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(54) **POINT OF INTEREST SEARCH ALONG A ROUTE WITH RETURN**

(71) Applicant: **Uber Technologies, Inc.**, San Francisco, CA (US)

(72) Inventors: **Richard F. Poppen**, San Jose, CA (US); **Weidong Tang**, Dailian (CN)

(73) Assignee: **Uber Technologies, Inc.**, San Francisco, CA (US)

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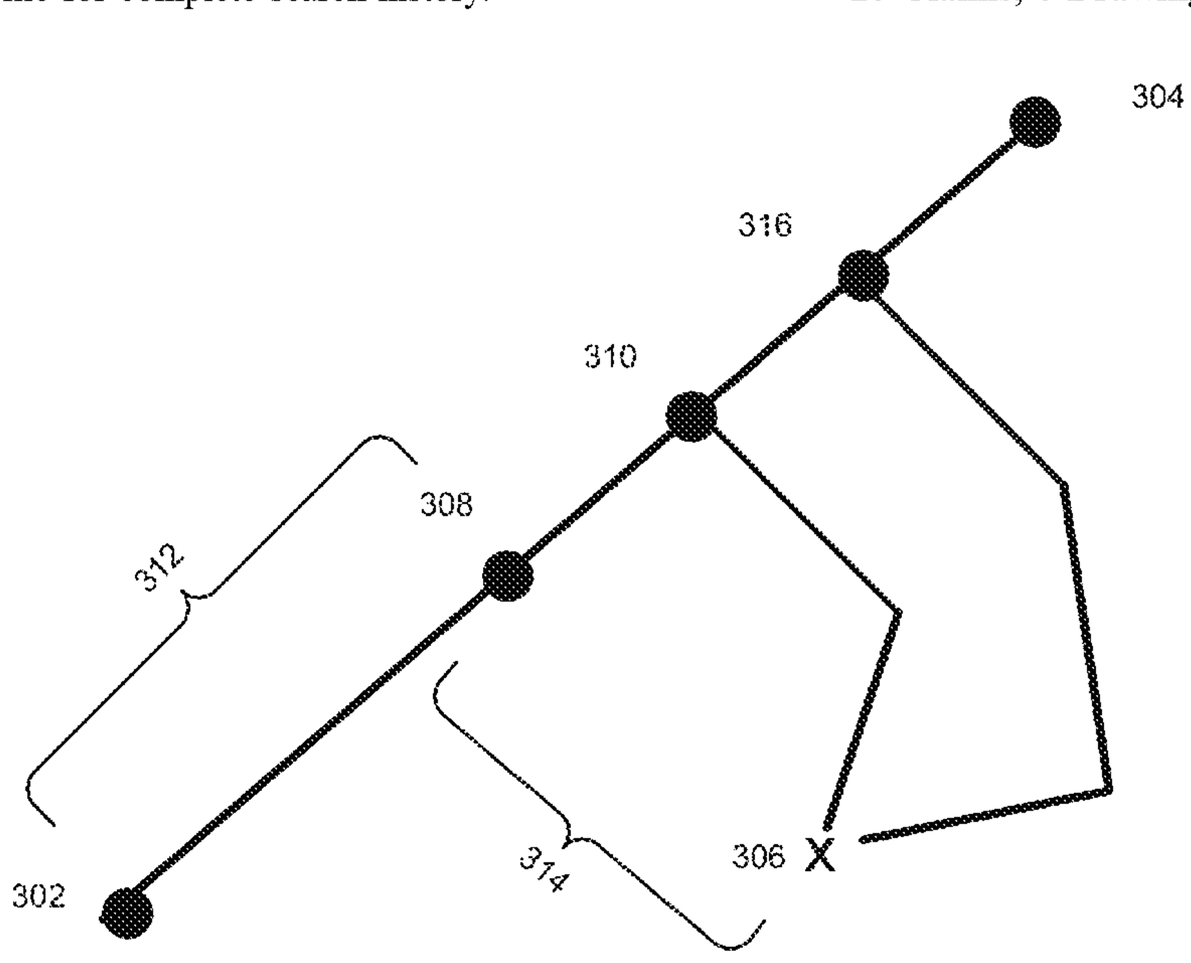
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Primary Examiner — Jonathan M Dager
(74) *Attorney, Agent, or Firm* — Fenwick & West LLP

(57) **ABSTRACT**

A routing module identifies POIs that can be reached from a route with a cost less than distance m. A routing engine performs a reverse exploration on nodes in the planned route to locate POIs from which the route can be reached with a cost of less than a second cost n. POIs identified as being reachable from the route with a cost of less than m, and from which the route is reachable with a cost less than n are then further filtered to identify a subset of the POIs for which the sum of the time or distance from the route to the POI and the time or distance from the POI back to the route is less than a threshold time or distance, t.

20 Claims, 6 Drawing Sheets



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continuation of application No. 14/846,577, filed on Sep. 4, 2015, now Pat. No. 9,488,486, which is a continuation of application No. 13/748,065, filed on Jan. 23, 2013, now Pat. No. 9,151,614, which is a continuation of application No. 13/246,201, filed on Sep. 27, 2011, now Pat. No. 8,401,786, which is a continuation of application No. PCT/CN2009/071126, filed on Apr. 1, 2009.

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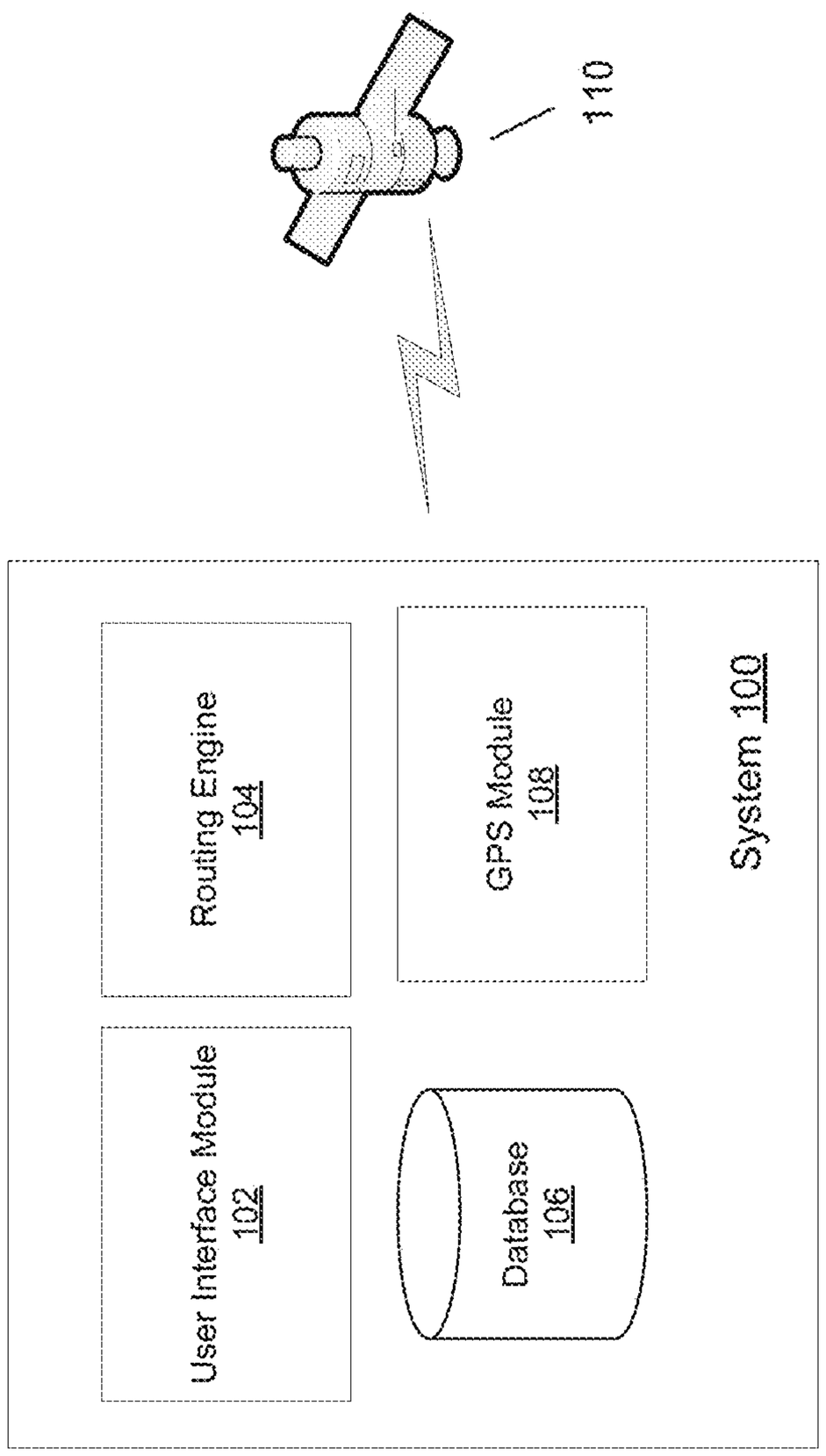

110
System 100
Routing Engine 104
GPS Module 108
User Interface Module 102
Database 106

Fig. 1

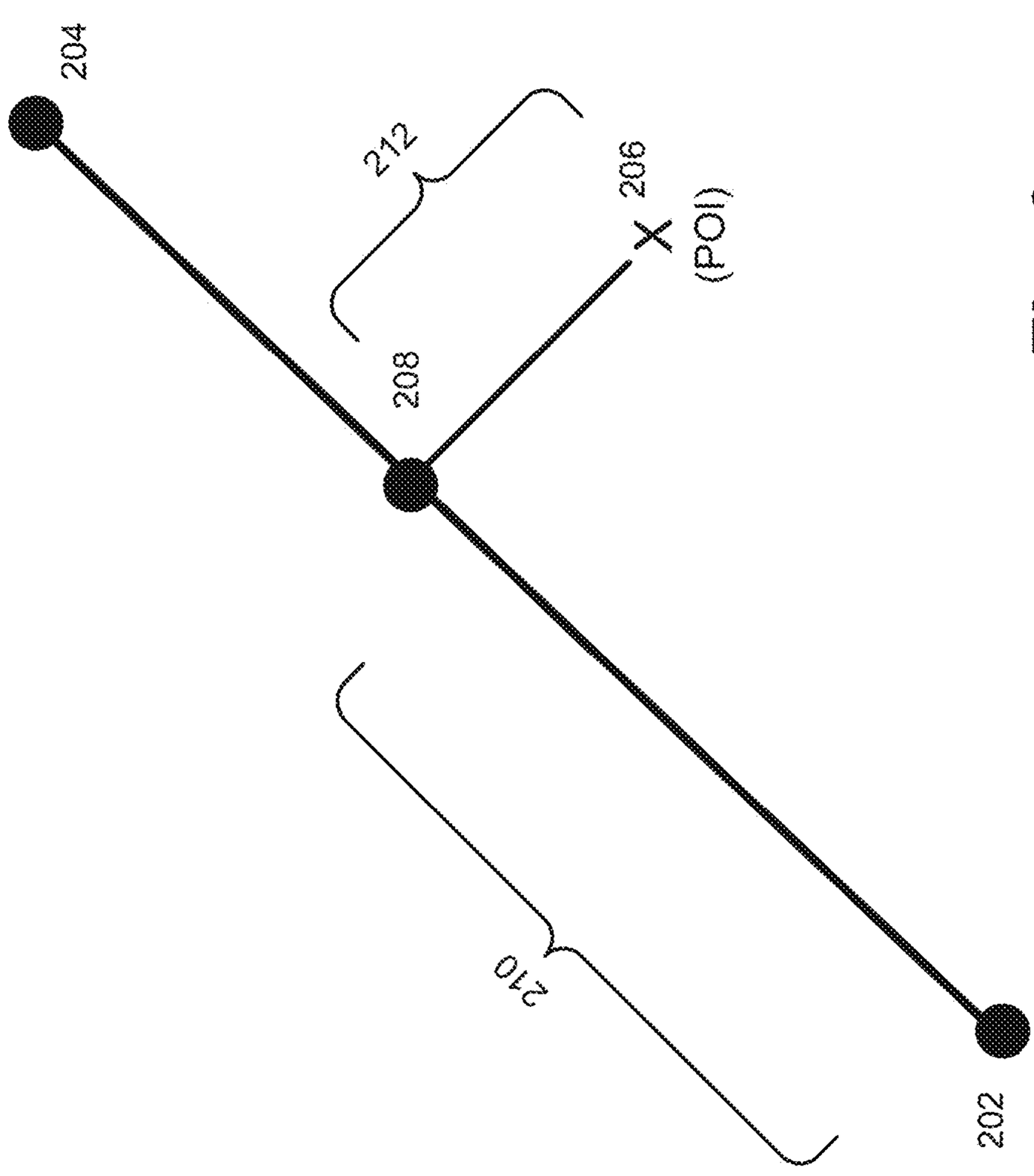


Fig. 2

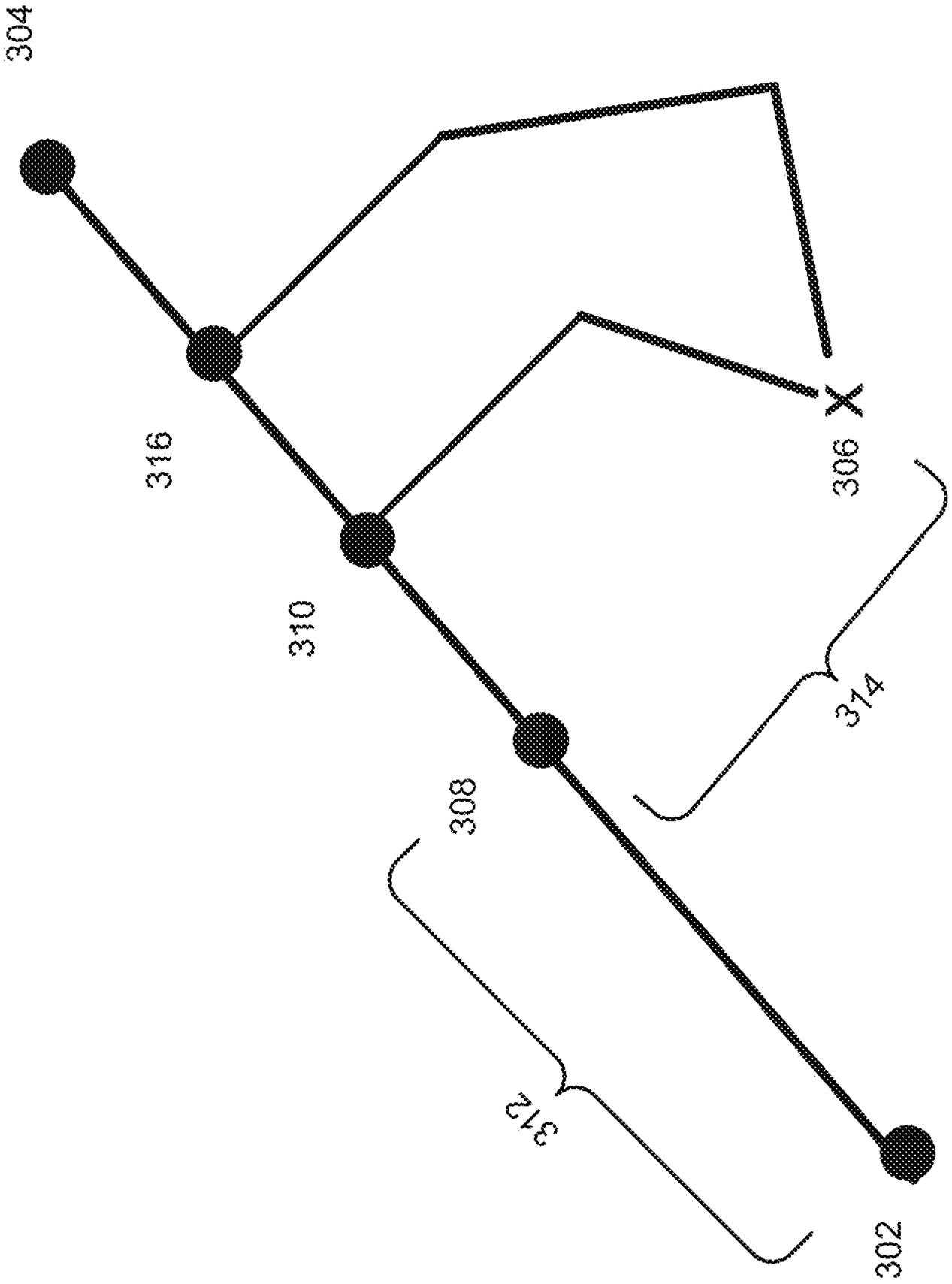


Fig. 3

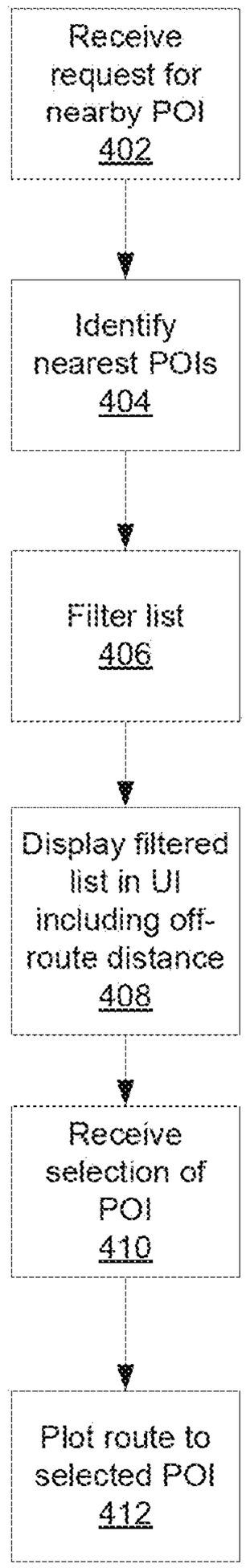

Receive request for nearby POI 402
Identify nearest POIs 404
Filter list 406
Display filtered list in UI including off-route distance 408
Receive selection of POI 410
Plot route to selected POI 412

Fig. 4

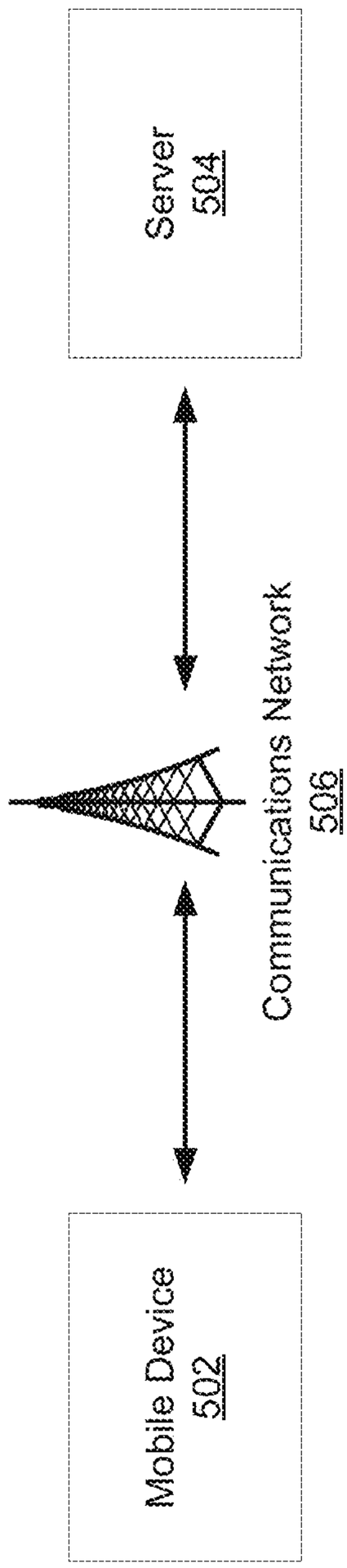


Fig. 5

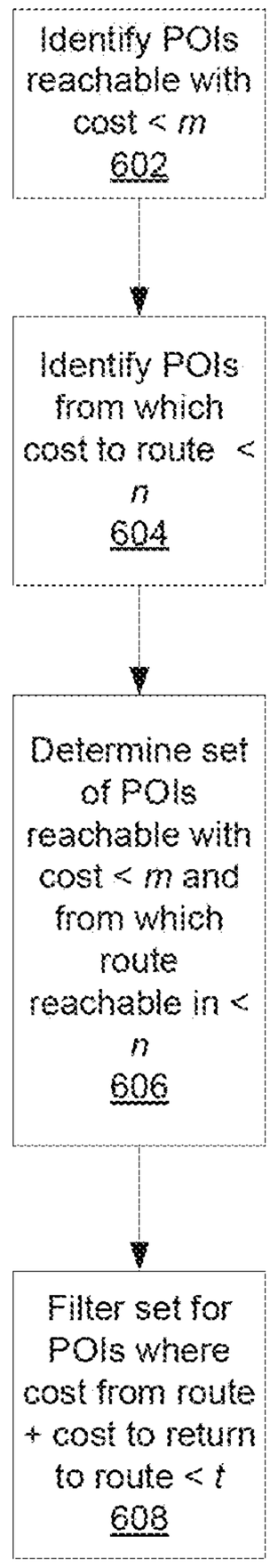

Identify POIs reachable with cost < m
602
Identify POIs from which cost to route < n
604
Determine set of POIs reachable with cost < m and from which route reachable in < n
606
Filter set for POIs where cost from route + cost to return to route < t
608

Fig. 6

POINT OF INTEREST SEARCH ALONG A ROUTE WITH RETURN

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/286,562, filed on Oct. 6, 2016, which is a continuation of U.S. patent application Ser. No. 14/846,577, filed on Sep. 4, 2015, now U.S. Pat. No. 9,488,486, issued Nov. 8, 2016, which is a continuation of U.S. patent application Ser. No. 13/748,065, filed on Jan. 23, 2013, now U.S. Pat. No. 9,151,614, issued Oct. 6, 2015, which is a continuation of U.S. patent application Ser. No. 13/246,201, filed on Sep. 27, 2011, now U.S. Pat. No. 8,401,786, issued Mar. 19, 2013, which is a continuation of PCT application PCT/CN2009/071126, filed on Apr. 1, 2009. All of the above applications are incorporated by reference herein in its entirety.

BACKGROUND

Technical Field

The present invention is directed to the use of navigation systems. In particular, the present invention enables better timing and routing information to be provided related to points of interest along a route.

Description of the Related Art

Navigation systems are popularly used to guide travelers to destinations. Such systems are available built into vehicles or free-standing, to be moved from vehicle to vehicle; for use by drivers and/or pedestrians; as purpose-built devices or as applications on general-purpose devices such as personal digital assistants or mobile telephones; and as systems that are entirely self-contained or as systems that utilize a remote server to perform some or all of their calculations. We refer generally to these systems as "navigation systems."

Since a common use of navigation systems is to guide the traveler to a desired destination, an important function of such systems is the selection of the destination. In some cases, the driver selects the destination by entering the address. In others, the driver selects the destination from a personal list of stored destinations, typically including home and work. In addition, the driver often wants to select a destination from a directory of "points of interest".

Points of interest ("POIs") include many kinds of destinations that drivers may want to find, either when running errands near home or when traveling away from home, such as hotels, restaurants, gas stations, stores of various kinds, roadside rest areas, and emergency services such as hospitals or police stations. The driver may want to search for any POI in a given category (e.g., any restaurant), or for a POI with a given name in a given category (e.g., a restaurant whose name contains "Taqueria"), or for a POI with a given name in any category (e.g., a POI whose name contains "Taqueria", without knowing whether the category should be "restaurant" or "fast food"). The driver may want to search for POIs radially around the current location, without regard to any previous or current destination. Alternatively, the driver may want to search for POIs near an already-computed route, for example, finding a gas station near the currently planned route to a destination. All of these kinds of search are commonly supported in modern navigation systems.

SUMMARY

The present invention enables searches for points of interest along a route, taking into consideration the cost (in time or distance) of deviating off the route to the POI, as well as the cost of returning to the route. A driver may be looking more or less urgently for a POI, and may therefore be willing to travel a greater or lesser distance off the currently-planned route. A driver who suddenly notices a fuel gauge approaching "empty" may be willing to travel several miles off-route to find a gas station soon, while a driver who is just beginning to feel hungry may be willing to drive half an hour down the route to find a restaurant very close to the route. The present invention also enables searching for POIs along a current route, even when the route has not been pre-programmed by the driver.

A system in accordance with the present invention includes a GPS module, user interface module, database and routing engine. The routing module identifies all POIs that can be reached from the route with a cost less than some threshold distance, m. This identification can be carried out, for example by performing an exploration using Dijkstra's algorithm. The routing engine then (or simultaneously) performs a reverse exploration on nodes in the planned route to locate POIs from which the route can be reached with a cost of less than a second threshold cost, n. This process can be performed, for example, by using a reverse Dijkstra exploration, exploring backwards in cost for n cost (e.g., miles or minutes) from the route along the directed graph to determine which POIs lie within a cost of n. POIs identified as being reachable from the route with a cost of less than m, and from which the route is reachable with a cost less than n are then further filtered to identify a subset of the POIs for which the sum of the time or distance from the route to the POI and the time or distance from the POI back to the route is less than a threshold time or distance, t.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a navigation device in accordance with an embodiment of the present invention.

FIG. **2** illustrates a routing from an origin to a destination and a point of interest in accordance with an embodiment of the present invention.

FIG. **3** illustrates multiple routings from an origin to a point of interest in accordance with an embodiment of the present invention.

FIG. **4** is a flowchart illustrating a method for providing point-of-interest search along a route in accordance with an embodiment of the present invention.

FIG. **5** illustrates communication between a mobile device and a server in accordance with an embodiment of the present invention.

FIG. **6** is a flowchart illustrating a method for providing point-of-interest search along a route in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

Since navigation systems are commonly used by drivers of vehicles, we frequently refer to the user of such a system as "the driver". However, the description that follows is not intended to be limited only to vehicle drivers; it may be applied equally to any use in which the user of the system

is any kind of traveler, including, for example, a pedestrian, a bicycle rider, or a person using multiple modes of transportation, such as walking and riding public transit vehicles. In addition, while described in the context of public roadways and highways, the described systems and methods may also be used for aircraft navigation and marine navigation.

FIG. **1** is a diagram of a system **100** in accordance with an embodiment of the present invention. System **100** includes a user interface (UI) module **102**, a routing engine **104**, a database **106**, and GPS module **108**. UI module **102** provides one or more screens of information and enables the driver to communicate with the navigation system **100**. Routing engine **104** manages route planning and guidance functions, including routing to and from POIs along a route as described below. Database **106** provides local storage for navigation system **100** and may include information about POIs and other features such as roads, intersections, terrain, and the like. GPS module **108** performs GPS location functions and receives GPS signals from GPS satellites **110**. Note that although in the described embodiment navigation system **100** uses GPS to determine its location, alternative technology may be used, particularly as newer technology is developed. The present invention is equally applicable regardless of the manner in which system **100** derives its location.

User interface module **102** provides many of the user interface functions conventionally available on personal navigation devices. For example, UI module **102** allows a user to specify a destination by entering an address or selecting from a list. In addition, UI module **102** in various embodiments of the present invention includes interface elements for receiving POI search preferences from a driver, and for presenting POI search results and routing information, as described more fully below.

We begin with an example to illustrate the operation of system **100**. In this example, a driver sets out on a lengthy road trip from San Francisco, Calif. to Alexandria, Va. Routing engine **104** plots the best route, taking into account any preferences selected by the driver—for example, avoiding toll roads. User interface module **102** displays the plotted route, and the driver sets out along Interstate **80** heading east.

After driving for several hours, the driver begins to get hungry. By referring to the user interface, the driver observes he has just passed through Mill City, Nev. The next major town along his route is Winnemucca, which is likely to have several restaurant options. Alternatively, the small town of Cosgrave, which has a single restaurant, is much closer. Cosgrave, however, is not along the interstate, and would require a deviation of some distance from the driver's planned route. While eating sooner would be a positive experience for the driver, it is also important to him to arrive in Salt Lake City, Utah before dark. He is unsure of the delay involved in deviating to the Cosgrave restaurant, and would prefer to make an informed choice.

By selecting a POI search function in the user interface, the driver is presented by system **100** with a list of POIs from which to choose. The list may be presented in a number of ways, depending on implementation. In one embodiment, for example, the user selects POI search, then filters by a restaurants category. User interface module **102** then presents the driver with a list of restaurants within a given distance (which may be radial, driving time, or driving distance, as explained below). For each POI not along the driver's route, user interface module **102** displays two distances: the distance down the route to a point from which the driver would deviate toward the POI (the "along-route distance" to the "route departure point"), and the distance by which the POI is off the route (the "off-route distance"). In our example, the along-route distance is 8.5 miles, and the off-route distance is 1.1 miles. Alternatively, the driver can configure system **100** to display the estimated time off-route caused by the deviation based on information stored in database **106** about the detour, including for example the estimated speed along the off-route portion. In this example, the delay is about two minutes. The driver decides that the two minutes is an acceptable time, and therefore deviates to Cosgrave.

FIG. **2** illustrates the distinction between along-route distance and off-route distance. In FIG. **2**, the driver's planned route is from point **202** to point **204**. Assume a POI is located at point **206**, and to get to the POI the driver has to turn off the route onto another road at point **208**. Then the along-route distance **210** is the distance from **202** to **208**, and the off-route distance **212** is the distance from point **208** to **206**.

In another embodiment, the two distances are, first, the sum of the along-route distance and the off-route distance (the "total distance") and, second, the off-route distance. In yet another embodiment, the two distances are the along-route distance and the total distance.

In conventional navigation systems showing one distance to each POI, the POIs are typically sorted in order of increasing distance. In one embodiment of the present invention, routing engine **104** sorts POIs in order of increasing along-route distance. In other embodiments, routing engine **104** sorts POIs in order of increasing total distance or in order of increasing off-route distance. Note that the distance used as the sort criterion need not be one of the distances displayed by user interface module **102**.

In one embodiment, and referring to FIG. **3**, the along-route and off-route distances are computed purely geometrically. In this embodiment, the route departure point **308** is the point on the route nearest to the POI **306** in Euclidean distance, the off-route distance of the POI is the Euclidean distance **314** from the route departure point **308** to the POI **306**, and the along-route distance **312** is the distance, measured along the route, from the current location **302** to the route departure point **308**. In another embodiment, the along-route and off-route distances are computed by measuring driving distance. In this embodiment, the route departure point is a point on the route **310** from which the driving distance (rather than the Euclidean distance) to the POI is minimized, the off-route distance is the driving distance along roads, rather than the Euclidean distance, from the route departure point **310** to the POI **306**, and the along-route distance is the driving distance along the route from the current location **302** to the route departure point **310**. In another embodiment, another metric to be minimized is used instead of driving distance. For example, estimated driving time can be used. In that case, the route departure point is a point **302** on the route from which the estimated driving time to the POI **306** is minimized, the off-route "distance" is the estimated driving time from the route departure point **316** to the POI **306**, and the along-route "distance" is the estimated driving time from the current point **302** to the route departure point **316**. One of ordinary skill in the art will understand that a wide variety of distance measures can be used.

In some embodiments, the definition of along-route and off-route distance can be varied slightly, in the following way: The route departure point is a point on the route such that the distance along the route to the point plus the distance from the point to the POI is minimized. Here "distance" can

be driving distance, estimated driving time, or any other measure of distance to be minimized.

In one embodiment, the search for POIs is limited to a "search distance", that is, a specified distance (in terms of Euclidean distance, driving distance, estimated driving time, or another distance measure) from the route. That is, only POIs within this distance threshold will be displayed to the user. In one embodiment, the user specifies different default search distances for different categories. For example, the driver may be willing to travel 5 miles from the route to reach a gas station, but only 3 miles from the route to reach a restaurant. In one embodiment, user interface module **102** offers the driver, in addition to a list of POIs with their along-route and off-route distances, a "more urgent" and/or a "less urgent" button. As will be understood, as with other parts of the user interface, the "button" may be a real button, a virtual button on a touchscreen, or other suitable type of user interface element. When the "more urgent" button is pressed, the routing engine **104** repeats the search, but with a greater limit for the maximum off-route distance. Routing engine **104** will then tend to find more POIs closer to the current position, but farther off the route. When the "less urgent" button is pressed, routing engine **104** repeats the search, but with a smaller limit for the maximum off-route distance. Routing engine **104** will then tend to find POIs farther from the current position, but closer to the route and therefore more convenient for the driver if the driver is willing to drive farther before reaching the POI.

In one embodiment, common POI searches are made more convenient to the driver by having one or more "I need" buttons accessible to the user with fewer actions (e.g., by pressing fewer buttons) than for general POI searches. In one embodiment, for example, the map display screen of user interface module **102** has an "I need gas" button and an "I need food" button on screen for quick access to searches. In another embodiment, the map display screen has an "I need" button; when the "I need" button is pressed, the screen switches to a simple menu with very common, popular choices, for example, "I need gas", "I need a hotel" and "I need food." In some embodiments, the selection of "I need" buttons on the primary map screen or on the secondary screen is configurable by the user. Thus, one driver who likes coffee can put coffee outlets in the quick "I need" menu, while another driver who doesn't like coffee but does like to buy soft drinks at convenience stores can leave coffee off the quick "I need" menu but include convenience stores.

In some embodiments, routing engine **104** is able to search along a route even when there is no route currently calculated. For example, a driver may not have calculated a route because the driver is so familiar with the route that guidance is not necessary. Still, the driver may want to search for unfamiliar POIs such as gas stations or fast-food outlets even along a familiar route. Routing engine **104** is enabled to perform this kind of search by inferring a likely route. In one embodiment, routing engine **104** assumes that the driver will continue along a route with the same name as far as possible, and, when the road name does not continue, that the driver will continue as nearly straight as possible along roads of the same or greater importance. Routing engine **104** then uses that inferred route as the route along which to search. In such a case, the route may be searched in a conventional manner, or using the techniques described here. In alternative embodiments, routing engine **102** makes the inference more likely by tracking the driver's behavior over multiple trips, and, when the driver is on a road that system **100** recognizes as being used often in the driver's habitual behavior, inferring that the driver will follow the route that he or she most often follows when on the current road. In one embodiment, system **100** stores a history of previous routes (whether pre-programmed or not) taken by the driver. The number of routes in the history is variable according to the preference of the implementer and/or the driver. Route generator **104** then searches previous routes to predict whether the driver is currently following one of them. Route generator **104** then chooses the route with the highest prediction score in order to infer the route and provide POI assistance. In another embodiment, route generator **104** maintains a list of past destinations (as opposed to routes to the destinations), and identifies one or more of the past destinations located in or near the direction of travel. A destination is in or near the direction of travel in one embodiment if the distance to the destination is decreasing. Route generator **104** then selects the previous destination being approached most rapidly and plots a route to it. This route is then the predicted route along which POIs are searched.

FIG. **4** is a flowchart illustrating a method for providing point-of-interest search along a route in accordance with an embodiment of the present invention. System **100** receives **402** a request from a driver to display a list of nearby POIs. As noted, this request may be limited to specific categories, or may simply be a request for all known POIs along the route. Also as noted, the request includes a distance or time limitation, or alternatively a default limitation is used. Route engine **104** performs a search, for example using database **106**, and identifies **404** a set of nearby POIs. Route engine **104** then filters **406** the list according to the distance or time parameters supplied by the driver or by default. User interface module **102** displays **408** the filtered list, along with deviation information including along-route and off-route distances or times, etc., as described above. In one embodiment, for example where the driver does not need directions to the POI, the driver simply proceeds without obtaining further route guidance. Alternatively, the driver requests and the user interface module receives **410** a selection of the POI, and then plots **412** a route to the selected POI.

In various embodiments, the computations described above are performed not on the mobile device but rather on a server. FIG. **5** illustrates a server **504** that is in communication via a communications network **506** with mobile device **502**. The driver's particular request for a POI and data about the driver's current location and planned route or direction of travel are sent by mobile device **502** to server **504** via communications network **506**. Server **504** determines the list of appropriate results and returns the information to mobile device **102** for display to the user. This allows mobile device **502** to operate with less processing and storage requirements, and also allows for more centralized updating of POI and routing information.

Techniques for searching based on Euclidean distance are known to one of ordinary skill in the art. There are many ways to search in an area such as the area along a route. One indexing scheme is taught in U.S. Pat. No. 5,963,956, incorporated herein by reference in its entirety. In that method, and in many other known indexing methods, it is possible to find records that come within a specified distance of the route. One can retrieve all POIs in such records, and then compute the Euclidean distance to the route and the nearest point on the route, and discard those POIs for which the Euclidean distance to the route exceeds the desired threshold.

When searching is to be based on driving distance, the search can be performed by starting with a search based on Euclidean distance and then adding an additional filtering

step. Suppose the threshold distance is d km. If a POI is more than d km from the route in Euclidean distance, it is certainly more than d km from the route in driving distance, since the driving distance must be at least as long as the Euclidean distance, which is essentially a straight line. Thus a first search operation can find those POIs within d km of the route in Euclidean distance. Then the road network can be explored to determine whether the POI is within d km of the route in driving distance.

This secondary filtering operation can be performed in either of two ways. The road network can be explored (using, for example, Dijkstra's algorithm, which is well known to practitioners of the art) outward from the POI until all roads within a distance if d km have been explored or until the route is reached, whichever comes first. If the route is not found within d km of the POI, the POI is more than d km in driving distance from the route and can be rejected. If the route is found within d km of the POI, we know the nearest point on the route and the distance to that nearest point.

Alternatively, the distance to multiple POIs can be checked simultaneously by exploring the road network (using, for example, Dijkstra's algorithm) outward from the route, rather than from the POIs. The exploration can be performed until all roads within d km of the route have been explored. For those POIs which have been reached in the exploration, we know the nearest point on the route and the distance to that point. Those POIs which are not reached in the exploration are not within d km of the route.

In some cases, exploration from the POIs is more efficient, and in others exploration from the route is more efficient. In general, the denser the POIs are in the area around the route, the more efficient it is to perform the search starting at the route. In some embodiments, a decision is made at run time whether to search from the POIs or from the route on the basis of a criterion involving the length of the route, the search radius, and the number of POIs that pass the initial test. In one such embodiment, the test is performed as follows: The assumption is made that the amount of computation expended in searching is roughly proportional to the search area. If the length of the route is |, and the maximum search distance is r, the area to be searched if searching starts at the route is approximately $2|r+\pi r^2$. If, further, the number of POIs that pass the initial filter is n, the area to be searched if searching starts at the POIs is approximately $n\pi r^2$. This means that the amount of computation expended if starting at the POIs exceeds that expended if starting at the route if and only if $n\pi r^2>2|r+\pi r^2$, i.e., if and only if (n 1)$\pi r>2|$, i.e., if and only if $n>1+2|/\pi r$. Accordingly, the search is made from the POIs if $n<1+2|/\pi r$ and from the route if $n>1+2|/\pi r$. (The case in which n is exactly equal to $1+2|/\pi r$ is rare, and thus there is little or no difference which decision is made in that case.)

When searching is based on driving time, the search is performed in much the same manner. If driving time is to be estimated, then there is a speed associated with each road element in the map. Route engine **104** can therefore know the maximum speed associated with any road anywhere in the database. By using that maximum speed, it can determine a maximum distance such that any POIs within the maximum driving time at the maximum speed must also be within the maximum distance. (If the driving-time threshold is t hours, and the maximum speed anywhere in the database is s km/h, then any point within a driving time of t hours will also be within a driving distance of st km, and therefore also within a Euclidean distance of st km.) The first filtering can be performed as described above, and then exploration using driving time can be performed exactly as described above for exploration using driving distance.

As noted above, in some embodiments, the route departure point is chosen so as to minimize not the driving distance from the route to the POI, but rather the total distance from the origin to the route departure point plus the distance to the POI. In such embodiments, the step of finding the route departure point can be performed with a modification to Dijkstra's algorithm. Dijkstra's algorithm as usually implemented maintains a best known distance from the origin to each node in the exploration, as well as an indication of the previous node in the best route from the origin. In this embodiment, Dijkstra's algorithm is modified so that, for each node, both a best known distance from the origin and a distance from the initial route are maintained, as well as an indication of the previous node. For each node in the initial route, the best known distance from the origin is initialized to be the distance from the origin to that node, and the distance from the route is initialized to zero. Then Dijkstra's algorithm is applied in the usual way, but a given node is not explored from if the distance from the route is greater than the limiting distance. POIs not reached in this exploration are beyond the limiting distance. The route that minimizes the distance to each POI from the origin is obtained by following the references to previous nodes from the POI back until the original route is reached.

Returning to the Route

We now describe additional embodiments that take into account not just the cost (in time or distance) of departing from the route, but also the cost of returning to the route from the POI. This is more than a trivial concern, because quite often routes are not reversible. Consider, for example, a freeway interchange that includes only an exit, but not an entrance—something that is common in the U.S. Interstate System, as well as other global freeway systems. In such a case, it may be true that a particular POI located at that exit is well within the threshold distance or time specified by the driver or manufacturer; however, it may also be true that returning to the freeway from the POI requires traveling along a secondary road—and in some cases, in the wrong direction relative to the driver's destination—to re-enter the freeway. That experience can easily transform a stop that seemed like a good idea at the time into a frustrating and unexpected detour.

Referring to FIG. **6**, routing engine **104** begins by identifying **602** all POIs that can be reached from the route with a cost less than m. For example, if cost is a measure of driving time, then routing engine **104** identifies all POIs that can be reached within m minutes from some point on the route. This can be achieved by performing an exploration using Dijkstra's algorithm, for example. Next, routing engine **104** performs **604** a reverse exploration on nodes in the planned route to locate POIs from which the route can be reached with a cost less than n. A reverse Dijkstra algorithm explores backwards in time (i.e. in cost) for n minutes (or n miles) from the route along the directed graph to determine which POIs lie within that n minute (or n mile) distance. In the reverse Dijkstra exploration, the search from each node determines the nodes from which that node can be reached. This is distinguished from a normal (forward) Dijkstra exploration, in which the search from each node determines the nodes that can be reached from that node.

Routing engine **104** then keeps **606** the set of POIs that can both be reached from the route with a cost of less than m, and from which the route can be reached with a cost of less than n. That is, if both m and n are set equal to a time t, then the kept set of POIs comprises all of the points that

the driver can reach and return to the route from in less than time t. Of course, this set also includes a number of false positives (POIs that require longer than time t to go to and return to the route from), but the way in which the set is generated results in no false negatives. Routing engine **104** then filters **608** the kept set to identify those POIs for which the sum of the time to the POI from the route and the time to the route from the POI is less than t.

Note that it is also possible that a POI lies not at a node, but along a link between two nodes. In that case, if the node at the far end of the link is reachable within time t, then the POI is reachable in slightly less than time t, since it occurs earlier in the link, and takes correspondingly longer time to return to the route from. Therefore, the node at the end of the link passes the t minute test if and only if the POI also passes the test, and therefore the POI on a link is acceptable exactly if the node at the end of the link passes the test.

Although routing engine **104** is still performing a sizable number of explorations, because the route may be asymmetric routing engine **104** cannot simply assume that any POI reachable in time t/2 and from which the route is reachable in time t/2 represents the complete set of POIs being sought. For example, imagine a POI that takes only 1 minute to reach from the route, but from which 9 minutes is required to reach a point on the route—for example, where the freeway exit has no corresponding on-ramp. If t is 10 minutes, then the POI should be included in the final result set. However, if routing engine **104** simply considered POIs reachable in t/2 minutes and returnable from in t/2 minutes, this POI would be missed.

To reach a node, the driver travels down the route for some distance, and then off the route for an additional distance. If the distance down the route is r, and the distance from route departure to the node is s, then the total distance d is r+s. In one embodiment, routing engine **104** tracks s and d (from which r can be inferred when needed). Alternatively, routing engine could track r and d, or r and s, the third variable inferred from the other two.

Typically, in following Dijkstra's algorithm to perform an exploration, if a second path to a node is found, the second path is kept, and the first path replaced, if the second path is lower cost than the first. In one embodiment, routing engine **104**, however, considers a better path to be a path having a lower cost from the route origin, as opposed to from the route departure point, and if the second path to the node has a lower cost from the route origin, replaces the previously known best path with the second path, and stores the associated pair of costs (e.g., s and d above). As a consequence, routing engine **104** may sometimes replace a path that has a lower cost from the route departure point with a path that has a greater cost from the route departure point, but a lower cost from the origin. For example, a first path, which involves a cost of 5 minutes down the route and 1 minute off the route, for a total of 6 minutes, would be replaced with a second path having a cost of 3 minutes down the route and 2 minutes off, for a total of 5 minutes—even though the off-route cost of 1 in the first path is less than the off-route cost of 2 in the second path. The stopping criterion for exploration is a cost of m off of the route and n to return to the route, so when both explorations have finished, routing engine **104** has determined the best way to get from the route origin to the node, and which doesn't involve deviating from the route for more than t minutes.

Routing engine **104** in one embodiment filters the results based on cost from origin to route departure point, plus cost from the departure point to the node, plus cost from the node to the return point on the route, plus cost from the return point to the destination, and minus the cost from the origin to the destination along the original route. This results in the amount of extra driving (in time or distance) incurred by deviating to the POI along the best known way.

In some situations, a POI may lie very close to a potential route from origin to destination, although that potential route is not the shortest (or fastest) route from origin to destination. For example, there are two highway routes from San Jose, Calif. to San Francisco. The shorter of the two is along US Highway **101**; the longer of the two is along Interstate **280**. The difference is not substantial, however—about 1-5 miles, depending on the ultimate destination in San Francisco. Assume now that there is a POI within 2 miles of a particular exit on Interstate **280**, and the user has defined a threshold maximum of 10 miles as an acceptable total detour distance. If Highway **101** is the initially planned route, then taking Interstate **280** instead would result in a net extra driving distance of fewer than 10 miles, which would be acceptable to the driver. To find this POI, however, routing engine **104** would have to undertake an expansive exploration from the original route—perhaps looking as far as 30 miles from the original route (since Highway **101** and Interstate **280** run roughly parallel to each other, but on opposite sides of Silicon Valley). This exploration is certainly possible using the techniques described above, and in one embodiment routing engine **104** is configured to and does perform such an exploration. In an alternative embodiment, however, routing engine **104** places a tighter bound on the distance from the route and on the distance required to return to the route—for example 5 miles. That bounding would miss the POI along Interstate **280** for the reasons noted above, but would require substantially less computing power. In that embodiment, routing engine **104** is still guaranteed to find every known POI less than t minutes extra drive, and less than 5 miles from the original route and less than 5 miles back to the route from the POI.

While the present invention has been described above in particular detail with respect to a limited number of embodiments, other embodiments are possible as well. The particular naming of the components and their programming or structural aspect is not mandatory or significant, and the mechanisms that implement the invention or its features may have different names, formats, or protocols. Further, the system may be implemented via a combination of hardware and software, as described, or entirely in hardware elements. Also, the particular division of functionality between the various system components described herein is merely exemplary, and not mandatory; functions performed by a single system component may instead be performed by multiple components, as illustrated for example by the description of FIG. **4**, and functions performed by multiple components may instead performed by a single component. For example, the particular functions of the routing engine **104** may be provided in many or one module.

The operations described above, although described functionally or logically, may be implemented by computer programs stored on one or more computer readable media and executed by a processor. Computer readable storage media include, for example, any type of disk including floppy disks, optical disks, CD-ROMs, magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, application specific integrated circuits (ASICs), or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus. Furthermore, the computers referred to in the specification may include a

single processor or may be architectures employing multiple processor designs for increased computing capability.

Throughout the description, discussions using terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a particular computer system, or similar electronic computing device, that manipulates and transforms data representing or modeling physical characteristics, and which is represented as physical (electronic) quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The algorithms and displays presented above are not inherently related to any particular computer or other apparatus. Various general-purpose systems may also be modified by using the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the described method steps. The required structure for a variety of these systems will appear from the description above. In addition, the present invention is not described with reference to any particular programming language, any suitable one of which may be selected by the implementer.

Finally, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and may not have been selected to delineate or circumscribe the inventive subject matter. Accordingly, the disclosure of the present invention is intended to be illustrative, but not limiting, of the scope of the invention.

What is claimed is:

1. A computer-implemented method for providing routing to a point of interest, the method comprising:

determining, by one or more processors, a first cost to reach a destination along a first navigation route from a current location of a computing device, the first cost less than a second cost to reach the destination along a second navigation route from the current location;

determining, by the one or more processors, a third cost to detour to the point of interest from the first navigation route and to reach the destination from the point of interest along the first navigation route;

determining, by the one or more processors, a fourth cost to detour to the point of interest from the second navigation route and to reach the destination from the point of interest along the second navigation route; and

in response to determining that the fourth cost is less than the third cost, providing the second navigation route for presentation on the computing device.

2. The computer-implemented method of claim **1**, wherein the first cost and the second cost are determined based on a first distance of the first navigation route and a second distance of the second navigation route, respectively, the first distance shorter than the second distance.

3. The computer-implemented method of claim **2**, further comprising:

determining, by the one or more processors, that the point of interest is a first detour distance from the first navigation route and a second detour distance from the second navigation route, the first detour distance greater than the second detour distance.

4. The computer-implemented method of claim **2**, further comprising:

determining, by the one or more processors, that the point of interest is less than a threshold distance from the second navigation route, the threshold distance greater than a difference between the first distance and the second distance.

5. The computer-implemented method of claim **1**, wherein the first cost and the second cost are determined based on a first time of the first navigation route and a second time of the second navigation route, respectively, the first time shorter than the second time.

6. The computer-implemented method of claim **1**, further comprising:

determining, by the one or more processors, that a detour time from the second navigation route to the point of interest is different than a return time from the point of interest to the second navigation route.

7. The computer-implemented method of claim **6**, wherein the detour time is from a freeway exit of the second navigation route and the return time is to a freeway on-ramp of the second navigation route, the freeway on-ramp and the freeway exit located at different portions of the second navigation route.

8. The computer-implemented method of claim **6**, wherein an average of the detour time and the return time is less than a threshold time.

9. The computer-implemented method of claim **8**, wherein at least one of the detour time and the return time is greater than the threshold time.

10. A non-transitory computer-readable storage medium storing instructions for providing routing to a point of interest, the instructions when executed by one or more processors cause the one or more processors to perform steps including:

determining, by one or more processors, a first cost to reach a destination along a first navigation route from a current location of a computing device, the first cost less than a second cost to reach the destination along a second navigation route from the current location;

determining, by the one or more processors, a third cost to detour to the point of interest from the first navigation route and to reach the destination from the point of interest along the first navigation route;

determining, by the one or more processors, a fourth cost to detour to the point of interest from the second navigation route and to reach the destination from the point of interest along the second navigation route; and

in response to determining that the fourth cost is less than the third cost, providing the second navigation route for presentation on the computing device.

11. The non-transitory computer-readable storage medium of claim **10**, wherein the first cost and the second cost are determined based on a first distance of the first navigation route and a second distance of the second navigation route, respectively, the first distance shorter than the second distance.

12. The non-transitory computer-readable storage medium of claim **11**, having further instructions that when executed by the one or more processors cause the one or more processors to perform further steps including:

determining, by the one or more processors, that the point of interest is a first detour distance from the first navigation route and a second detour distance from the second navigation route, the first detour distance greater than the second detour distance.

13. The non-transitory computer-readable storage medium of claim **11**, having further instructions that when executed by the one or more processors cause the one or more processors to perform further steps including:

determining, by the one or more processors, that the point of interest is less than a threshold distance from the

second navigation route, the threshold distance greater than a difference between the first distance and the second distance.

14. The non-transitory computer-readable storage medium of claim **10**, wherein the first cost and the second cost are determined based on a first time of the first navigation route and a second time of the second navigation route, respectively, the first time shorter than the second time.

15. The non-transitory computer-readable storage medium of claim **10**, having further instructions that when executed by the one or more processors cause the one or more processors to perform further steps including:

determining, by the one or more processors, that a detour time from the second navigation route to the point of interest is different than a return time from the point of interest to the second navigation route.

16. The non-transitory computer-readable storage medium of claim **15**, wherein the detour time is from a freeway exit of the second navigation route and the return time is to a freeway on-ramp of the second navigation route, the freeway on-ramp and the freeway exit located at different portions of the second navigation route.

17. The non-transitory computer-readable storage medium of claim **15**, wherein an average of the detour time and the return time is less than a threshold time.

18. The non-transitory computer-readable storage medium of claim **17**, wherein at least one of the detour time and the return time is greater than the threshold time.

19. A system for providing routing to a point of interest, comprising:

a global navigation satellite system radio configured to determine a current location of the system;

a routing engine coupled to the global navigation satellite system radio and configured to:

determine, by one or more processors, a first cost to reach a destination along a first navigation route from the current location, the first cost less than a second cost to reach the destination along a second navigation route from the current location;

determine, by the one or more processors, a third cost to detour to the point of interest from the first navigation route and to reach the destination from the point of interest along the first navigation route;

determine, by the one or more processors, a fourth cost to detour to the point of interest from the second navigation route and to reach the destination from the point of interest along the second navigation route; and

a user interface coupled to the routing engine and configured to provide the second navigation route for presentation on the system in response to determining that the fourth cost is less than the third cost.

20. The system of claim **19**, wherein the first cost and the second cost are determined based on a first distance of the first navigation route and a second distance of the second navigation route, respectively, the first distance shorter than the second distance, and wherein the routing engine is further configured to:

determine, by the one or more processors, that the point of interest is less than a threshold distance from the second navigation route, the threshold distance less than a difference between the first distance and the second distance.

* * * * *