Figure 8 illustrates a panoramic or street view image 700 incorporating a
2 variable density depthmap. The street view image 700 includes buildings 701 and
3 objects 703. As the buildings 701 are located farther from the position of the
4 navigation device 100, the buildings 701 appear smaller on display 611. Similarly, the
5 objects are displayed relatively closer together as the locations of the objects are
6 farther from the position of the navigation device.

7 The street view image 700 is divided into a plurality of regions, as shown by
8 dotted lines in Figure 8. The dotted lines do not appear in the street view image but
9 are shown to illustrate the variable density depthmap. A nearby region 711 may
10 correspond to the first level of cells 305 shown in Figure 3. A plurality of nearby
11 objects 703a in the nearby region 711 are positioned relatively farther apart because
12 the depthmap is at a high density in the nearby region 711. The nearby objects 703a
13 are positioned close to the actual physical positions of the underlying points of
14 interest.

15 An intermediate region 713 may correspond to the second level of cells 303. A
16 plurality of intermediate objects 703b in the intermediate region 703 are positioned at
17 a medium density to approximate the actual physical positions of the underlying
18 points of interest. A distant region 715 may correspond to the third level of cells 301.
19 A plurality of distant objects 703c in the distant region 715 are positioned in the same
20 cell in the variable density depthmap and accordingly, are displayed stacked or
21 clustered around the same location in the street view image 700.

22 Figure 9 illustrates a flowchart for an algorithm for constructing a variable
23 density depthmap. Fewer, more, or different steps or acts may be provided, and a
24 combination of steps may be provided. Also, the steps or acts may be performed in
25 the order as shown or in a different order. The method is implemented by the system
26 and/or devices described herein or by different devices or systems.

27 As discussed above, either the server controller 500 or the navigation
28 controller 600 may execute the algorithm for constructing a variable density
29 depthmap. At act S101, the controller receives a location data point from a navigation
30 device, which may be a mobile device. The location data point may include
31 geographical coordinates and may be determined using GPS, cellular positioning, or a
32 combination.

1 At act S103, the controller identifies a plurality of data points indexed by a
2 distance from the location data point. The data points may include object information
3 that defines a point of interest and associates the point of interest with a particular
4 location. The plurality of data points may be all objects within a preliminary threshold
5 distance from the location data point.

6 At act S105, the controller compares the distance from each of the plurality of
7 data points to the location data point. In act S107, data points are assigned to various
8 cells. The various cells include a plurality of types of cells, which may be defined as
9 corresponding to different sizes of geographical area. The data points may be assigned
10 to the plurality of types of size according to distance from the location data point. For
11 example, data points within a minimum distance from the location data point may be
12 assigned to a first type of cell and data points greater than the minimum distance from
13 the location data point into a second type of cell. Any number of types of cells may be
14 used. For example, data points farther than a second minimum distance may be
15 assigned to a third type of cells.

16 At act S109 the controller constructs a depthmap including the plurality of
17 types of cells, which may include at least one of the first type of cell and the second
18 type of cell, with the second type of cell is larger than the first type of cell.
19 Accordingly, the second type of cell covers a larger geographic area than the first type
20 of cell. Likewise, the portion of the depthmap including the first type of cell is at a
21 higher resolution than the portion of the depthmap including the second type of cell.

22 The controller that constructs the depthmap at act S109 may be either the
23 server controller 500 or the navigation controller 600. The navigation controller 600
24 may be in a mobile device and/or any device running a map or navigation application.
25 In addition to the location data point, the controller may receive orientation data. The
26 orientation data may be automatically detected using position circuitry 607 or
27 determined based on a user input to the map or navigation application. The controller
28 determines a map based on the location data point and the orientation data. The
29 controller associates the map with the depthmap, which may be an overlay, in order to
30 display the data points and/or object information on the navigation device 100. In the
31 server-based embodiments, the depthmap and map may be sent together to the
32 navigation device 100 from the server 120. In the user device-based embodiments, the

1 depthmap and map may be sent together to the display 611 from the navigation
2 controller 600.

3 Compared to conventional depthmaps, variable density depthmaps contain less
4 data. In the application of panoramic or street level view images, unnecessary depth
5 information is removed for locations in the background of the image. Placement of
6 points of interest in the background of the image is less precise, but in exchange for
7 valuable savings in data storage, processing power, processing time, and
8 communication resources. Variable density depthmaps require less time to serve over
9 a network and less time to decode, which provides the application more quickly to the
10 user.

11 The embodiments described above may be implemented using computer
12 executable instructions stored in the memory 501 and/or the memory 601, which are
13 non-transitory. The processors may execute computer executable instructions. The
14 computer executable instructions may be written in any computer language, such as
15 C++, C#, Java, Pascal, Visual Basic, Perl, HyperText Markup Language (HTML),
16 JavaScript, assembly language, extensible markup language (XML) and any
17 combination thereof.

18 The computer executable instructions may be logic encoded in one or more
19 tangible media or one or more non-transitory tangible media for execution by the
20 processors. Logic encoded in one or more tangible media for execution may be
21 defined as instructions that are executable by the processors and that are provided on
22 the computer-readable storage media, memories, or a combination thereof.

23 Instructions for instructing a network device may be stored on any logic. As used
24 herein, "logic", includes but is not limited to hardware, firmware, software in
25 execution on a machine, and/or combinations of each to perform a function(s) or an
26 action(s), and/or to cause a function or action from another logic, method, and/or
27 system. Logic may include, for example, a software controlled microprocessor, an
28 ASIC, an analog circuit, a digital circuit, a programmed logic device, and a memory
29 device containing instructions.

30 The computer readable instructions may be stored on any non-transitory
31 computer readable medium. A non-transitory computer readable medium may
32 include, but are not limited to, a floppy disk, a hard disk, an ASIC, a compact disk,
33 other optical medium, a random access memory (RAM), a read only memory (ROM),

1 a memory chip or card, a memory stick, and other media from which a computer, a
2 processor or other electronic device can read.

3 As used herein, the phrases “in communication” and “couple” are defined to
4 mean directly connected to or indirectly connected through one or more intermediate
5 components. Such intermediate components may include both hardware and software
6 based components.

7 Various embodiments described herein can be used alone or in combination
8 with one another. The foregoing detailed description has described only a few of the
9 many possible implementations of the present invention. It is intended that the
10 foregoing detailed description be regarded as illustrative rather than limiting and that
11 it is understood that the following claims including all equivalents are intended to
12 define the scope of the invention.

13

1 WE CLAIM:

2

3 1. A method for organizing spatial data, the method comprising:
4 receiving a location data point from a navigation device;
5 identifying a plurality of data points indexed by a distance from the location
6 data point;
7 comparing the distance from each of the plurality of data points to the location
8 data point;
9 assigning at least one of the plurality of data points within a minimum distance
10 from the location data point into a first cell;
11 assigning a subset of the plurality of data points greater than the minimum
12 distance from the location data point into a second cell, wherein the subset of the
13 plurality of data points comprises two or more data points;
14 constructing a depthmap including the first cell and the second cell, wherein
15 the second cell is larger than the first cell; and
16 sending the depthmap for display on the navigation device.

17

18 2. The method of claim 1, wherein the second cell is associated with a larger
19 geographical area than the first cell.

20

21 3. The method of claim 1, wherein the depthmap is constructed as a k
22 dimensional tree.

23

24 4. The method of claim 1, wherein each of the plurality of data points indicates a
25 location of a point of interest.

26

27 5. The method of claim 1, further comprising:
28 receiving orientation data from the navigation device; and
29 determining a map based on the location data point and the orientation data.

30

31 6. The method of claim 5, further comprising:

1 associating the map with the depthmap, wherein sending the depthmap for
2 display on the navigation device comprises sending the map associated with the
3 depthmap for display on the navigation device.

4

5 7. The method of claim 6, wherein the map is a street level view map.

6

7 8. The method of claim 1, wherein the at least one of the plurality of data points
8 is a single data point.

9

10 9. An apparatus for organizing spatial data, the apparatus comprising:
11 a memory configured to store a plurality of objects indexed by location;
12 a communication interface configured to receive a location data point from a
13 navigation device; and

14 a controller configured to calculate a distance from each of the plurality of
15 objects to the location data point and construct a variable density depthmap by
16 associating each of the plurality of objects with one of a plurality of cells of the
17 variable density depthmap according to the distance,

18 wherein at least one of the plurality of objects less than a predetermined
19 distance from the location data point is associated with a first cell of the plurality of
20 cells and at least one of the plurality of objects greater than the predetermined
21 distance from the location data is associated with a second cell of the plurality of
22 cells, and

23 wherein the second cell corresponds to a larger geographic area than the first
24 cell.

25

26 10. The apparatus of claim 10, wherein the communication interface is configured
27 to send the variable density depthmap to the navigation device.

28

29 11. The apparatus of claim 10, wherein the variable density depthmap is
30 constructed as a k dimensional tree.

31

32 12. The apparatus of claim 10, wherein each of the plurality of objects includes a
33 point of interest.

1

2 13. The apparatus of claim 10, wherein the communication interface is configured
3 to receive orientation data from the navigation device and the plurality of objects are
4 selected based on the location data point and the orientation data.

5

6 14. The apparatus of claim 10, wherein the processor is configured to associate a
7 panoramic image with the variable density depthmap.

8

9 15. The apparatus of claim 14, wherein the plurality of objects are positioned with
10 the panoramic image according to the variable density depthmap.

11

12 16. The apparatus of claim 10, wherein at least one of the plurality of objects
13 greater than a second predetermined distance from the location data point is
14 associated with a third cell of the plurality of cells and the third cell corresponds to a
15 larger geographic area than the second cell.

16

17 17. A non-transitory computer readable medium configured to store a computer
18 program configured to organize spatial data, the program comprising instructions to:
19 receive a location data point from a mobile device;
20 identify a plurality of data points indexed by a distance from the location data
21 point;
22 compare the distance from each of the plurality of data points to the location
23 data point;
24 assign at least one of the plurality of data points within a minimum distance
25 from the location data point into one of a plurality of high resolution cells;
26 assign at least one of the plurality of data points greater than the minimum
27 distance from the location data point into one of a plurality of low resolution cells;
28 construct a depthmap including the plurality of low resolution cells and the
29 plurality of high resolution cells; and
30 send the depthmap to the mobile device.

31

32 18. The non-transitory computer readable medium of claim 17, the program
33 comprising instructions to:

1 receive orientation data from the mobile device;
2 determine a panoramic view based on the location data point and the
3 orientation data; and
4 position points of interest associated with the plurality of data points in the
5 panoramic view.

6
7 19. The non-transitory computer readable medium of claim 17, the program
8 comprising instructions to:
9 position points of interest of associated with the plurality of data points in a
10 street level view image.

11
12 20. The non-transitory computer readable medium of claim 17, wherein the
13 depthmap is constructed as a k dimensional tree.

14

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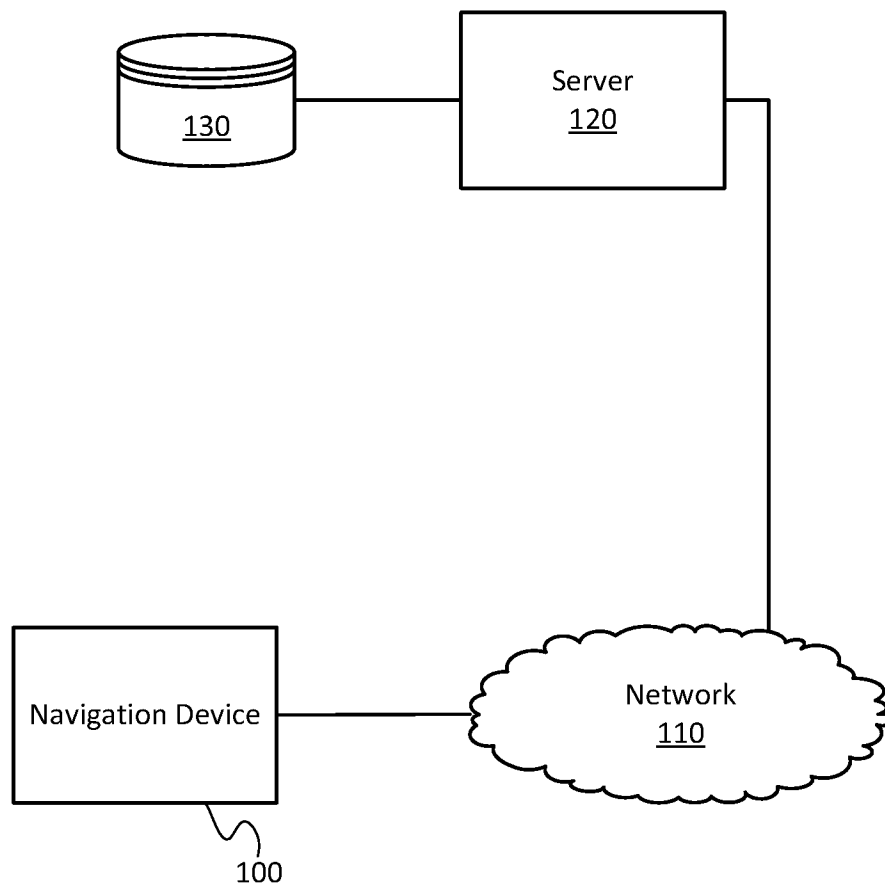
150

FIG. 1

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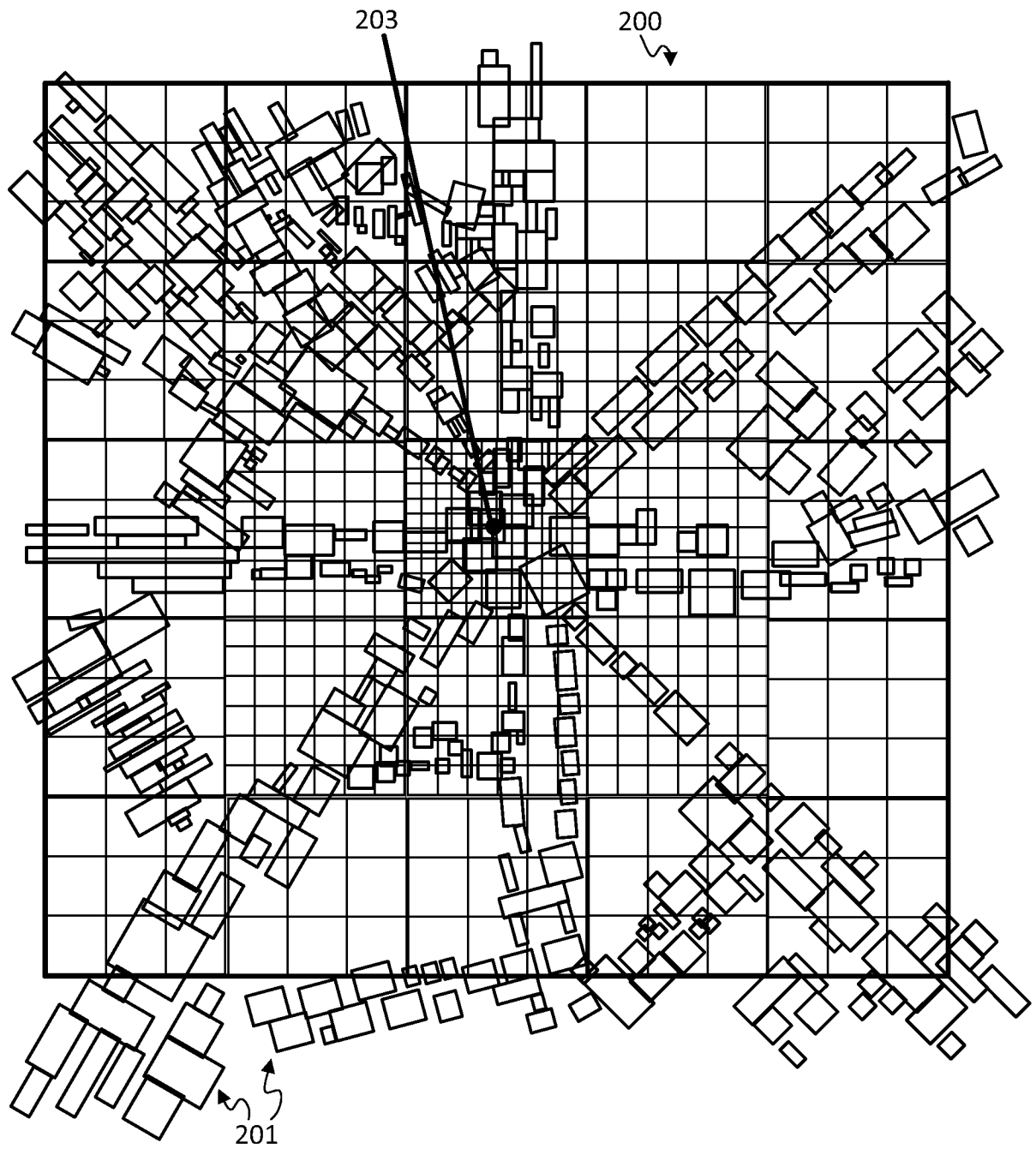


FIG. 2

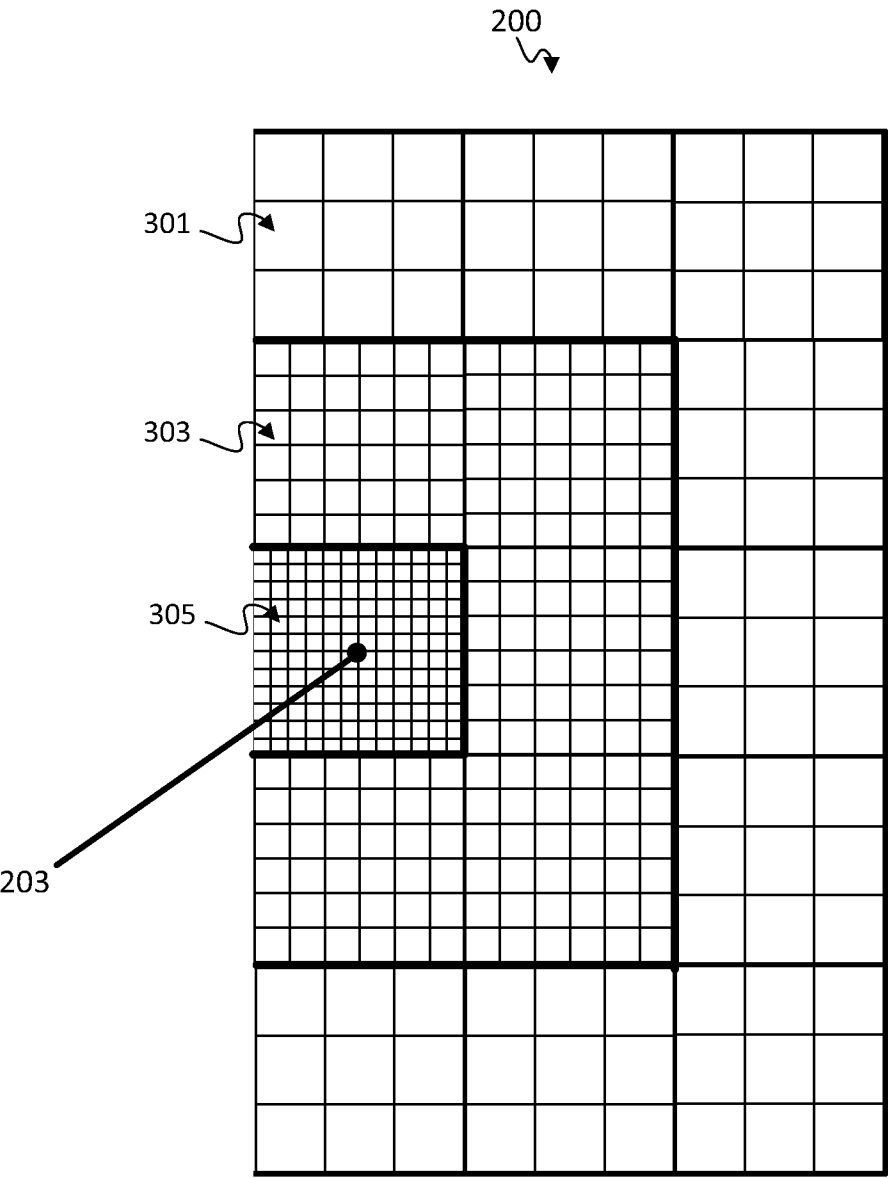


FIG. 3

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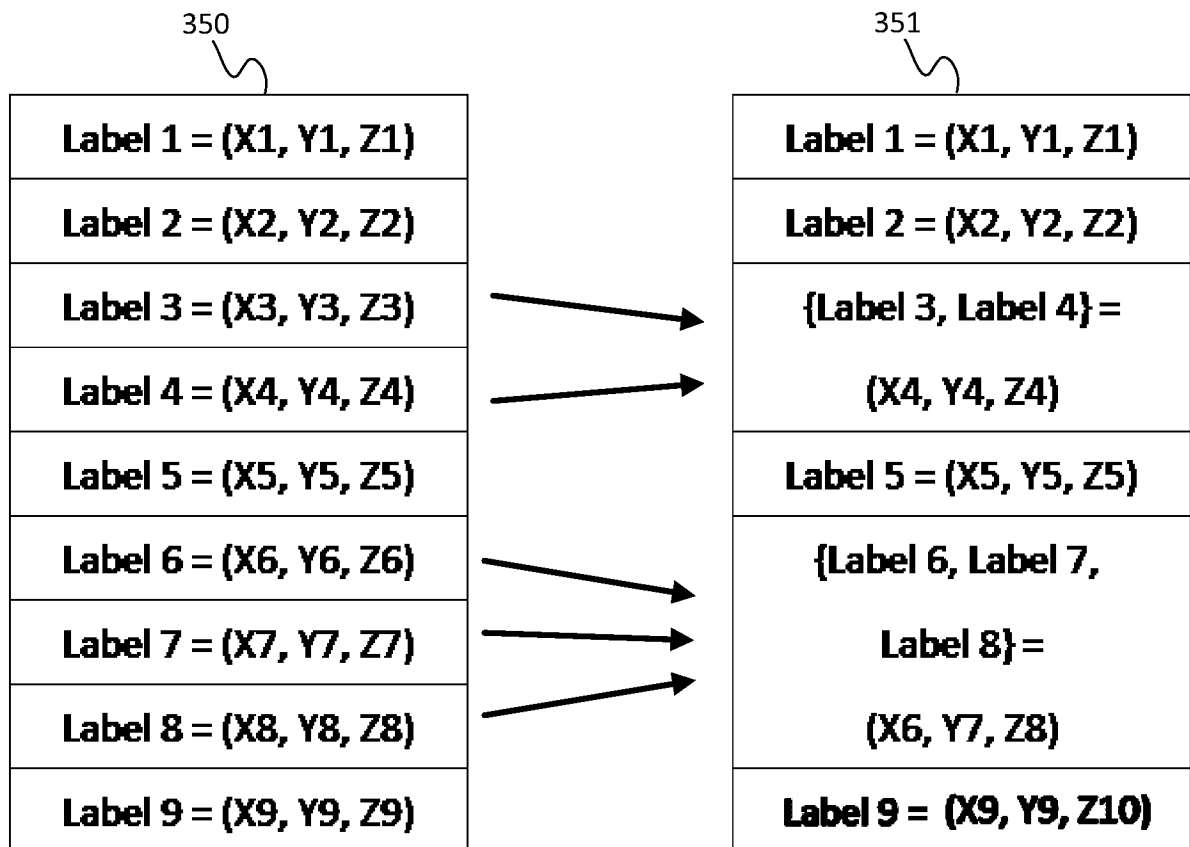


FIG. 4

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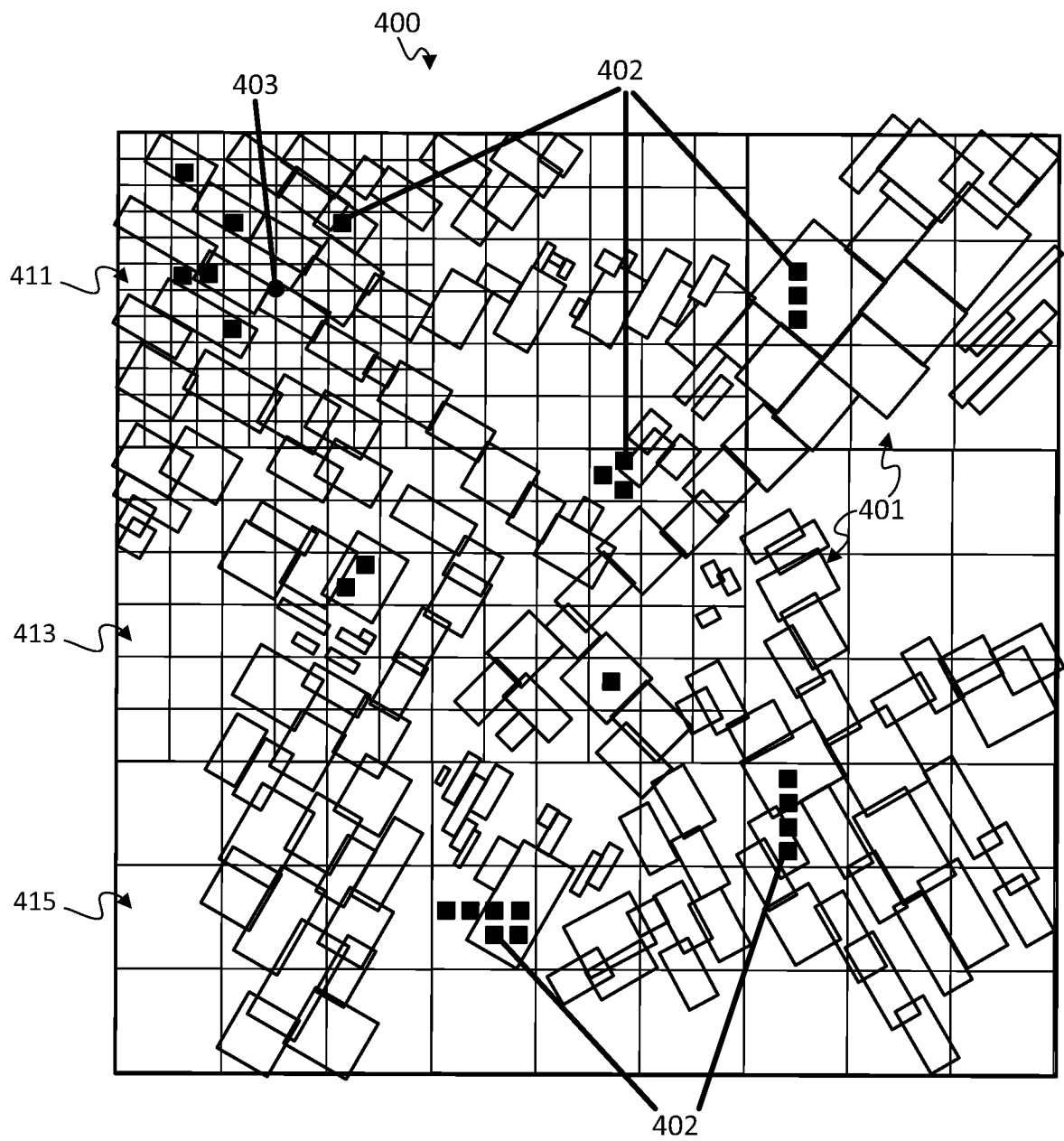


FIG. 5

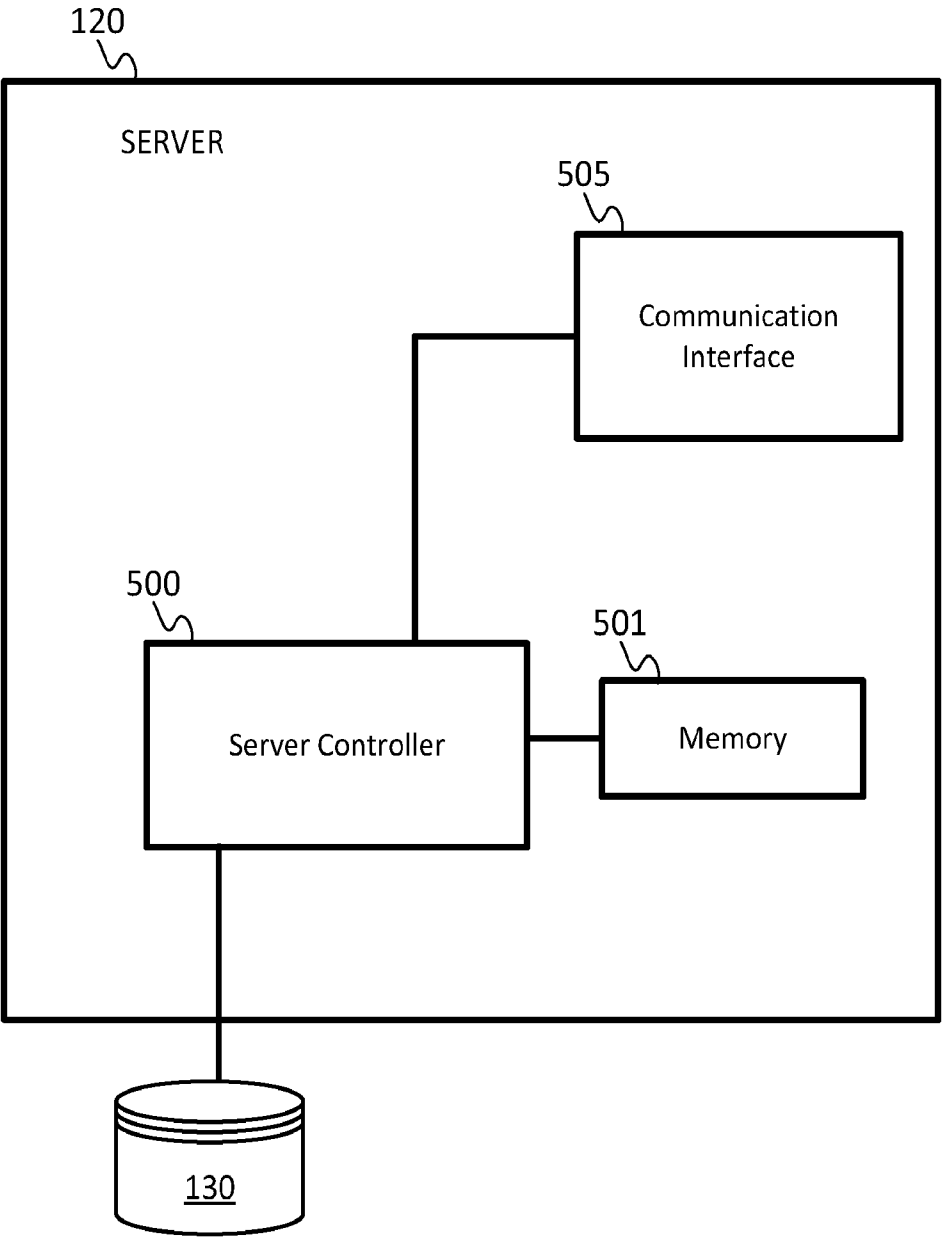


FIG. 6

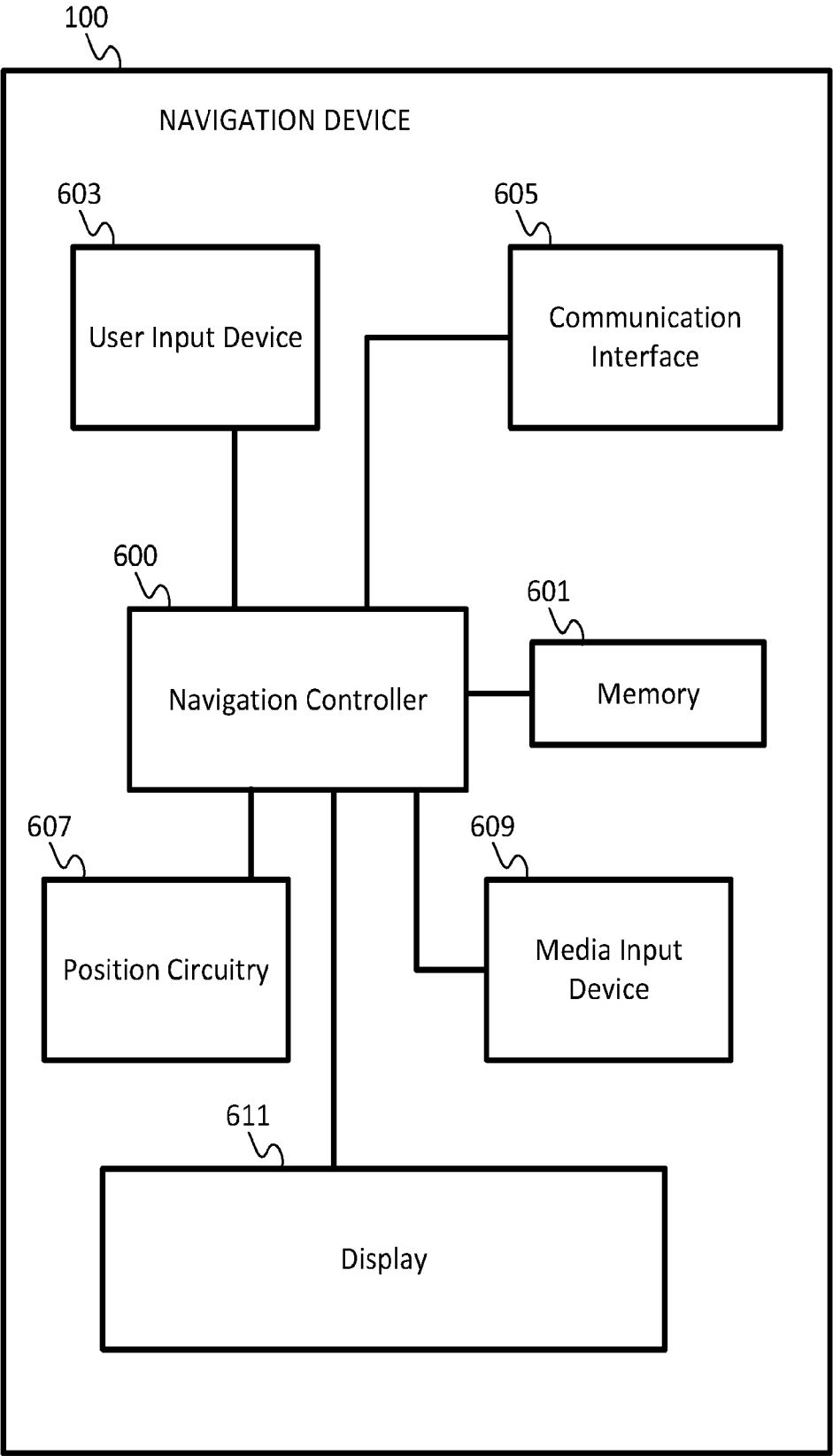


FIG. 7

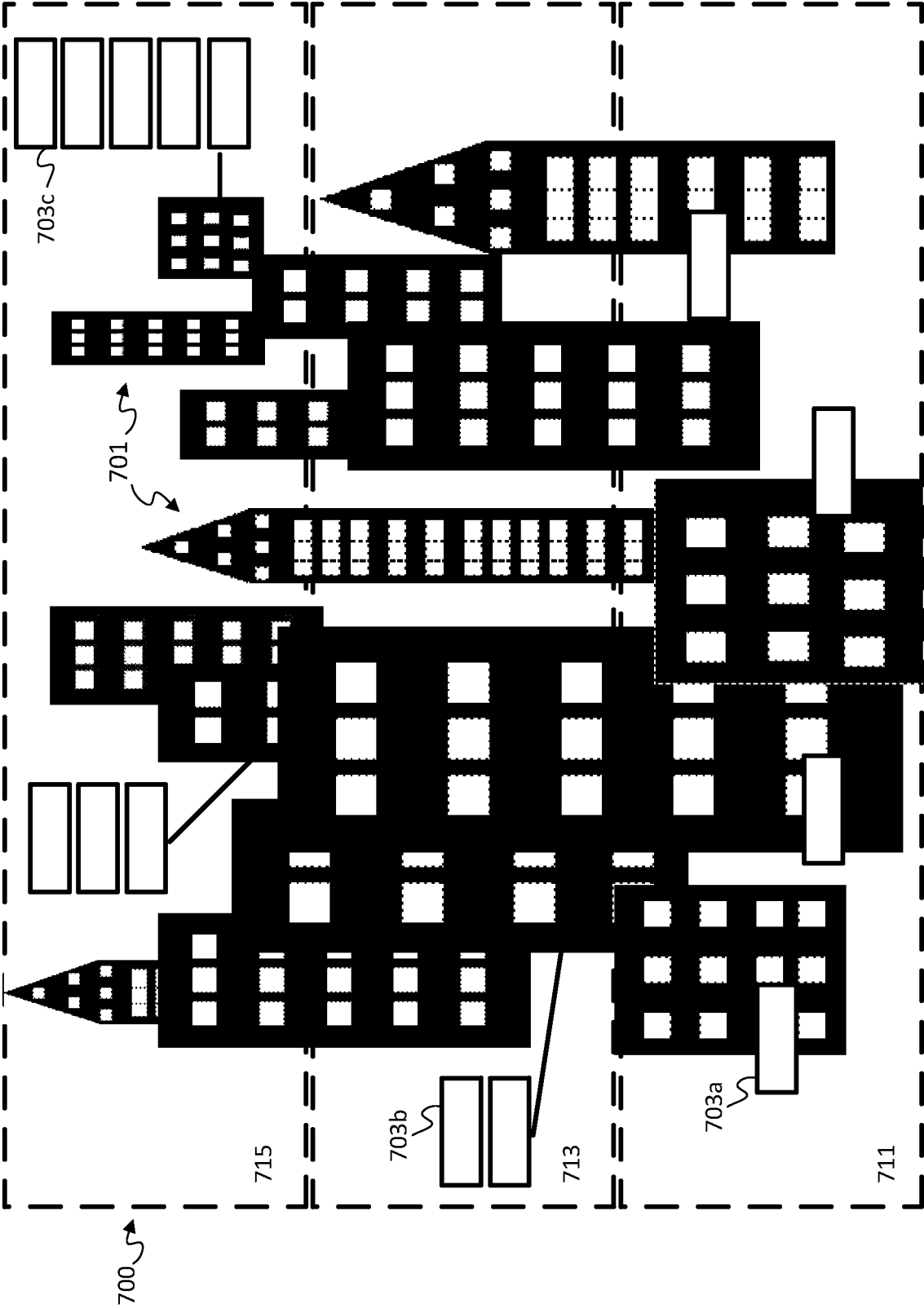


FIG. 8

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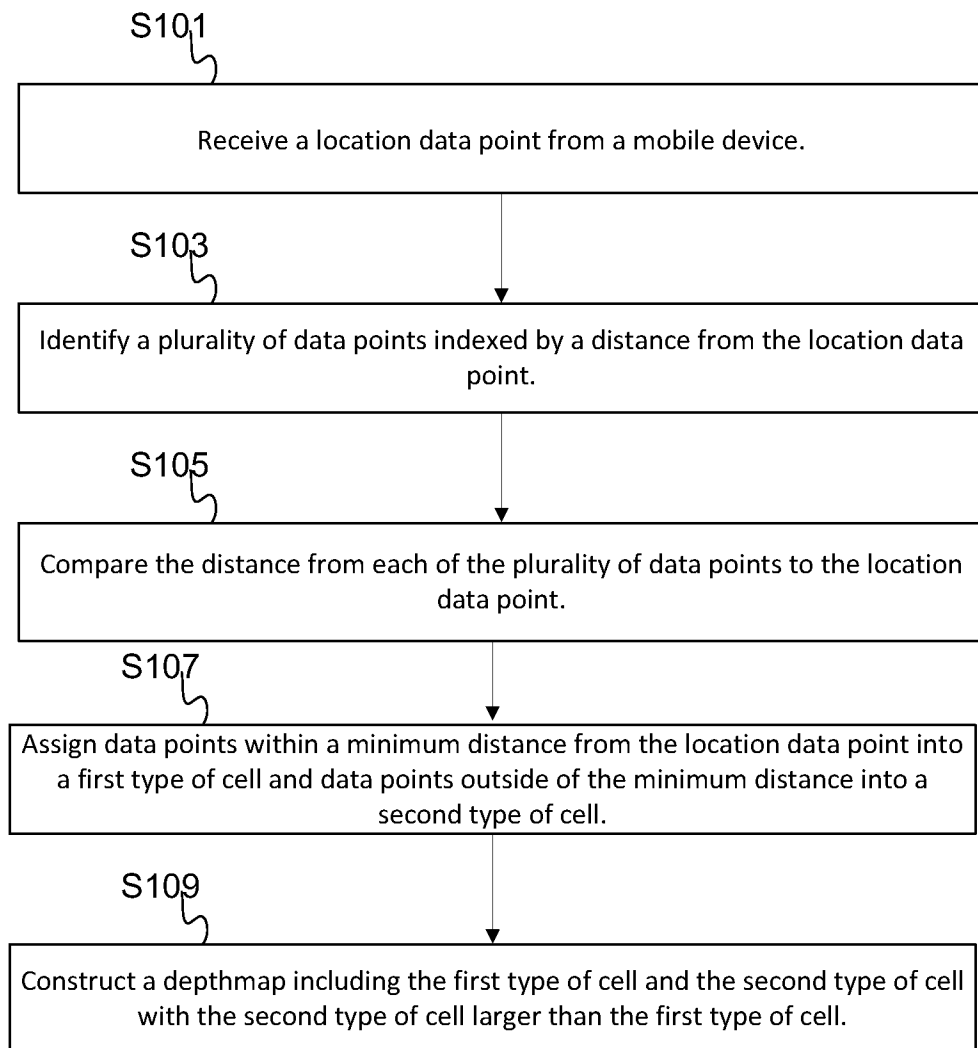


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/47794

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G01C 11/12 (2012.01)

USPC - 356/2

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)
USPC: 356/2; IPC(8): G01C 11/12 (2012.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 356/625; 382/106; IPC(8): G01C 11/12 (2012.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DialogWeb (347,348,349,351,371,652,654); Google Scholar; Google Web; Google Patents.
Search Terms: SPATIAL, ORGANIZE, SYSTEMATIZE, SORT, LOCATION, POSITION, PLACE, DATA POINT, NAVIGATE, DISTANCE, SPACE, MINIMUM, SHORTEST, CLOEST, NEAREST, MORE, LONGER, GREATER, LARGER, BIGGER, FURTHER, DEPTHMAP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,148,295 A (Megiddo et al.) 14 November 2000 (14.11.2000), entire document, especially col. 3, in 54 to col. 4, in 50; col. 11, in 44-61; col. 13, in 29-43	1-20
Y	US 2010/0079336 A1 (Skibiski et al.) 01 April 2010 (01.04.2010), entire document, especially para [0005], [0039], [0050]	1-20
Y	US 2007/0071311 A1 (Rovira-Mas et al.) 29 March 2007 (29.03.2007), entire document, especially para [0003], [0047], [0084]	1-20
Y	US 2011/0087425 A1 (Deng et al.) 14 April 2011 (14.04.2011), entire document, especially para [0042], [0045]	7, 19
Y	US 2008/0143709 A1 (Fassero et al.) 19 June 2008 (19.06.2008), entire document, especially para [0007], [0036]	14, 15, 18
A	US 6,703,947 B1 (Wallner) 09 March 2004 (09.03.2004), entire document	1-20
A	US 5,629,626 A (Russell et al.) 13 May 1997 (13.05.1997), entire document	1-20

☐ Further documents are listed in the continuation of Box C.


* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

17 September 2012 (17.09.2012)

Date of mailing of the international search report

16 OCT 2012

Name and mailing address of the ISA/US

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P.O. Box 1450, Alexandria, Virginia 22313-1450

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