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(54) **ADAPTIVE MOBILE DEVICE NAVIGATION**

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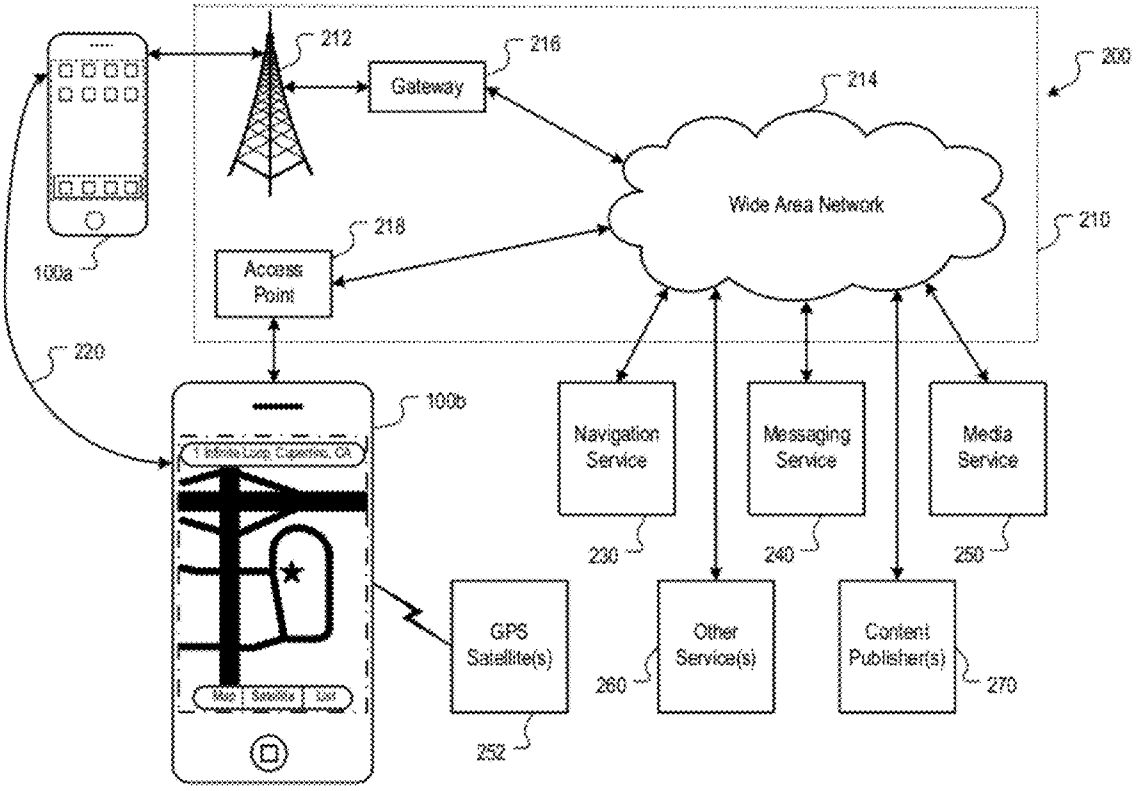
(52) **U.S. Cl.** **701/450**

(57) **ABSTRACT**

Adaptive mobile device navigation system, methods, and apparatus provide location information for a mobile device performing location estimation using dead reckoning. Multiple estimation modes can be selected including a mode for restricting measured movements to surrounding streets. Updated location fixes can be obtained through turn comparison with surrounding map information and user feedback. User feedback prompts can include photographs having geographic tag information corresponding to locations near an estimated location of the device.



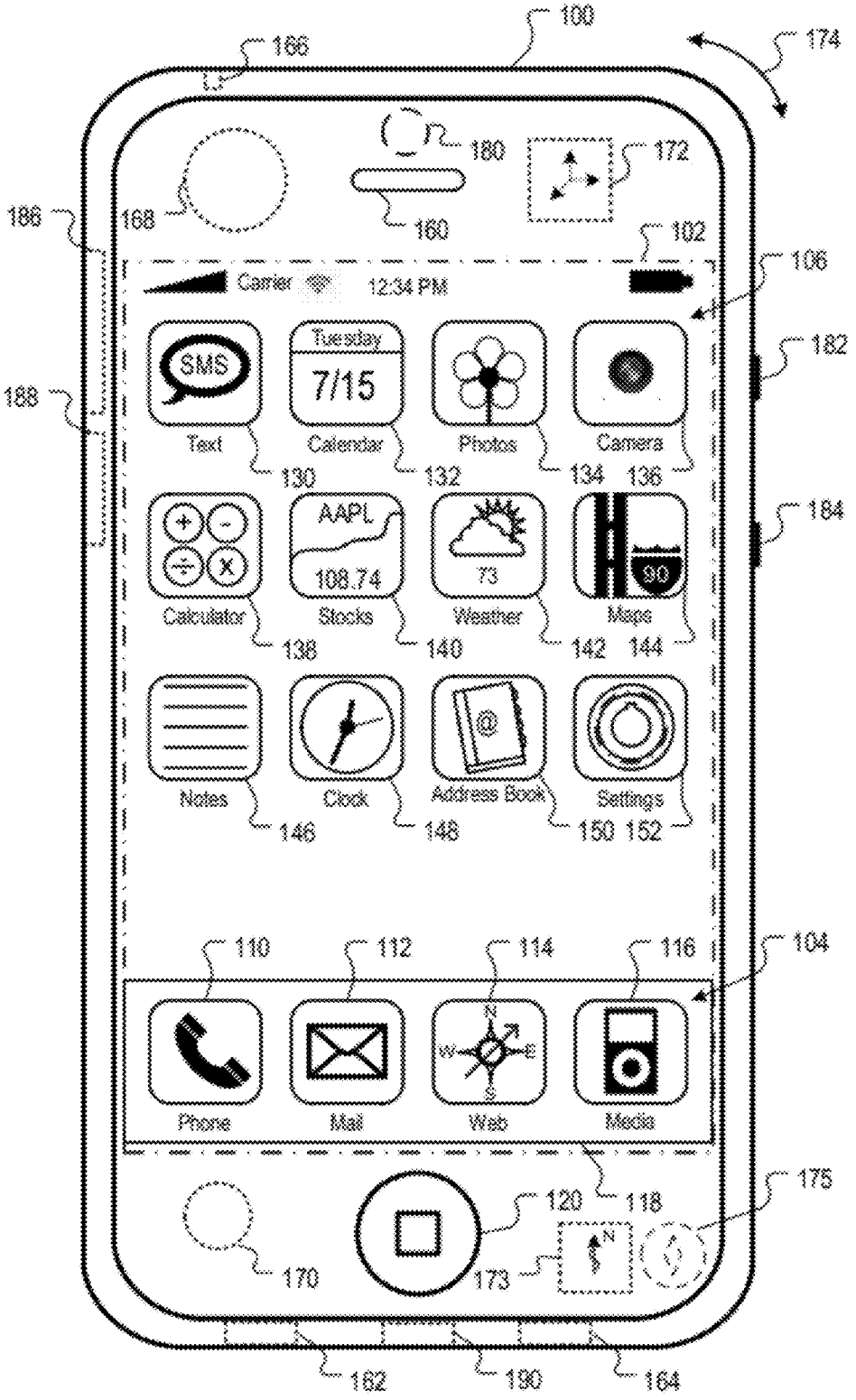

100
166
174
180
172
168
160
186
102
106
Carrier
12:34 PM
182
188
SMS
Tuesday
7/15
Text
Calendar
Photos
Camera
130
132
134
136
184
AAPL
108.74
73
90
Calculator
Stocks
Weather
Maps
138
140
142
144
Notes
Clock
Address Book
Settings
146
148
150
152
110
112
114
116
104
Phone
Mail
Web
Media
118
120
175
170
173
162
190
164

FIG. 1

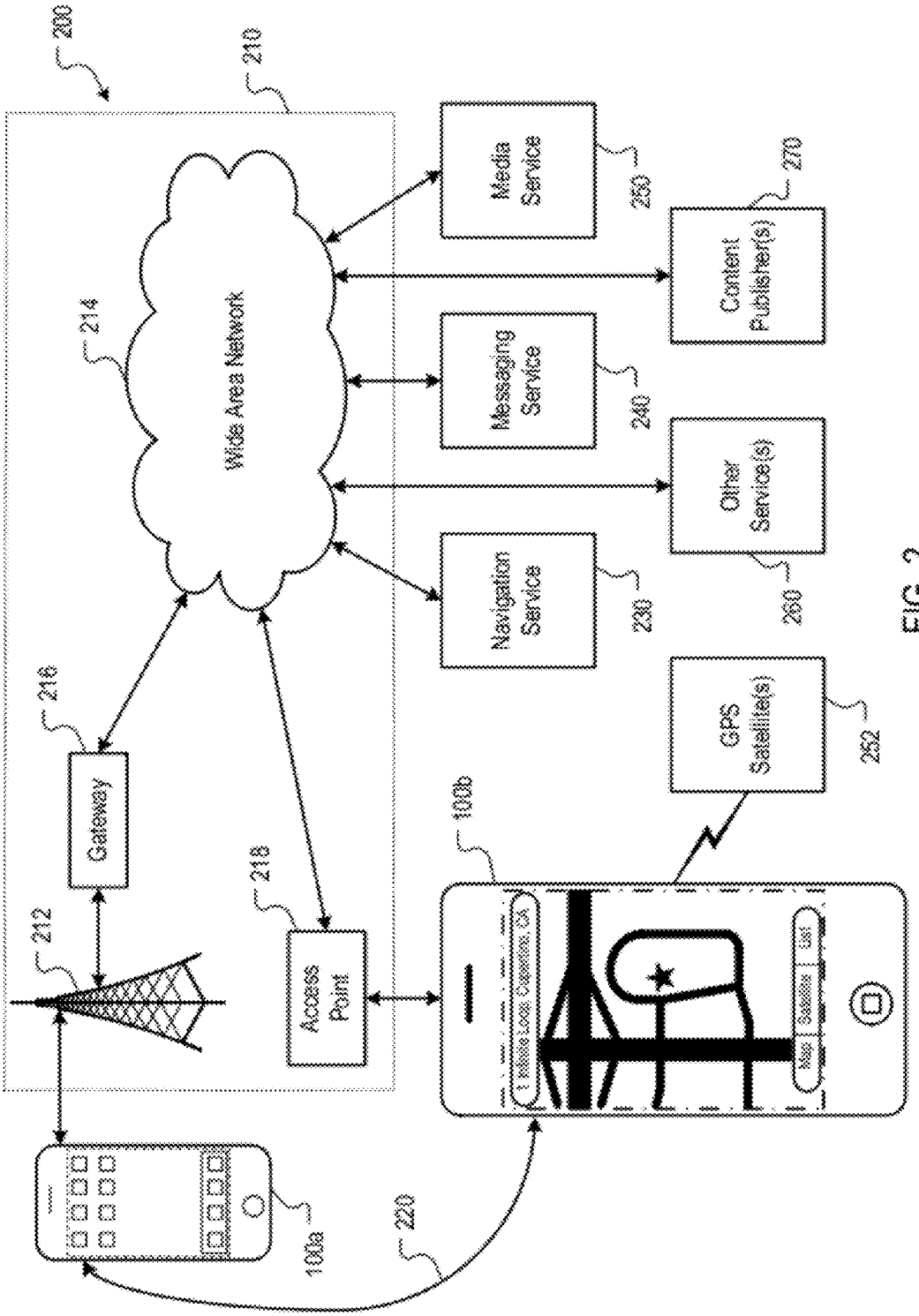

200
210
214
Wide Area Network
Media Service
250
Content Publisher(s)
270
Messaging Service
240
Other Service(s)
260
Navigation Service
230
GPS Satellite(s)
252
216
Gateway
212
218
Access Point
100b
100a
220

FIG. 2

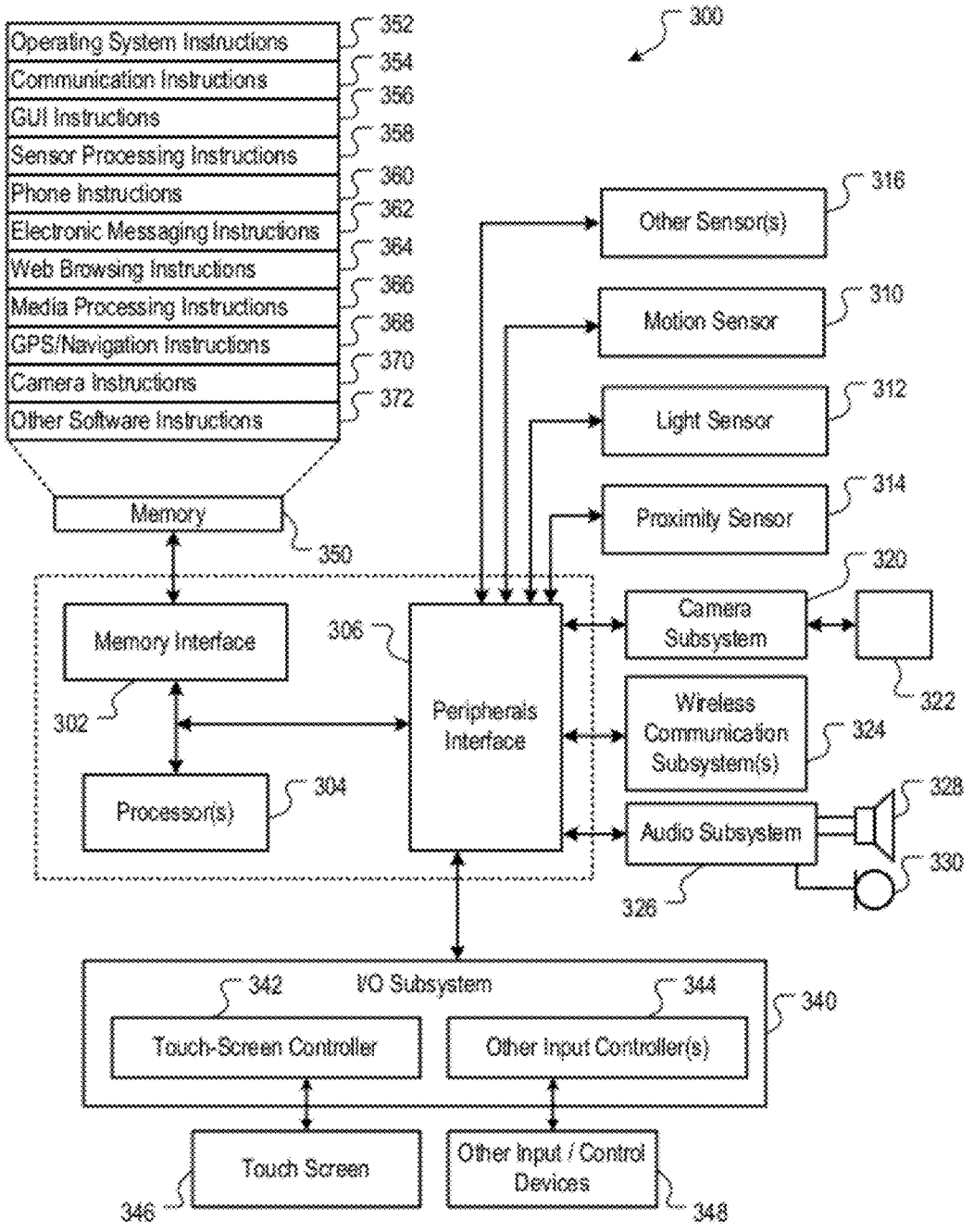

300
Operating System Instructions
352
Communication Instructions
354
GUI Instructions
356
Sensor Processing Instructions
358
Phone Instructions
360
Electronic Messaging Instructions
362
Web Browsing Instructions
364
Media Processing Instructions
366
GPS/Navigation Instructions
368
Camera Instructions
370
Other Software Instructions
372
Memory
350
Memory Interface
302
Processor(s)
304
306
Peripherals Interface
Other Sensor(s)
316
Motion Sensor
310
Light Sensor
312
Proximity Sensor
314
Camera Subsystem
320
322
Wireless Communication Subsystem(s)
324
Audio Subsystem
326
328
330
I/O Subsystem
340
342
344
Touch-Screen Controller
Other Input Controller(s)
Touch Screen
346
Other Input / Control Devices
348

FIG. 3

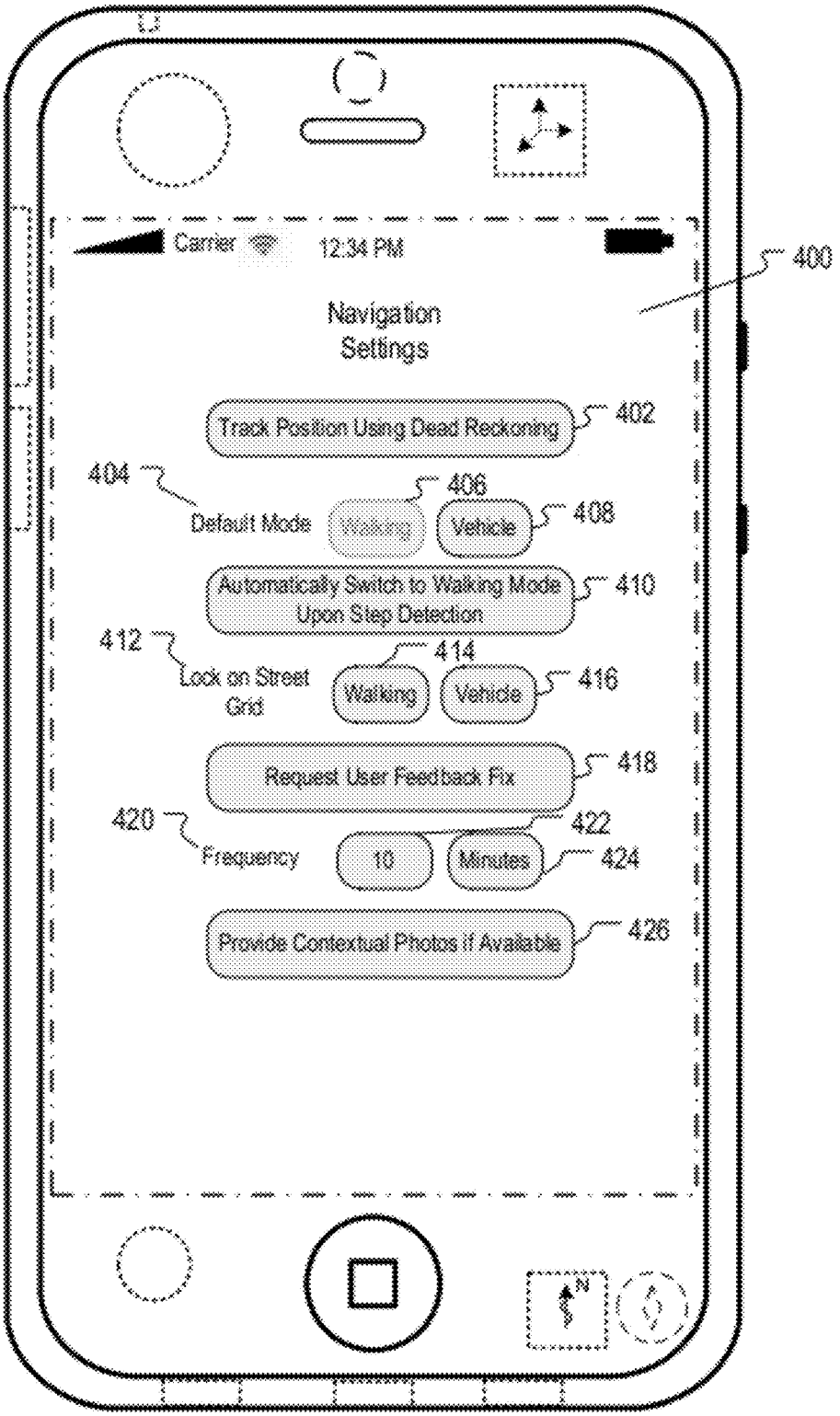

Carrier
12:34 PM
400
Navigation Settings
Track Position Using Dead Reckoning
402
404
Default Mode
406
Walking
Vehicle
408
Automatically Switch to Walking Mode Upon Step Detection
410
412
Lock on Street Grid
414
Walking
Vehicle
416
Request User Feedback Fix
418
420
Frequency
422
10
Minutes
424
Provide Contextual Photos if Available
426

FIG. 4

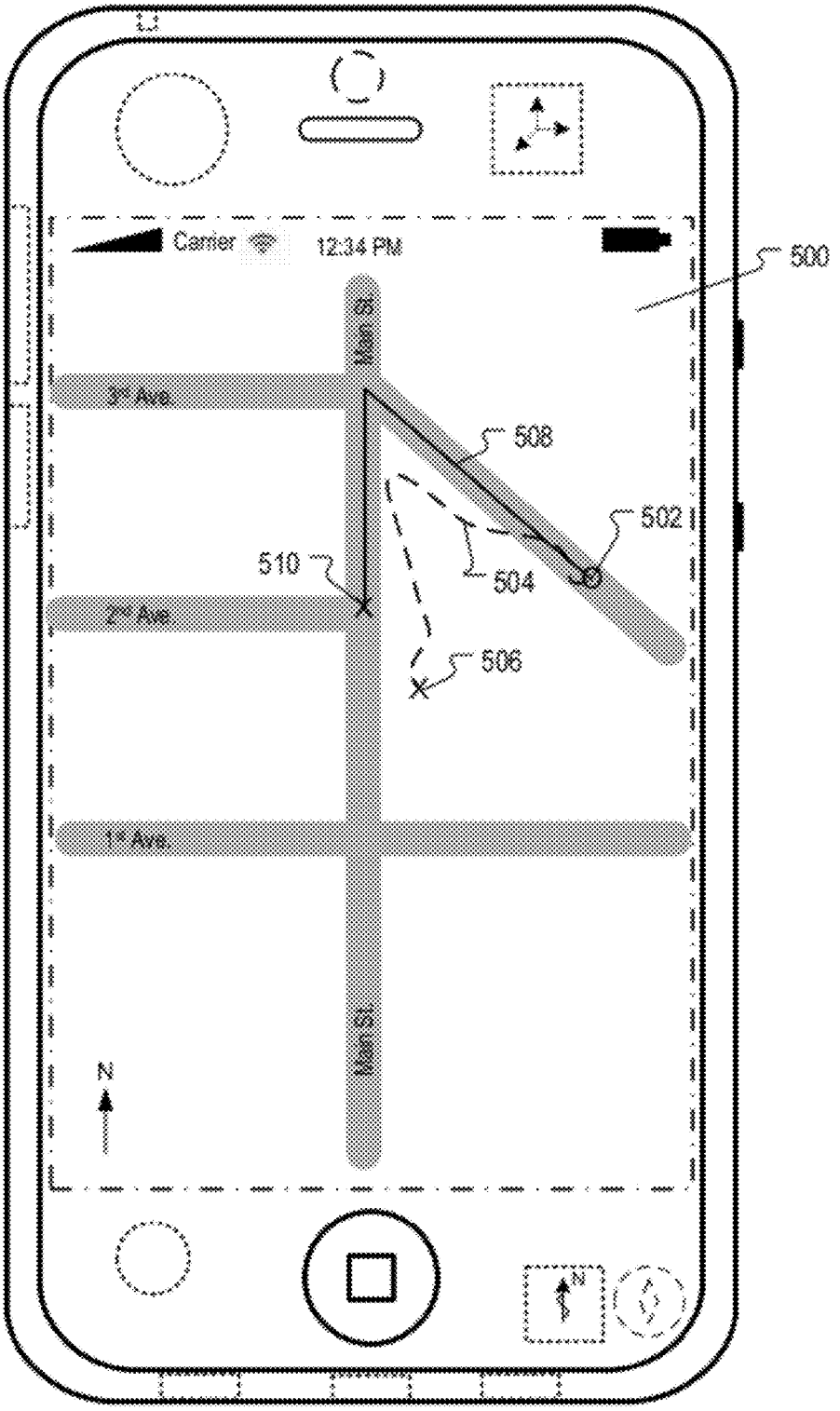

Carrier
12:34 PM
500
Main St
3rd Ave.
508
502
504
510
2nd Ave.
506
1st Ave.
Main St
N

FIG. 5

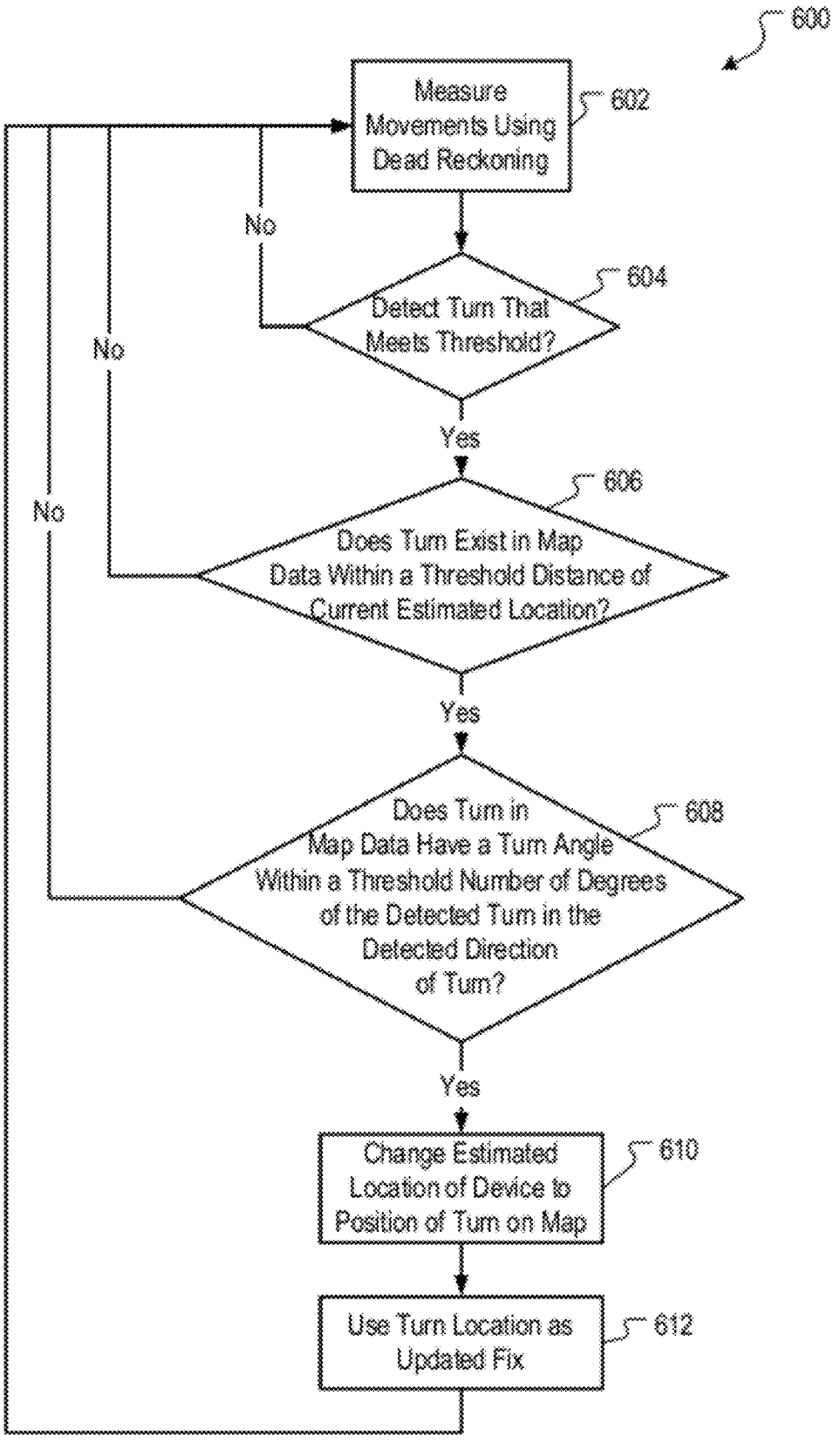

600
Measure Movements Using Dead Reckoning
602
No
Detect Turn That Meets Threshold?
604
No
Yes
Does Turn Exist in Map Data Within a Threshold Distance of Current Estimated Location?
606
No
Yes
Does Turn in Map Data Have a Turn Angle Within a Threshold Number of Degrees of the Detected Turn in the Detected Direction of Turn?
608
Yes
Change Estimated Location of Device to Position of Turn on Map
610
Use Turn Location as Updated Fix
612

FIG. 6

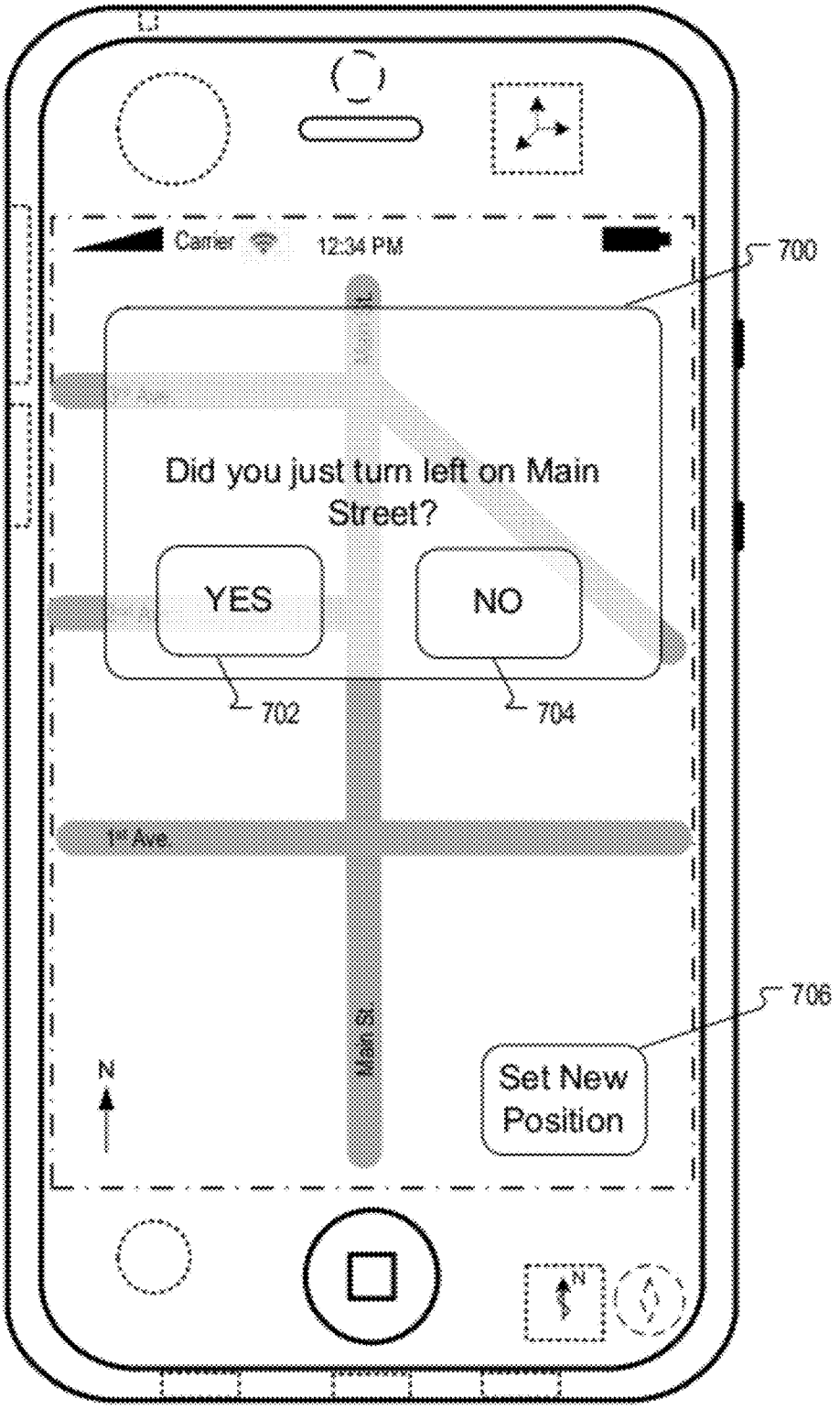

Carrier
12:34 PM
700
Did you just turn left on Main Street?
YES
NO
702
704
1st Ave
Main St
N
Set New Position
706

FIG. 7

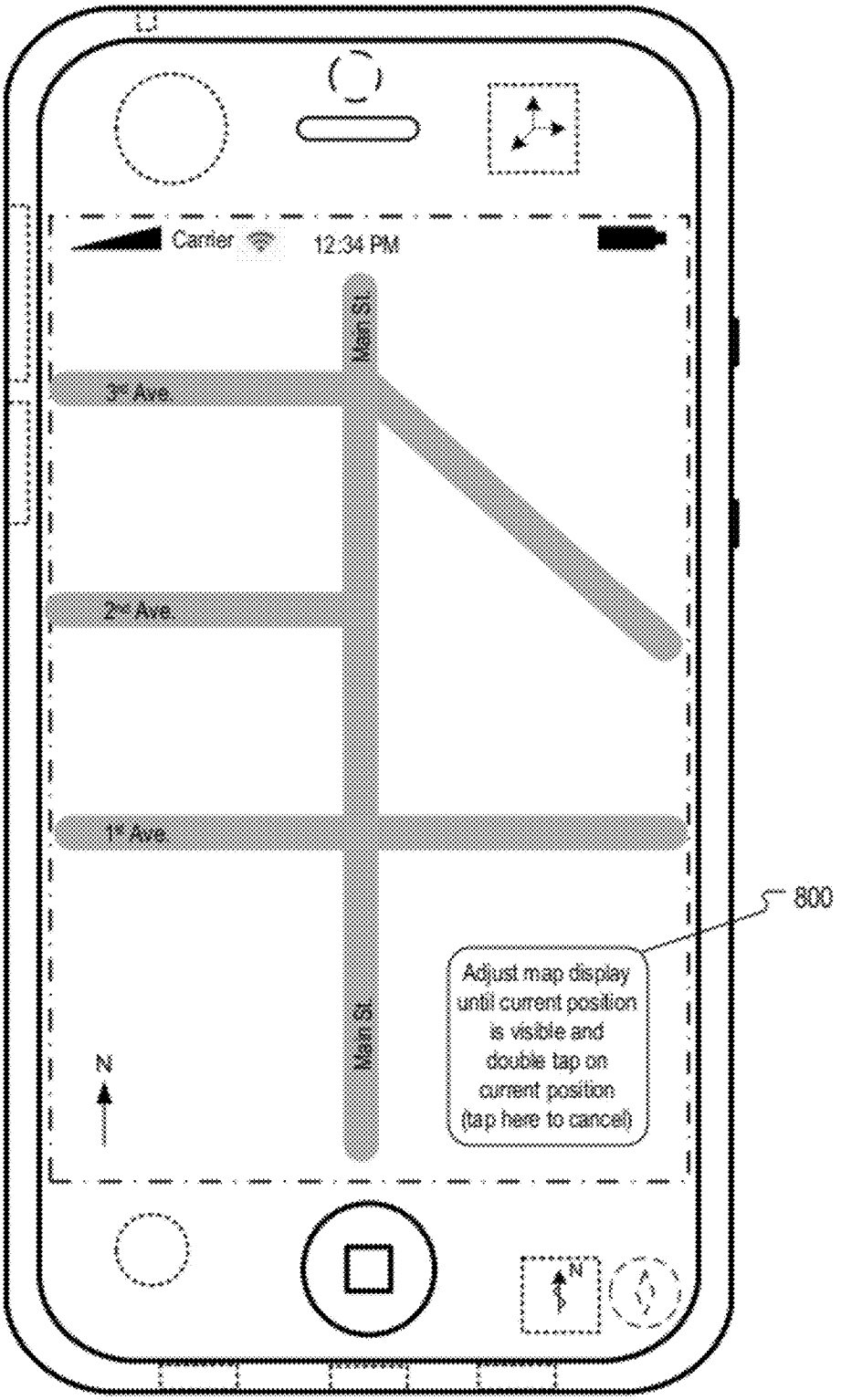

Carrier
12:34 PM
Main St
3rd Ave
2nd Ave
1st Ave
Main St
N
Adjust map display until current position is visible and double tap on current position (tap here to cancel)
800

FIG. 8

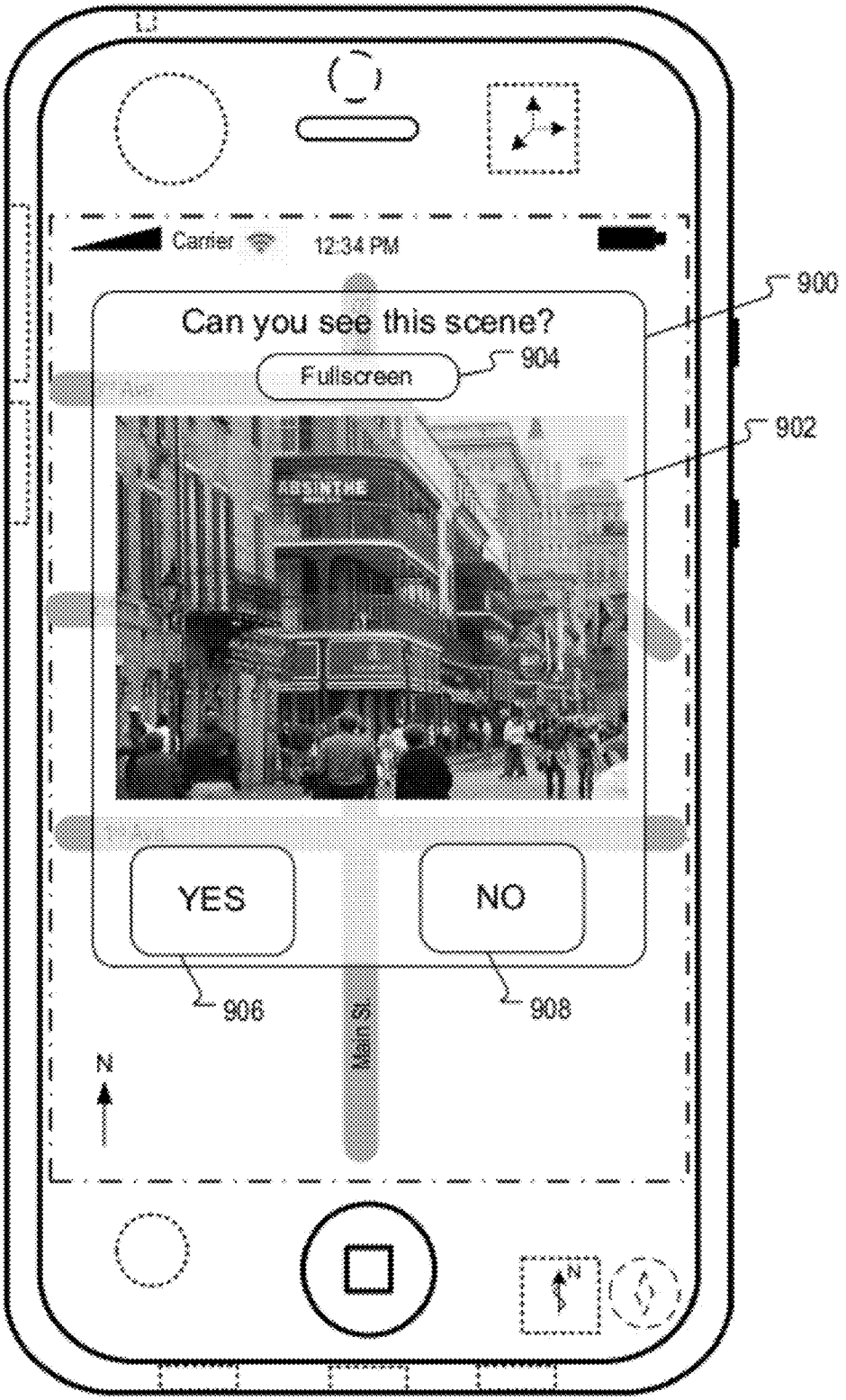

Carrier
12:34 PM
900
Can you see this scene?
Fullscreen
904
902
YES
NO
906
908
N
Main St

FIG. 9

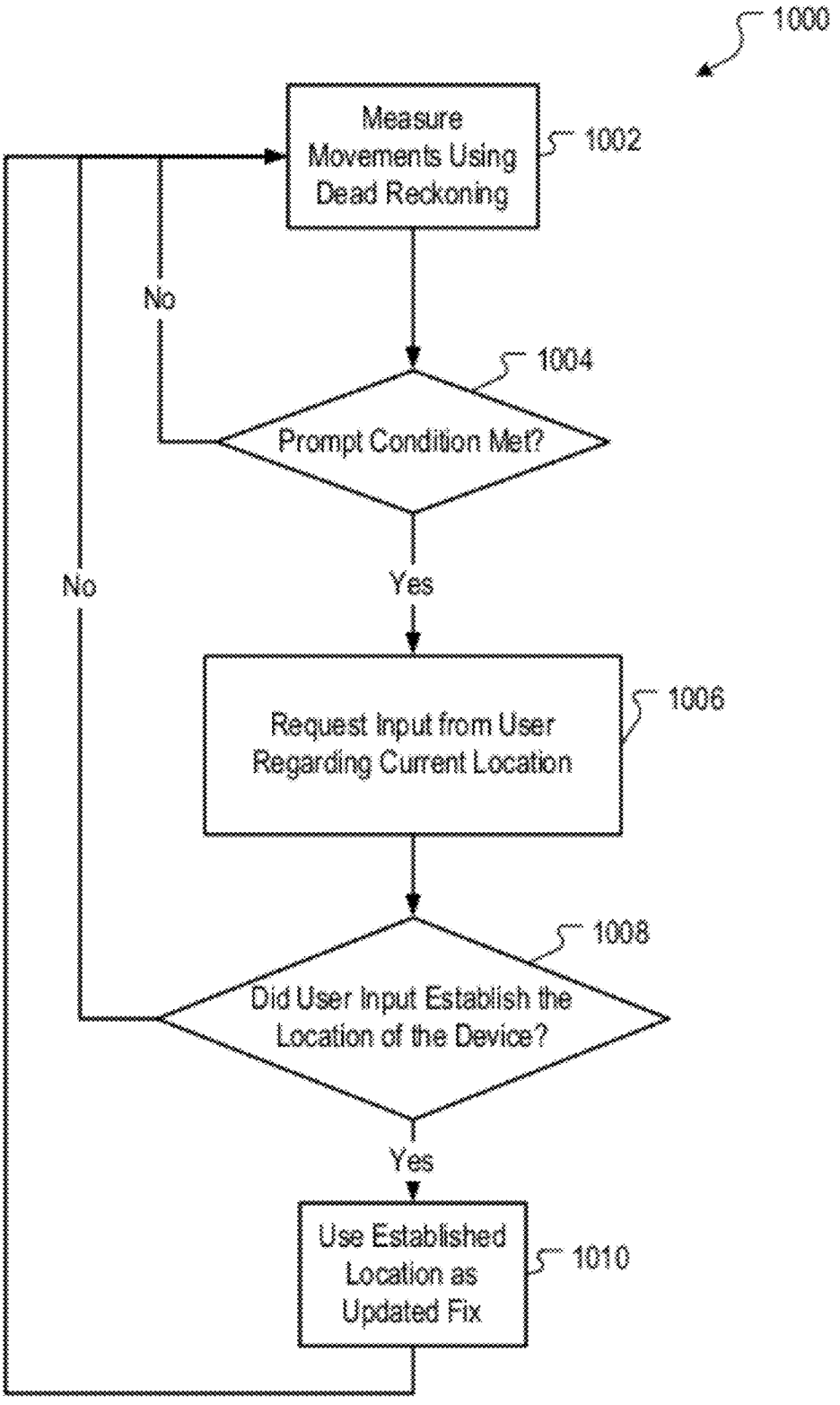

1000
Measure Movements Using Dead Reckoning
1002
No
1004
Prompt Condition Met?
No
Yes
Request Input from User Regarding Current Location
1006
1008
Did User Input Establish the Location of the Device?
Yes
Use Established Location as Updated Fix
1010

FIG. 10

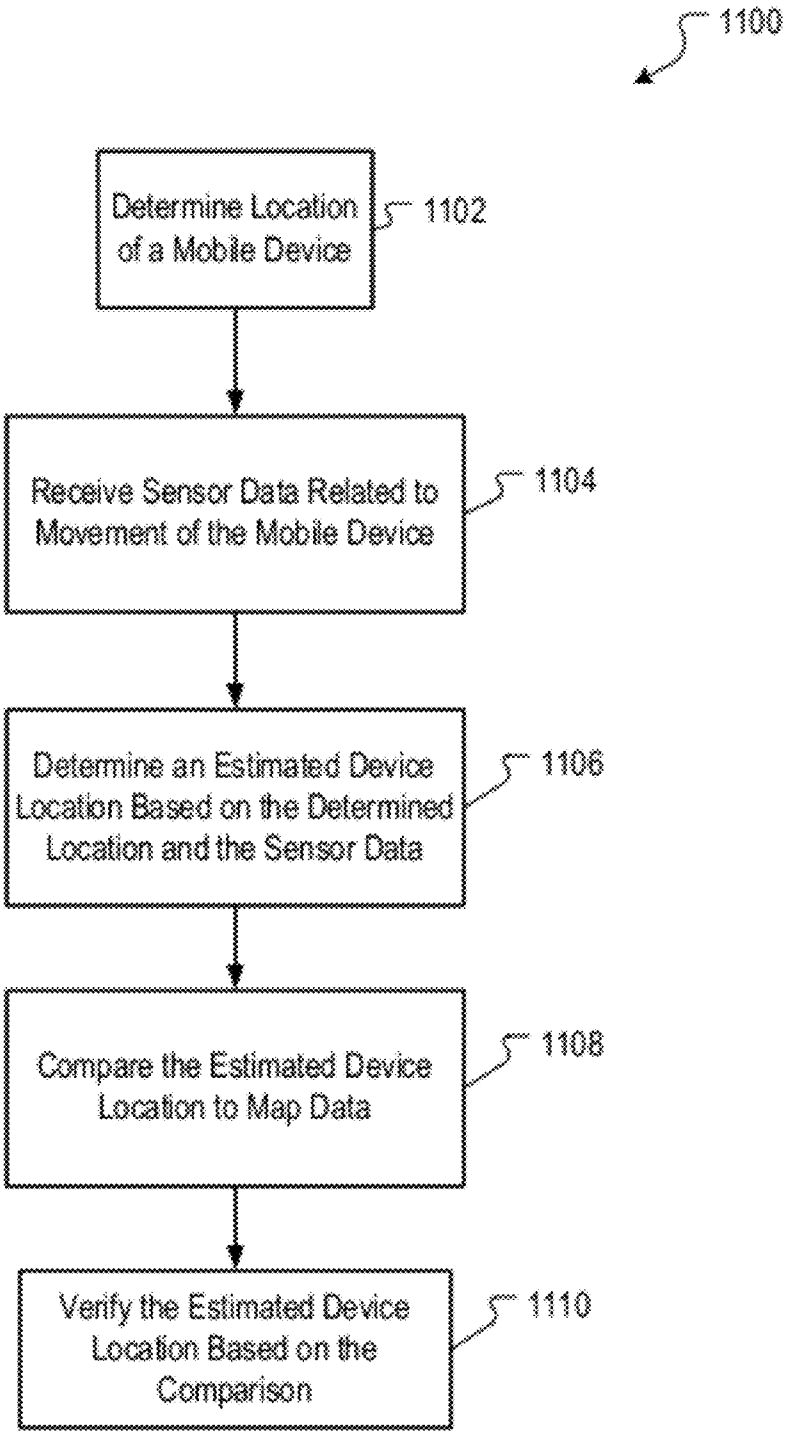

1100
Determine Location of a Mobile Device
1102
Receive Sensor Data Related to Movement of the Mobile Device
1104
Determine an Estimated Device Location Based on the Determined Location and the Sensor Data
1106
Compare the Estimated Device Location to Map Data
1108
Verify the Estimated Device Location Based on the Comparison
1110

FIG. 11

ADAPTIVE MOBILE DEVICE NAVIGATION

RELATED APPLICATION

[0001] This application claims a benefit of priority from U.S. patent application Ser. No. 11/970,766, filed Jan. 8, 2008, which claims a benefit of priority from U.S. Provisional Patent Application No. 60/946,817, filed Jun. 28, 2007, both of which are incorporated by reference herein in their entirety.

TECHNICAL FIELD

[0002] The present invention relates generally to mobile device aided navigation.

BACKGROUND

[0003] The role of traditional printed maps is being supplanted by modern devices capable of rendering dynamic map displays. Devices that include mapping or navigation applications provide information regarding an area selected by a user by recalling map data from local memory or networked services.

[0004] Mapping devices often include the ability to provide directions from a point of origin to a destination. When coupled with any of a number of positioning technologies, a mapping device can display a current position on a map as well as deliver navigation instructions based on the current position to route a user to a desired destination. Positioning technologies include satellite positioning systems such as GPS, information from nearby cellular base stations, and information from other transmitters such as, such as Wi-Fi networks.

[0005] Not all mobile mapping devices include the necessary hardware and software to receive positioning information. In addition, due to interfering factors of the environment in which a mobile device is being operated, the mobile device may not be able to receive positioning information even if it is equipped to do so.

SUMMARY

[0006] Disclosed herein are systems and methods for adaptive mobile device navigation. In one implementation, a device position is stored in memory. Sensor data is received from a motion sensor measuring movement of the device. The sensor data is compared to map data corresponding to the device location. An estimated current device location is determined. The determination is based at least in part on the device position, received sensor data, and an interpretation of the received sensor data as corresponding to movement along at least one pathway defined by the map data.

[0007] In an implementation, the pathway can be a sidewalk or a street. The motion sensor can be one or a combination of an accelerometer, a compass, and/or a gyroscope.

[0008] In an implementation, a device position is stored in memory. Sensor data is received from at least one motion sensor measuring movement of the device. An estimated current device location is determined. The determination is based at least in part on the device location and the received sensor data. The sensor data is compared to map data corresponding to the stored location. Feedback is requested regarding the comparison. In an implementation, a second device position established by a response to the feedback is stored in memory.

[0009] In an implementation the prompt includes a photograph. The photograph can be identified from a database of photographs, where the photograph includes geographical tagging information corresponding to a location that is within a threshold distance of the estimated current device location.

[0010] In an implementation, a mobile device location is determined. Sensor data is received that is related to movement of the mobile device. An estimated mobile device location is determined based on the device location and the sensor data. The estimated device location is compared to map data, and the estimated device location is verified based on the comparison.

[0011] Instructions for performing the aforementioned methods may be included in a computer program product configured for execution by one or more processors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** is a block diagram of an example mobile device.

[0013] FIG. **2** is a block diagram of an example network operating environment for the mobile device of FIG. **1**.

[0014] FIG. **3** is a block diagram of an example implementation of the mobile device of FIG. **1**.

[0015] FIG. **4** is a block diagram of an example navigation settings screen of the mobile device of FIG. **1**.

[0016] FIG. **5** is a block diagram of an example map display of the mobile device of FIG. **1**.

[0017] FIG. **6** is a flowchart of an example process for obtaining an updated dead reckoning fix through comparison of a detected turn with map data.

[0018] FIG. **7** is a block diagram of an example user feedback prompt of the mobile device of FIG. **1**.

[0019] FIG. **8** is a block diagram of an example screen for accepting an updated current location from a user on the mobile device of FIG. **1**.

[0020] FIG. **9** is a block diagram of an example user feedback prompt including a photograph on the mobile device of FIG. **1**.

[0021] FIG. **10** is a flowchart of an example process for prompting a user to obtain an updated fix of the mobile device of FIG. **1**.

[0022] FIG. **11** is a flowchart of an example process for verifying an estimated location of the mobile device of FIG. **1**.

[0023] Like reference numerals refer to corresponding parts throughout the drawings.

DETAILED DESCRIPTION

[0024] FIG. **1** is a block diagram of an example mobile device **100**. The mobile device **100** can be, for example, a handheld computer, a personal digital assistant, a cellular telephone, a network appliance, a camera, a smart phone, an enhanced general packet radio service (EGPRS) mobile phone, a network base station, a media player, a navigation device, an email device, a game console, or a combination of any two or more of these data processing devices or other data processing devices.

Mobile Device Overview

[0025] In some implementations, the mobile device **100** includes a touch-sensitive display **102**. The touch-sensitive display **102** can implement liquid crystal display (LCD) technology, light emitting polymer display (LPD) technology, or

some other display technology. The touch-sensitive display **102** can be sensitive to haptic and/or tactile contact with a user.

[0026] In some implementations, the touch-sensitive display **102** can comprise a multi-touch-sensitive display **102**. A multi-touch-sensitive display **102** can, for example, process multiple simultaneous touch points, including processing data related to the pressure, degree and/or position of each touch point. Such processing facilitates gestures and interactions with multiple fingers, chording, and other interactions. Other touch-sensitive display technologies can also be used, e.g., a display in which contact is made using a stylus or other pointing device. Some examples of multi-touch-sensitive display technology are described in U.S. Pat. Nos. 6,323,846, 6,570,557, 6,677,932, and U.S. Patent Publication 2002/0015024A1, each of which is incorporated by reference herein in its entirety.

[0027] In some implementations, the mobile device **100** can display one or more graphical user interfaces on the touch-sensitive display **102** for providing the user access to various system objects and for conveying information to the user. In some implementations, the graphical user interface can include one or more display objects **104**, **106**. In the example shown, the display objects **104**, **106**, are graphic representations of system objects. Some examples of system objects include device functions, applications, windows, files, alerts, events, or other identifiable system objects.

Exemplary Mobile Device Functionality

[0028] In some implementations, the mobile device **100** can implement multiple device functionalities, such as a telephony device, as indicated by a phone object **110**; an e-mail device, as indicated by the e-mail object **112**; a network data communication device, as indicated by the Web object **114**; a Wi-Fi base station device (not shown); and a media processing device, as indicated by the media player object **116**. In some implementations, particular display objects **104**, e.g., the phone object **110**, the e-mail object **112**, the Web object **114**, and the media player object **116**, can be displayed in a menu bar **118**. In some implementations, device functionalities can be accessed from a top-level graphical user interface, such as the graphical user interface illustrated in FIG. **1**. Touching one of the objects **110**, **112**, **114** or **116** can, for example, invoke corresponding functionality.

[0029] In some implementations, the mobile device **100** can implement network distribution functionality. For example, the functionality can enable the user to take the mobile device **100** and its associated network while traveling. In particular, the mobile device **100** can extend Internet access (e.g., Wi-Fi) to other wireless devices in the vicinity. For example, mobile device **100** can be configured as a base station for one or more devices. As such, mobile device **100** can grant or deny network access to other wireless devices.

[0030] In some implementations, upon invocation of device functionality, the graphical user interface of the mobile device **100** changes, or is augmented or replaced with another user interface or user interface elements, to facilitate user access to particular functions associated with the corresponding device functionality. For example, in response to a user touching the phone object **110**, the graphical user interface of the touch-sensitive display **102** may present display objects related to various phone functions; likewise, touching of the email object **112** may cause the graphical user interface to present display objects related to various e-mail functions; touching the Web object **114** may cause the graphical user interface to present display objects related to various Web-surfing functions; and touching the media player object **116** may cause the graphical user interface to present display objects related to various media processing functions.

[0031] In some implementations, the top-level graphical user interface environment or state of FIG. **1** can be restored by pressing a button **120** located near the bottom of the mobile device **100**. In some implementations, each corresponding device functionality may have corresponding "home" display objects displayed on the touch-sensitive display **102**, and the graphical user interface environment of FIG. **1** can be restored by pressing the "home" display object.

[0032] In some implementations, the top-level graphical user interface can include additional display objects **106**, such as a short messaging service (SMS) object **130**, a calendar object **132**, a photos object **134**, a camera object **136**, a calculator object **138**, a stocks object **140**, a weather object **142**, a maps object **144**, a notes object **146**, a clock object **148**, an address book object **150**, and a settings object **152**. Touching the SMS display object **130** can, for example, invoke an SMS messaging environment and supporting functionality; likewise, each selection of a display object **132**, **134**, **136**, **138**, **140**, **142**, **144**, **146**, **148**, **150** and **152** can invoke a corresponding object environment and functionality.

[0033] Additional and/or different display objects can also be displayed in the graphical user interface of FIG. **1**. For example, if the device **100** is functioning as a base station for other devices, one or more "connection" objects may appear in the graphical user interface to indicate the connection. In some implementations, the display objects **106** can be configured by a user, e.g., a user may specify which display objects **106** are displayed, and/or may download additional applications or other software that provides other functionalities and corresponding display objects.

[0034] In some implementations, the mobile device **100** can include one or more input/output (I/O) devices and/or sensor devices. For example, a speaker **160** and a microphone **162** can be included to facilitate voice-enabled functionalities, such as phone and voice mail functions. In some implementations, a loud speaker **164** can be included to facilitate hands-free voice functionalities, such as speaker phone functions. An audio jack **166** can also be included for use of headphones and/or a microphone.

[0035] In some implementations, a proximity sensor **168** can be included to facilitate the detection of the user positioning the mobile device **100** proximate to the user's ear and, in response, to disengage the touch-sensitive display **102** to prevent accidental function invocations. In some implementations, the touch-sensitive display **102** can be turned off to conserve additional power when the mobile device **100** is proximate to the user's ear.

[0036] Other sensors can also be used. For example, in some implementations, an ambient light sensor **170** can be utilized to facilitate adjusting the brightness of the touch-sensitive display **102**. In some implementations, one or more of an accelerometer **172**, a compass **173**, and a gyroscope **175** can be utilized to detect movement of the mobile device **100**, as indicated by the directional arrow **174**. Accordingly, display objects and/or media can be presented according to a detected orientation, e.g., portrait or landscape. In some implementations, the mobile device **100** may include circuitry and sensors for supporting a location determining capability, such as that provided by the global positioning

system (GPS) or other positioning systems (e.g., systems using Wi-Fi access points, television signals, cellular grids, Uniform Resource Locators (URLs)). In some implementations, a positioning system (e.g., a GPS receiver) can be integrated into the mobile device **100** or provided as a separate device that can be coupled to the mobile device **100** through an interface (e.g., port device **190**) to provide access to location-based services.

[0037] The mobile device **100** can also include a camera lens and sensor **180**. In some implementations, the camera lens and sensor **180** can be located on the back surface of the mobile device **100**. The camera can capture still images and/or video.

[0038] The mobile device **100** can also include one or more wireless communication subsystems, such as an 802.11b/g communication device **186**, and/or a Bluetooth™ communication device **188**. Other communication protocols can also be supported, including other 802.x communication protocols (e.g., WiMax, Wi-Fi, 3G), code division multiple access (CDMA), global system for mobile communications (GSM), Enhanced Data GSM Environment (EDGE), etc.

[0039] In some implementations, a port device **190**, e.g., a Universal Serial Bus (USB) port, or a docking port, or some other wired port connection, can be included. The port device **190** can, for example, be utilized to establish a wired connection to other computing devices, such as other communication devices **100**, network access devices, a personal computer, a printer, or other processing devices capable of receiving and/or transmitting data. In some implementations, the port device **190** allows the mobile device **100** to synchronize with a host device using one or more protocols, such as, for example, the TCP/IP, HTTP, UDP and any other known protocol. In some implementations, a TCP/IP over USB protocol can be used.

Network Operating Environment

[0040] FIG. **2** is a block diagram of an example network operating environment **200** for the mobile device **100** of FIG. **1**. The mobile device **100** of FIG. **1** can, for example, communicate over one or more wired and/or wireless networks **210** in data communication. For example, a wireless network **212**, e.g., a cellular network, can communicate with a wide area network (WAN) **214**, such as the Internet, by use of a gateway **216**. Likewise, an access point **218**, such as an 802.11g wireless access point, can provide communication access to the wide area network **214**. In some implementations, both voice and data communications can be established over the wireless network **212** and the access point **218**. For example, the mobile device **100***a* can place and receive phone calls (e.g., using VoIP protocols), send and receive e-mail messages (e.g., using POP3 protocol), and retrieve electronic documents and/or streams, such as web pages, photographs, and videos, over the wireless network **212**, gateway **216**, and wide area network **214** (e.g., using TCP/IP or UDP protocols). Likewise, the mobile device **100***b* can place and receive phone calls, send and receive e-mail messages, and retrieve electronic documents over the access point **218** and the wide area network **214**. In some implementations, the mobile device **100** can be physically connected to the access point **218** using one or more cables and the access point **218** can be a personal computer. In this configuration, the mobile device **100** can be referred to as a "tethered" device.

[0041] The mobile devices **100***a* and **100***b* can also establish communications by other means. For example, the wireless device **100***a* can communicate with other wireless devices, e.g., other wireless devices **100**, cell phones, etc., over the wireless network **212**. Likewise, the mobile devices **100***a* and **100***b* can establish peer-to-peer communications **220**, e.g., a personal area network, by use of one or more communication subsystems, such as the Bluetooth™ communication device **188** shown in FIG. **1**. Other communication protocols and topologies can also be implemented.

[0042] The mobile device **100** can, for example, communicate with one or more services **230**, **240**, **250**, and **260** and/or one or more content publishers **270** over the one or more wired and/or wireless networks **210**. For example, a navigation service **230** can provide navigation information, e.g., map information, location information, route information, and other information, to the mobile device **100**. In the example shown, a user of the mobile device **100***b* has invoked a map functionality, e.g., by pressing the maps object **144** on the top-level graphical user interface shown in FIG. **1**, and has requested and received a map for the location "1 Infinite Loop, Cupertino, Calif."

[0043] A messaging service **240** can, for example, provide e-mail and/or other messaging services. A media service **250** can, for example, provide access to media files, such as song files, movie files, video clips, and other media data. One or more other services **260** can also be utilized by the mobile device **100**.

[0044] The mobile device **100** can also access other data and content over the one or more wired and/or wireless networks **210**. For example, content publishers **270**, such as news sites, RSS feeds, web sites, blogs, social networking sites, developer networks, etc., can be accessed by the mobile device **100**. Such access can be provided by invocation of a web browsing function or application (e.g., a browser) in response to a user touching the Web object **114**.

[0045] The mobile device **100** can also communicate with one or more GPS Satellite(s) **252** to enable circuitry and sensors (e.g., a GPS receiver on the mobile device **100**) to support a location determining capability.

Exemplary Mobile Device Architecture

[0046] FIG. **3** is a block diagram **300** of an example implementation of the mobile device **100** of FIG. **1**. The mobile device **100** can include a memory interface **302**, one or more data processors, image processors and/or central processing units **304**, and a peripherals interface **306**. The memory interface **302**, the one or more processors **304** and/or the peripherals interface **306** can be separate components or can be integrated in one or more integrated circuits. The various components in the mobile device **100** can be coupled by one or more communication buses or signal lines.

[0047] Sensors, devices and subsystems can be coupled to the peripherals interface **306** to facilitate multiple functionalities. For example, a motion sensor **310**, a light sensor **312**, and a proximity sensor **314** can be coupled to the peripherals interface **306** to facilitate the orientation, lighting and proximity functions described with respect to FIG. **1**. Other sensors **316** can also be connected to the peripherals interface **306**, such as a positioning system (e.g., GPS receiver), a temperature sensor, a biometric sensor, or other sensing device, to facilitate related functionalities.

[0048] A camera subsystem **320** and an optical sensor **322**, e.g., a charged coupled device (CCD) or a complementary

metal-oxide semiconductor (CMOS) optical sensor, can be utilized to facilitate camera functions, such as recording photographs and video clips.

[0049] Communication functions can be facilitated through one or more wireless communication subsystems **324**, which can include radio frequency receivers and transmitters and/or optical (e.g., infrared) receivers and transmitters. The specific design and implementation of the communication subsystem **324** can depend on the communication network(s) over which the mobile device **100** is intended to operate. For example, a mobile device **100** may include communication subsystems **324** designed to operate over a GSM network, a GPRS network, an EDGE network, a Wi-Fi or WiMax network, and a Bluetooth™ network. In particular, the wireless communication subsystems **324** may include hosting protocols such that the device **100** may be configured as a base station for other wireless devices.

[0050] An audio subsystem **326** can be coupled to a speaker **328** and a microphone **330** to facilitate voice-enabled functions, such as voice recognition, voice replication, digital recording, and telephony functions.

[0051] The I/O subsystem **340** can include a touch screen controller **342** and/or other input controller(s) **344**. The touch-screen controller **342** can be coupled to a touch screen **346**. The touch screen **346** and touch screen controller **342** can, for example, detect contact and movement or break thereof using any of a plurality of touch sensitivity technologies, including but not limited to capacitive, resistive, infrared, and surface acoustic wave technologies, as well as other proximity sensor arrays or other elements for determining one or more points of contact with the touch screen **346**.

[0052] The other input controller(s) **344** can be coupled to other input/control devices **348**, such as one or more buttons, rocker switches, thumb-wheel, infrared port, USB port, and/or a pointer device such as a stylus. The one or more buttons (not shown) can include an up/down button for volume control of the speaker **328** and/or the microphone **330**.

[0053] In one implementation, a pressing of the button for a first duration may disengage a lock of the touch screen **346**; and a pressing of the button for a second duration that is longer than the first duration may turn power to the mobile device **100** on or off. The user may be able to customize a functionality of one or more of the buttons. The touch screen **346** can, for example, also be used to implement virtual or soft buttons and/or a keyboard.

[0054] In some implementations, the mobile device **100** can present recorded audio and/or video files, such as MP3, AAC, and MPEG files. In some implementations, the mobile device **100** can include the functionality of an MP3 player, such as an iPod™. The mobile device **100** may, therefore, include a 36-pin connector that is compatible with the iPod. Other input/output and control devices can also be used.

[0055] The memory interface **302** can be coupled to memory **350**. The memory **350** can include high-speed random access memory and/or non-volatile memory, such as one or more magnetic disk storage devices, one or more optical storage devices, and/or flash memory (e.g., NAND, NOR). The memory **350** can store an operating system **352**, such as Darwin, RTXC, LINUX, UNIX, OS X, WINDOWS, or an embedded operating system such as VxWorks. The operating system **352** may include instructions for handling basic system services and for performing hardware dependent tasks. In some implementations, the operating system **352** can be a kernel (e.g., UNIX kernel).

[0056] The memory **350** may also store communication instructions **354** to facilitate communicating with one or more additional devices, one or more computers and/or one or more servers. The memory **350** may include graphical user interface instructions **356** to facilitate graphic user interface processing; sensor processing instructions **358** to facilitate sensor-related processing and functions; phone instructions **360** to facilitate phone-related processes and functions; electronic messaging instructions **362** to facilitate electronic-messaging related processes and functions; web browsing instructions **364** to facilitate web browsing-related processes and functions; media processing instructions **366** to facilitate media processing-related processes and functions; GPS/Navigation instructions **368** to facilitate GPS and navigation-related processes and instructions; camera instructions **370** to facilitate camera-related processes and functions; and/or other software instructions **372** to facilitate other processes and functions.

[0057] Each of the above identified instructions and applications can correspond to a set of instructions for performing one or more functions described above. These instructions need not be implemented as separate software programs, procedures or modules. The memory **350** can include additional instructions or fewer instructions. Furthermore, various functions of the mobile device **100** may be implemented in hardware and/or in software, including in one or more signal processing and/or application specific integrated circuits.

[0058] In an implementation, the mobile device **100** includes an integrated GPS receiver. Alternatively, or in addition, the mobile device **100** can accept a GPS receiver as an accessory. Communication with an accessory GPS receiver can occur via a wired connection such as a USB connection, a secure digital interface, or other wired connection types. Communication can also occur via a wireless connection such as IEEE 802.x, Bluetooth™, or other wireless communication formats. The location of the mobile device can be measured using information received from orbiting GPS satellites using the GPS receiver. The present latitude and longitude of the mobile device can be determined and shown on the display **102** with a map of the surrounding area. For example, selection of the map object **144** can present a user with a map showing the user's current location and a menu of options for manipulating the map using navigation features of the device **100**. Other positioning systems (e.g., systems using Wi-Fi access points, television signals, cellular grids, etc.) can also be used.

[0059] In an implementation, past locations of the device **100** are stored in memory **350** so that a location history or a traveled path can be displayed. These past routes can be bookmarked or otherwise categorized for easy recall by the user.

[0060] As described above, environmental factors can prevent the location of the device being determined. For example, GPS reception is often not possible unless a line of sight can be established between the GPS receiver and the number of satellites needed to compute the receiver's location. Likewise, other location systems can also experience reception degradation, e.g., radio frequency interference or multiple time delayed versions of a transmission received due to reflections off of surrounding structures.

[0061] In an implementation, the device **100** includes one or more of an accelerometer **172**, a magnetic compass **173**, and/or a gyroscope **175**. The accelerometer **172**, compass

173, and/or gyroscope **175** can be used alone or in combination to measure movements of the device **100**. Additional sensors can be located external to the device **100** on the person of the user. For example, any, some, or all of an accelerometer, a compass, a gyroscope, and an impact sensor can be located on or in the user's footwear. An impact sensor detects footwear contact with the ground, facilitating the measurement of a number of steps. A distance traveled can be estimated using the product of the average length of a user's stride and a number of steps taken. Alternatively contact with the ground during walking can be measured using an accelerometer that detects the change in velocity of a shoe as it contacts the ground. The sensors can be located on or in one or both of the user's shoes. The external sensors can send information to the device **100** via a wireless link. The length of the user's stride can be set and stored in device memory.

[0062] Sensor data from accelerometers, a compass, gyroscopes, and impact sensors can be used alone or in combination to, for example, measure the movement of the device **100** from a point of origin or known location (a "fix") to determine the device's location relative to the fix. Location measurement techniques of this type are generally referred to as "dead reckoning." Dead reckoning can be used in conjunction with other location measurement techniques such as GPS or user input, and used in cases where no satellite or terrestrial positioning signal information is available (whether the unavailability is due to interference in the operating environment or the lack or reception capabilities in the device). In an implementation, the device **100** is configured to switch into a dead reckoning positioning mode upon another positioning mode becoming unavailable.

[0063] Dead reckoning position measurement is error prone, and small errors in measuring a turn, for example, can lead to large errors later if a new fix is not obtained before a lengthy distance is traversed. Frequently updated fixes improve the accuracy of a location shown, for example, on a moving map display of the mobile device **100** measured using dead reckoning.

[0064] FIG. **4** is a block diagram of an example navigation settings screen **400** of the mobile device of FIG. **1**. A user selectable touch-sensitive display button **402** to toggle dead reckoning functions on or off is shown in an enabled state. Touching the button toggles to a disabled state and changes its appearance to a lighter or "grayed out" appearance. A default mode selection **404** is shown. The "vehicle mode" button **408** is shown in an enabled state to indicate that when dead reckoning functions are active the default dead reckoning mode is the vehicle mode. The "walking mode" button **406** for this selection is showed in a disabled state. A touch of the "walking mode" button **406** in the state shown would cause a walking mode to become enabled, which, in turn, causes the "vehicle mode" button **408** to toggle to the disabled representation.

[0065] The "automatically switch to walking mode upon step detection" button **410** is shown as enabled. In an implementation, enabling this feature causes the mobile device **100** to switch to a walking mode of dead reckoning position measurement upon an accelerometer in the mobile device **100** or in communication with the mobile device **100**, e.g., a footwear impact sensor, detecting walking motions such as, for example, periodic accelerations indicative of steps being taken by a user.

[0066] The "lock on street" feature **412** is shown as enabled for both a walking mode **414** and a vehicle mode **416**. In an implementation, a dead reckoning mode of operation in the lock on street setting interprets data from any of the accelerometer **172**, compass **173**, and gyroscope **175** such that the measured movements of the device are presumed to be directed along streets of a map of the surrounding area.

[0067] The lock on street mode can, for example, be utilized to provide implicit fixes and resolve errors by adjusting a currently estimated position based on a comparison to map data. For example, the mobile device **100**, by use of the accelerometer **172**, compass **173**, user input and/or gyroscope **175**, may have a currently estimated location of a mobile device as 25 feet north of an intersection. If, however, the user of the mobile device is actually at the intersection, and turns west at the intersection and walks west in excess of a threshold distance, e.g., 10 feet, then the mobile device **100** may adjust the current estimated location to the position on the map that corresponds to 10 feet west of the intersection.

[0068] The lock on street mode can, for example, apply the implicit fixes in a bounded area, e.g., the implicit fix may not be applied if a user is walking in an open area, such as a park, in which there are no boundaries, e.g., building walls, to impede the user's path. A more detailed explanation of the lock on street mode is shown and described with respect to FIG. **5**.

[0069] The "request user feedback" button **418** is shown in an enabled state, indicating the mobile device is in a user feedback fix mode. The frequency setting **420** for the user feedback fix mode is set to 10 minutes. Touches of the "amount" button **422** can cycle through a range of options, for example, 1, 2, 5, 10, 15, and 20. The "units" button **424** can cycle through a range of options, for example, minutes, feet, meters, kilometers, and miles. The "provide contextual photos" mode button **426** is shown as enabled. When in the user feedback mode, the mobile device **100** can receive periodic user feedback to adjust an estimated current location. For example, in the mode setting shown in FIG. **4**, a user may be prompted to verify a current position every 10 minutes. To assist the user in verifying the current positions, a contextual photo, e.g., a photograph of a nearby landmark, can be provided. In some implementations, the user can manually enter his or her current location (e.g., latitude and longitude) and/or respond to prompts, as described in reference to FIG. **7**.

[0070] In an implementation, a vehicle dead reckoning mode uses an accelerometer reading to determine how the device is positioned relative to the earth's gravity. That is, the accelerometer is used to detect which direction is down relative to the positioning of the device. This axis changes and measurements are updated if the device is reoriented in the vehicle. In the vehicle mode, sudden accelerations in a positive or negative direction along the axis of the earth's gravity are given a reduced importance in the dead reckoning position measurement calculation being utilized. Accelerations along this axis are discounted as they are likely caused by undulations of a traveling surface and reactions thereto by a vehicle suspension system. Accelerations along the axes perpendicular to the detected gravity axis are given enhanced weight in the vehicle mode as it is primarily these accelerations that contribute to displacement of the vehicle from a known fix to a second position to be measured via dead reckoning and displayed on a map. In an implementation, accelerations along the axes perpendicular to the axis of gravity are compared with rotations detected by the gyroscope **175** to determine a change of direction. In an implementation, accelerations along the axes perpendicular to the axis of gravity are

compared with rotations detected by the magnetic compass **173** to determine a change of direction.

[0071] In an implementation, a walking dead reckoning mode of position measurement detects an axis of periodic sudden accelerations using the accelerometer **172** and counts the periodic accelerations as steps of the user. This axis changes and measurements are updated if the device is reoriented by a user while walking. In an implementation, the device is configured to switch to a walking mode of dead reckoning position measurement upon the detection of periodic accelerations. In an implementation, steps are counted by contact indications detected by impact sensors of footwear of the user. If only one shoe has an impact sensor, the number of impacts can be doubled to arrive at a step count. A pedometer function can calculate the product of the user's average stride and the step count to determine a distance traversed. Accelerations in axes perpendicular to the axis of periodic acceleration are measured to determine changes in direction. In an implementation, accelerations in axes perpendicular to the axis of periodic acceleration are compared with rotations detected by the gyroscope **175** to determine a change of direction. In an implementation, accelerations in axes perpendicular to the axis of periodic acceleration are compared with rotations detected by the magnetic compass **173** to determine a change of direction. In an implementation, the walking mode combines pedometer functions with compass measurements without use of accelerometer or gyroscope data.

[0072] FIG. **5** is a block diagram of an example map display **500** of the mobile device of FIG. **1**. The map shows a number of streets and a point of origin 'O' **502**. The dashed line **504** represents an example path measured by the device **100** from the origin **502** to a destination **506** measured using dead reckoning with a lock on street setting disabled. The solid line **508** represents an example path measured by the device **100** from the origin **502** to a destination **510** with a lock on street setting enabled.

[0073] In the two examples shown, the sensor measurements observed by the device **100** are the same, but the interpretation of the data is different. In the case of the path represented by the line **504**, the dead reckoning calculation did not lock the movements of the device to the streets of the map. In the case of the measured path represented by line **508**, the device interpreted the sensor data in accordance with the lock on street setting to keep the movement confined to the streets of a map surrounding the fix represented by the origin **502**. The lock on street mode can thus provide a more accurate estimate of a user's location if the user restricts her movement to streets and sidewalks along those streets.

[0074] FIG. **6** is a flowchart of an example process **600** for obtaining an updated dead reckoning fix through comparison of a detected turn with map data. The process **600** can, for example, be implemented in a processing device, such as the mobile device **100** of FIG. **1**, implementing user processing in software and/or hardware. Movements are measured to estimate a position using dead reckoning (**602**). For example, movements can be measured by interpreting sensor data in one or more processors of a mobile device **100** where the sensor data is received from one or all of the accelerometer **172**, compass **173**, and/or gyroscope **175**. Using an on board clock, the processor(s) can, for example, interpret the sensor data as movements of the device **100**. Using acceleration data, for example, the processor(s) can determine velocity, and position. Alternatively, or in addition, compass data can be used to determine a heading. In some implementations a number of steps and user stride information can be used to determine a distance walked.

[0075] Upon the detection of a turn meeting a threshold (such as a minimum angle of turn from a former direction of travel) (**604**), map data of the area surrounding the current estimated location is checked for turns within a threshold distance of the estimated location (**606**). For example, upon a processor of the mobile device **100** detecting a turn in sensor data, map data stored in local memory or provided by a networked service can be searched for the existence of such a turn at a candidate location within a threshold distance.

[0076] If a turn is found within the threshold distance, the map data is checked to determine if the turn of the map has an angle within a threshold number of degrees of the angle of the detected turn in the direction of the detected turn (**608**). If a turn is found in the map data that meets these criteria, the estimated location of the device is changed to the location of the turn on the map (**610**). The turn location is used as an updated fix for dead reckoning measurements made following the detected turn (**612**). For example, the last known location of a mobile device **100** can be updated to the turn location and used in subsequent dead reckoning location estimates.

[0077] In an implementation, an updated fix for dead reckoning position measurement is obtained by gathering input from a user during a journey. In an implementation, input is gathered by prompting the user to answer a map related query. Prompts can occur at periodic intervals of time, distance, or upon the detection of movement meeting threshold criteria. Prompts can be accompanied by an audible or vibrating alert from the device **100**. FIG. **7** is a block diagram of an example user feedback prompt **700** of the mobile device of FIG. **1**. A feedback prompt **700** includes a question "Did you just turn left on Main Street?" This prompt can be made, for example, on a display of a mobile device **100** accompanied by an alert to indicate the existence of the prompt to a user. If an affirmative answer is given by a user touching "YES" button **702**, the intersection of Main Street and the last road the user was traveling on is used as an updated fix for estimating the location of the device using dead reckoning.

[0078] "Set New Position" button **706** is also shown in FIG. **7**. In an implementation, a user press of button **706** can cause the example screen of FIG. **8** to be displayed. FIG. **8** is a block diagram of an example screen **800** for accepting an updated current location from a user on the mobile device of FIG. **1**. Button **800** prompts the user to adjust the map display, through zooming and panning controls, for example, so that the user's' current location (and that of the mobile device **100**) is shown. The button **800** further instructs the user to double tap on the user's current location. Upon the user double tapping, for example, the intersection of 1st Ave. and Main Street, this location is used as an updated fix for use in dead reckoning position estimation for later detected movements. In some implementations, the user can enter their current location using a virtual keyboard or other input mechanism.

[0079] In an implementation, the device displays a photo of an object or scene that should be viewable from the estimated current location of the device **100** and in some implementations queries the user as to whether the actual object or scene depicted can be seen by the user at her present location. FIG. **9** is a block diagram of an example user feedback prompt **900** including a photograph on the mobile device of FIG. **1**. In an implementation, the device displays a photo of an object or

scene that should be viewable from the estimated location of the mobile device **100** and queries the user as to whether the scene is viewable from the user's current location. A dialog box **900** includes the question "Can you see this scene?" A user touch of the "Fullscreen" button **904** causes the photo to be displayed in a larger format. The user can touch "Yes" button **906** or "No" button **908** to provide the requested information. An affirmative answer causes the location of the photo to be used as an updated fix.

[0080] Photos can be selected for display on the mobile device **100** by searching a database of geo-tagged photos. Geo-tagged photos are photos which have information saved along with the photo that indicates the location at which the photo was taken. A photo is selected for display if the photo matches the estimated location of the device **100** within a threshold distance. Photos can transmitted from a remote location to the device **100** via a network connection, for example, a cellular, IEEE 802.x, or other wireless connection. In an embodiment, photo timestamps are checked to provide photos taken at a similar time of day as the time of display on the device **100** so that, for example, a photo of a scene of an area at night is provided on the device when the device is being used at night. In an implementation, photos having a shorter focal length (wider angle) recorded in the photo's EXIF (exchangeable image file format) information are given priority for display over photos with a longer focal length (telephoto) recorded in the EXIF information to provide a wider field of view to the user.

[0081] FIG. **10** is a flowchart of an example process for prompting a user to obtain an updated fix of the mobile device of FIG. **1**. The process **100** can, for example, be implemented in a processing device, such as the mobile device **100** of FIG. **1**, in software and/or hardware. Movements of the device are measured using dead reckoning (**1002**). Movements can be measured, for example, by one or all of an accelerometer **172**, a compass **173**, and a gyroscope **175** providing sensor data to one or more processors of the mobile device **100**. If a user prompting condition is met (**1004**), input is requested from the user regarding the current location of the device (**1006**). User prompting conditions can, for example, include an elapsed time, a measured distance, a detected turn, manual entry of location (e.g., position coordinates), and identification of a nearby geo-tagged photograph. Prompts can, for example, be shown on a display of the mobile device **100** and be accompanied by an alert. If the user input establishes the location of the device (**1008**) then the established location is used as an updated fix for dead reckoning estimation of the location of the device for later movements. The updated position can be used, for example, as a last known location of the mobile device **100** for use in subsequent dead reckoning position calculations.

[0082] FIG. **11** is a flowchart of an example process **1100** for verifying an estimated location of the mobile device of FIG. **1**. The location of the mobile device is determined (**1102**). The location can be determined, for example, via user input, positioning system data, and/or dead reckoning measurements. Sensor data related to movement of the mobile device is received. The sensor data can be received, for example, from sensors such as the accelerometer **172**, compass **173**, gyroscope **175**, and/or footwear impact sensors. An estimated device location is determined based on the location determined in **1102** and the sensor data (**1108**). The estimated device location can be determined, for example, by performing dead reckoning calculations using the received sensor data to measure movements of the mobile device from the determined location. In an implementation, the estimated device location can be determined based on one or more of a plurality of estimate modes.

[0083] The estimated device location is compared to map data (**1108**). For example, one or more characteristics of the received sensor data can be compared to one or more characteristics of the map data to identify a candidate location. In an implementation, the candidate location is turn in a pathway defined by the map data. In an implementation, the comparison is a comparison of one or more characteristics of a detected turn with one or more turn characteristics of the map data. In an implementation, the comparison is a request for user feedback regarding the candidate location. The estimated device location is verified based on the comparison (**1110**). The estimated device location can be verified, for example, if one or more characteristics of received sensor data are consistent with one or more characteristics of the candidate location. In an implementation, the estimated device location is verified by a response to a feedback request.

[0084] The apparatus, methods, flow diagrams, and structure block diagrams described in this patent document can be implemented in computer processing systems including program code comprising program instructions that are executable by the computer processing system. Other implementations can also be used. Additionally, the flow diagrams and structure block diagrams described in this patent document, which describe particular methods and/or corresponding acts in support of steps and corresponding functions in support of disclosed structural means, can also be utilized to implement corresponding software structures and algorithms, and equivalents thereof.

[0085] The foregoing descriptions of implementations of the present invention are presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Rather, it should be appreciated that many modifications and variations are possible in view of the above teachings. The implementations were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various implementations with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A computer-implemented method, comprising:

storing a location of a mobile device in memory;

receiving sensor data related to movement of a mobile device;

detecting a turn in the movement of the mobile device based on the received sensor data;

estimating a current location of the device based on the sensor data and the stored location;

determining that a portion of a pathway defined by map data corresponding to the estimated current location has characteristics consistent with characteristics of the detected turn;

based on the determination, identifying a candidate location corresponding to the portion of the pathway that has characteristics consistent with characteristics of the detected turn; and

updating the stored location of the mobile device with the candidate location.

2. The method of claim 1, wherein the pathway is a street.

3. The method of claim 1, wherein the pathway is a sidewalk.

4. The method of claim 1, wherein the sensor data is generated by an accelerometer.

5. The method of claim 1, wherein the sensor data is generated by a gyroscope.

6. The method of claim 1, wherein the sensor data is generated by a compass.

7. The method of claim 1, wherein identifying the candidate location comprises determining that the estimated current location is within a threshold distance of the portion of the pathway defined by the map data.

8. The method of claim 1, wherein identifying the candidate location comprises determining that an angle of the detected turn is within a threshold number of degrees of an angle of a turn at the portion of the pathway defined by the map data.

9. The method of claim 1, further comprising:

presenting a prompt requesting that a user verify that the candidate location is the actual location of the mobile device;

receiving input confirming that the candidate location is the actual location of the mobile device; and

in response to receiving the confirmation, updating the stored location of the mobile device with the candidate location.

10. A non-transitory computer-readable medium including one or more sequences of instructions which, when executed by one or more processors, causes:

storing a location of a mobile device in memory;

receiving sensor data related to movement of a mobile device;

detecting a turn in the movement of the mobile device based on the received sensor data;

estimating a current location of the device based on the sensor data and the stored location;

determining that a portion of a pathway defined by map data corresponding to the estimated current location has characteristics consistent with characteristics of the detected turn;

based on the determination, identifying a candidate location corresponding to the portion of the pathway that has characteristics consistent with characteristics of the detected turn; and

updating the stored location of the mobile device with the candidate location.

11. The non-transitory computer-readable medium of claim 10, wherein the pathway is a street.

12. The non-transitory computer-readable medium of claim 10, wherein the pathway is a sidewalk.

13. The non-transitory computer-readable medium of claim 10, wherein the sensor data is generated by an accelerometer.

14. The non-transitory computer-readable medium of claim 10, wherein the sensor data is generated by a gyroscope.

15. The non-transitory computer-readable medium of claim 10, wherein the sensor data is generated by a compass.

16. The non-transitory computer-readable medium of claim 10, wherein the instructions that cause identifying the candidate location comprise instructions that cause determining that the estimated current location is within a threshold distance of the portion of the pathway defined by the map data.

17. The non-transitory computer-readable medium of claim 10, wherein the instructions that cause identifying the candidate location comprise instructions that cause determining that an angle of the detected turn is within a threshold number of degrees of an angle of a turn at the portion of the pathway defined by the map data.

18. The non-transitory computer-readable medium of claim 10, wherein the instructions cause:

presenting a prompt requesting that a user verify that the candidate location is the actual location of the mobile device;

receiving input confirming that the candidate location is the actual location of the mobile device; and

in response to receiving the confirmation, updating the stored location of the mobile device with the candidate location.

19. A system comprising:

one or more processors; and

a computer-readable medium including one or more sequences of instructions which, when executed by the one or more processors, causes:

storing a location of a mobile device in memory;

receiving sensor data related to movement of a mobile device;

detecting a turn in the movement of the mobile device based on the received sensor data;

estimating a current location of the device based on the sensor data and the stored location;

determining that a portion of a pathway defined by map data corresponding to the estimated current location has characteristics consistent with characteristics of the detected turn;

based on the determination, identifying a candidate location corresponding to the portion of the pathway that has characteristics consistent with characteristics of the detected turn; and

updating the stored location of the mobile device with the candidate location.

20. The system of claim 19, wherein the pathway is a street.

21. The system of claim 19, wherein the pathway is a sidewalk.

22. The system of claim 19, further comprising an accelerometer, wherein the sensor data is generated by the accelerometer.

23. The system of claim 19, further comprising a gyroscope, wherein the sensor data is generated by the gyroscope.

24. The system of claim 19, further comprising a compass, wherein the sensor data is generated by the compass.

25. The system of claim 19, wherein the instructions that cause identifying the candidate location comprise instructions that cause determining that the estimated current location is within a threshold distance of the portion of the pathway defined by the map data.

26. The system of claim 19, wherein the instructions that cause identifying the candidate location comprise instructions that cause determining that an angle of the detected turn is within a threshold number of degrees of an angle of a turn at the portion of the pathway defined by the map data.

27. The system of claim 19, wherein the instructions cause:

presenting a prompt requesting that a user verify that the candidate location is the actual location of the mobile device;

receiving input confirming that the candidate location is the actual location of the mobile device; and

in response to receiving the confirmation, updating the stored location of the mobile device with the candidate location.

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