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(54) **APPROACHES TO CROWDSOURCED-BASED WAIT TIME ESTIMATES**

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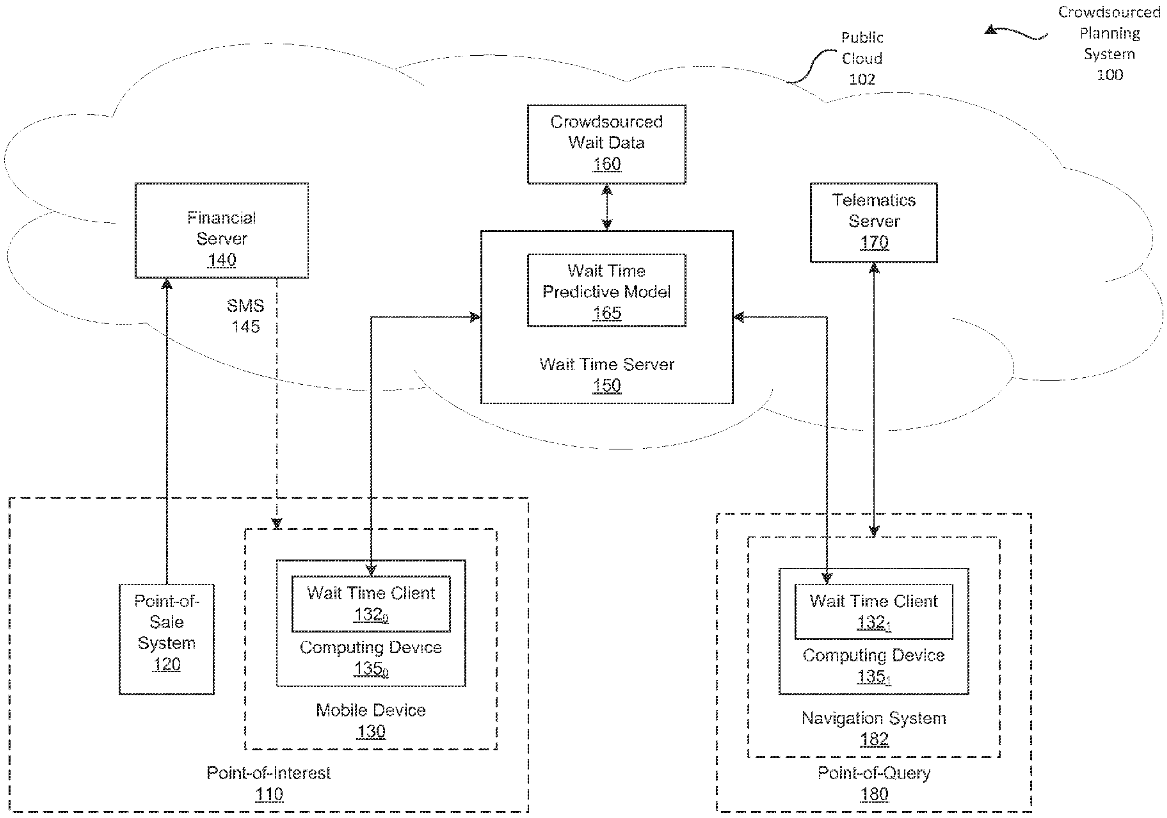
(57) **ABSTRACT**

In one embodiment of the present invention, a wait time client enables prediction of wait times (e.g., time required to checkout at a grocery store) based on crowdsourced wait data. In operation, the wait time application downloads predicted wait data from a server. The predicted wait data reflects measured wait times for one or more location, such as the ticket line at a movie theater. The wait time client then selects a wait time data point that corresponds to a location of a point-of-interest. Based on the selected wait time data point, the wait time client determines a predicted wait time at the point-of-interest. Advantageously, by leveraging crowdsourced, deterministically measured wait times, the wait time clients enables the incorporation of realistic and up-to-date predicted wait times into the trip planning process.



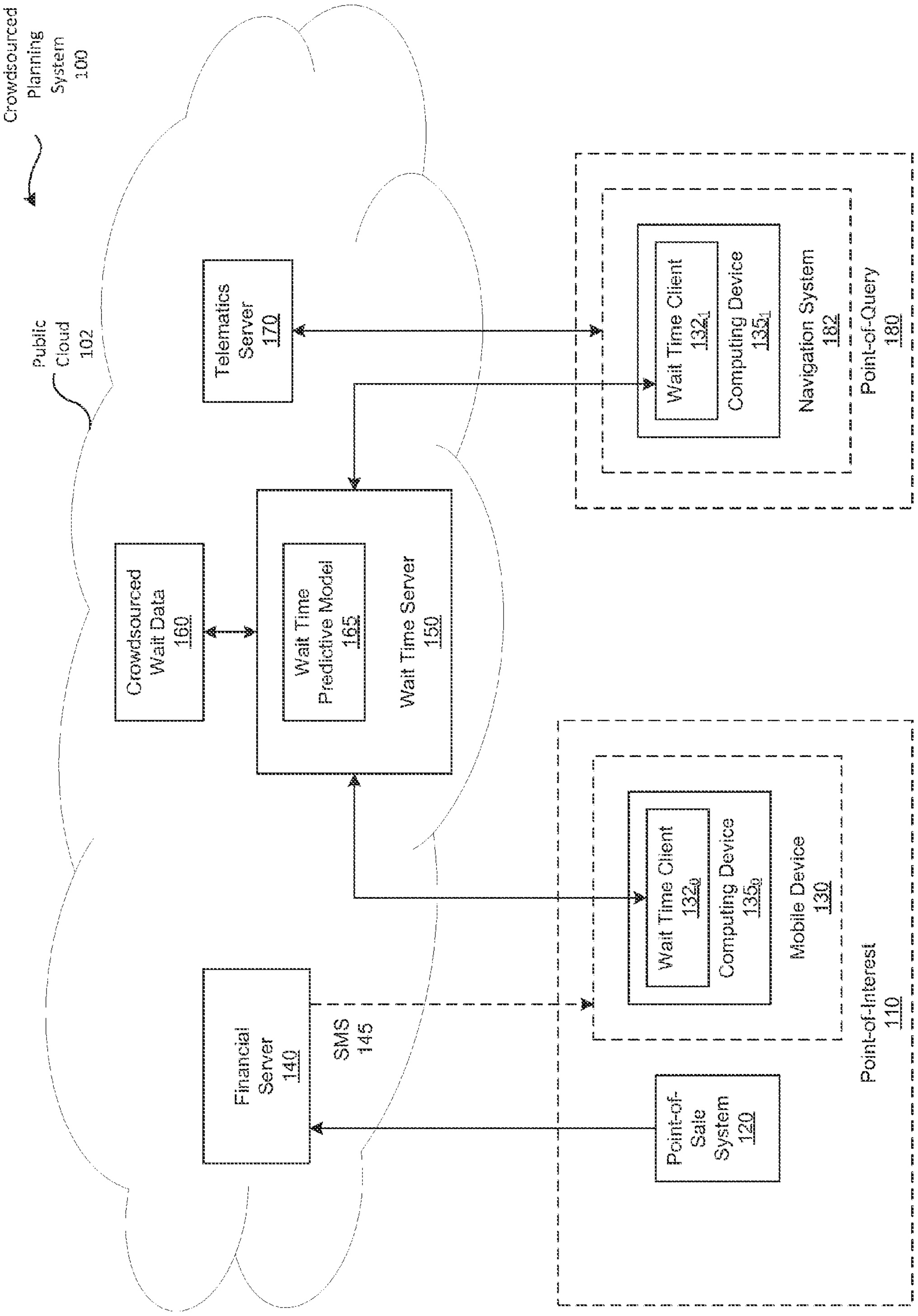

Crowdsourced Planning System 100
Public Cloud 102
Telematics Server 170
Crowdsourced Wait Data 160
Wait Time Predictive Model 165
Wait Time Server 150
Financial Server 140
SMS 145
Wait Time Client 132_1
Computing Device 135_1
Navigation System 182
Point-of-Query 180
Wait Time Client 132_0
Computing Device 135_0
Mobile Device 130
Point-of-Sale System 120
Point-of-Interest 110

FIGURE 1A

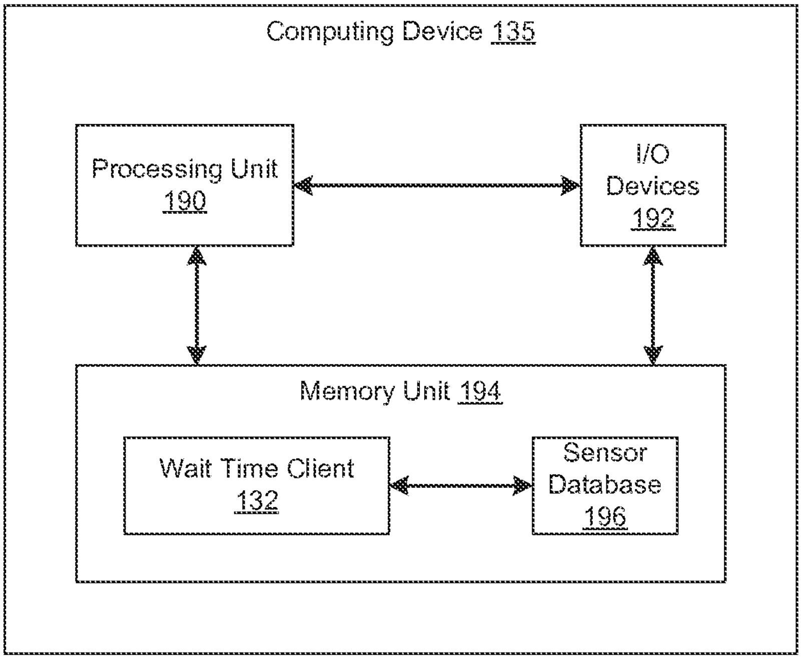

Computing Device 135
Processing Unit 190
I/O Devices 192
Memory Unit 194
Wait Time Client 132
Sensor Database 196

FIGURE 1B

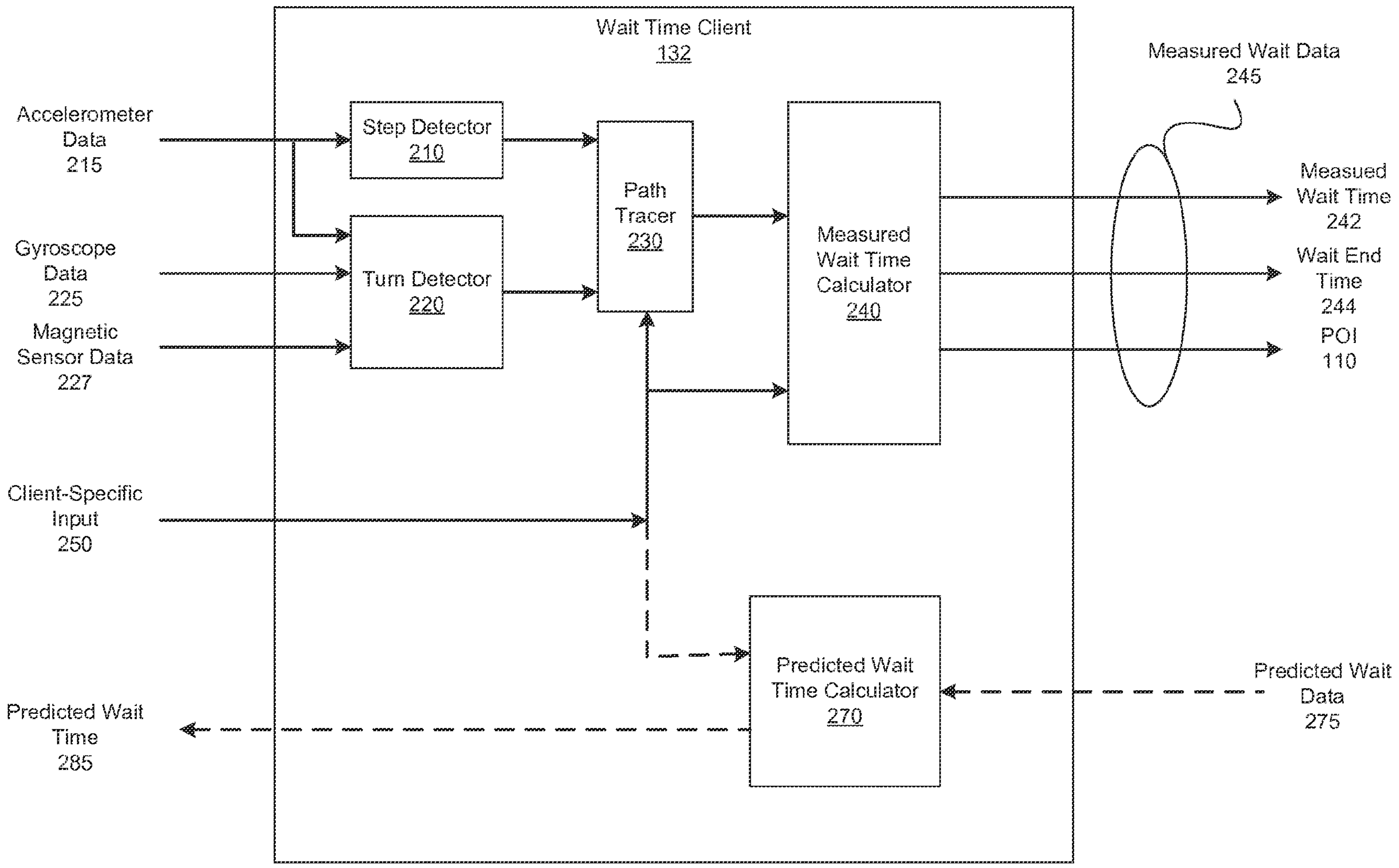

Wait Time Client
132
Accelerometer
Data
215
Gyroscope
Data
225
Magnetic
Sensor Data
227
Client-Specific
Input
250
Predicted Wait
Time
285
Step Detector
210
Turn Detector
220
Path
Tracer
230
Measured
Wait Time
Calculator
240
Predicted Wait
Time Calculator
270
Measured Wait Data
245
Measued
Wait Time
242
Wait End
Time
244
POI
110
Predicted Wait
Data
275

FIGURE 2

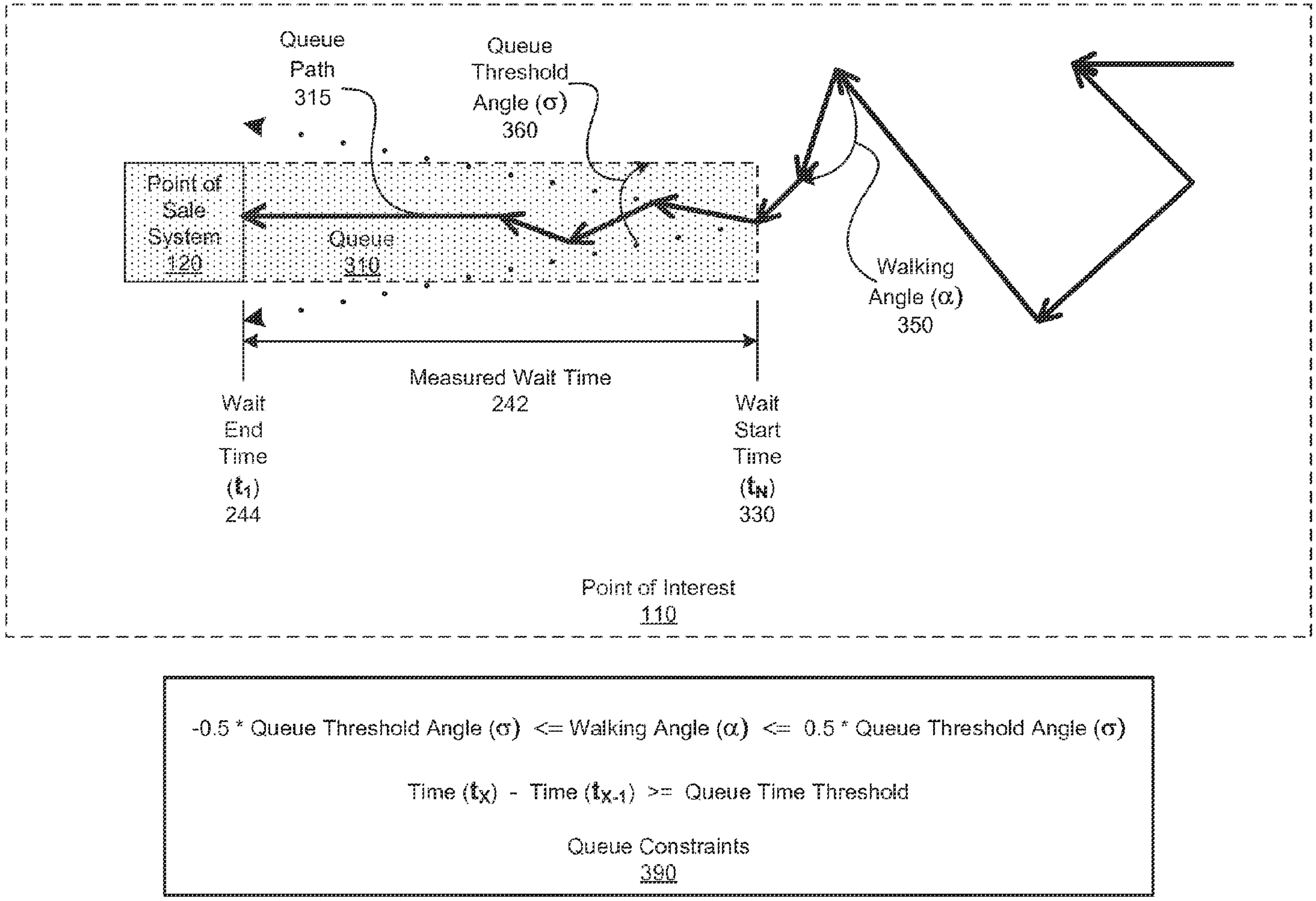

Queue
Path
315
Queue
Threshold
Angle (σ)
360
Point of
Sale
System
120
Queue
310
Walking
Angle (α)
350
Measured Wait Time
242
Wait
End
Time
(t1)
244
Wait
Start
Time
(tN)
330
Point of Interest
110
-0.5 * Queue Threshold Angle (σ) <= Walking Angle (α) <= 0.5 * Queue Threshold Angle (σ)
Time (tX) - Time (tX-1) >= Queue Time Threshold
Queue Constraints
390

FIGURE 3

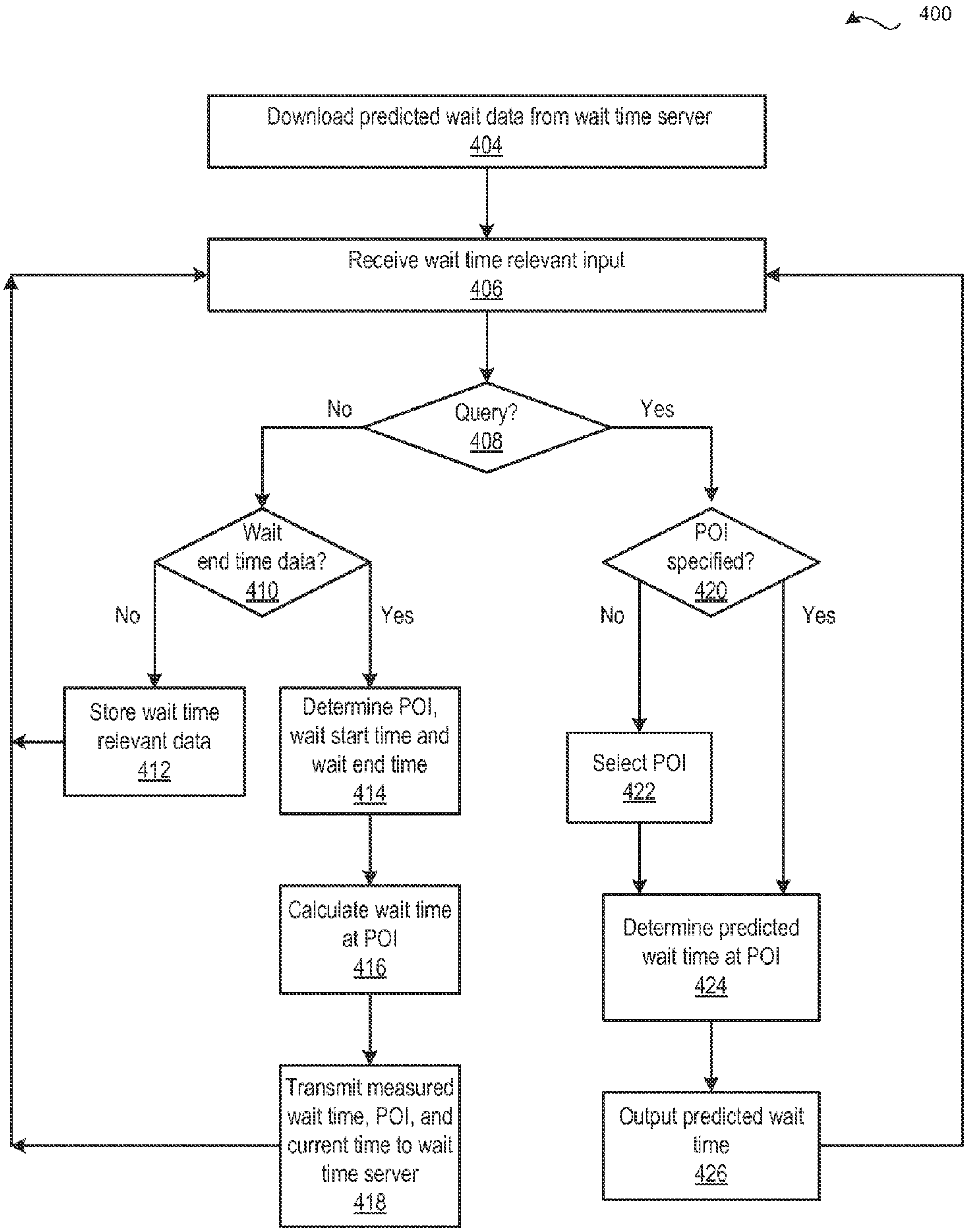

400
Download predicted wait data from wait time server 404
Receive wait time relevant input 406
Query? 408
No
Yes
Wait end time data? 410
No
Yes
POI specified? 420
No
Yes
Store wait time relevant data 412
Determine POI, wait start time and wait end time 414
Select POI 422
Calculate wait time at POI 416
Determine predicted wait time at POI 424
Transmit measured wait time, POI, and current time to wait time server 418
Output predicted wait time 426

FIGURE 4

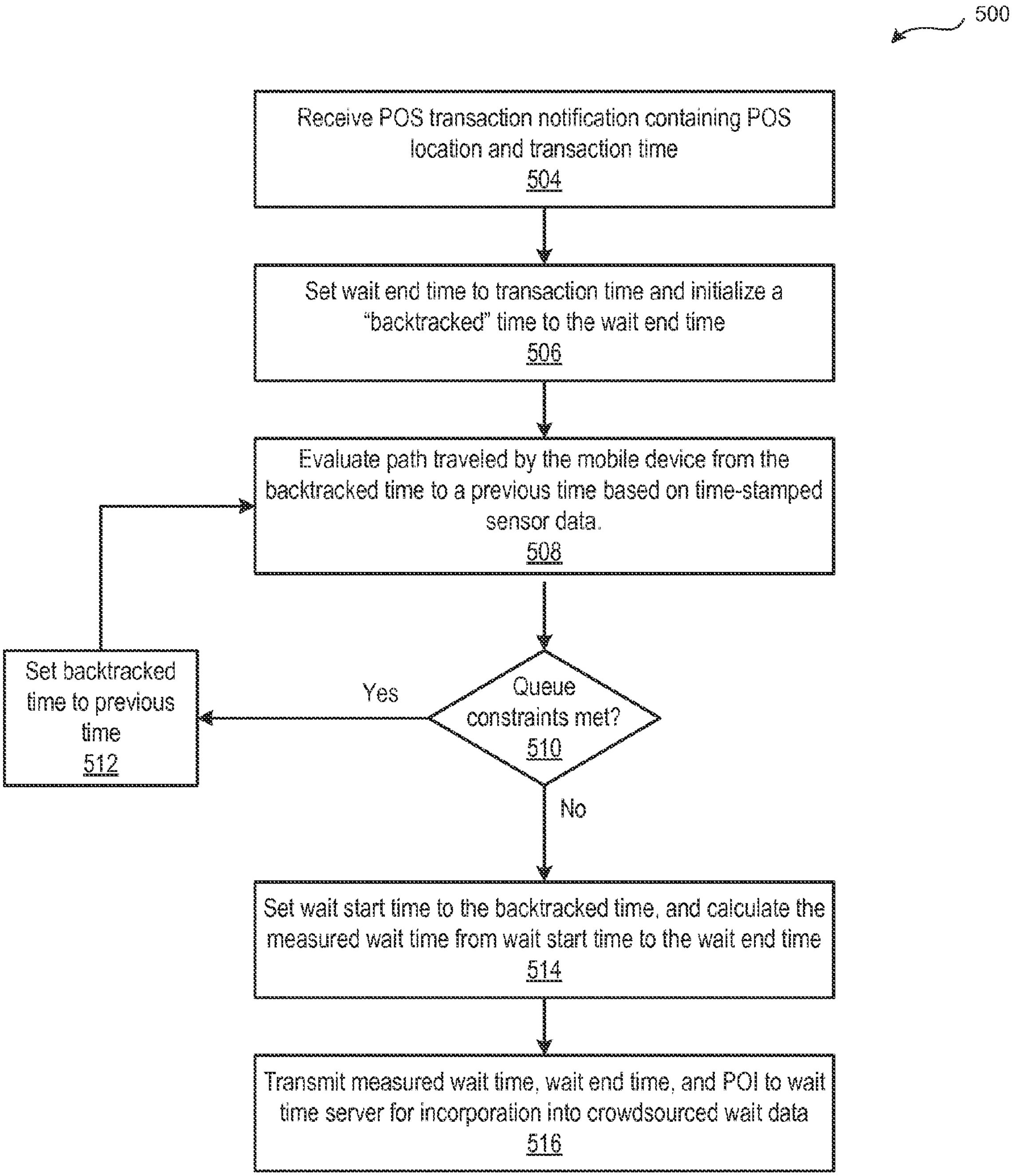

500
Receive POS transaction notification containing POS location and transaction time
504
Set wait end time to transaction time and initialize a "backtracked" time to the wait end time
506
Evaluate path traveled by the mobile device from the backtracked time to a previous time based on time-stamped sensor data.
508
Queue constraints met?
510
Yes
Set backtracked time to previous time
512
No
Set wait start time to the backtracked time, and calculate the measured wait time from wait start time to the wait end time
514
Transmit measured wait time, wait end time, and POI to wait time server for incorporation into crowdsourced wait data
516

FIGURE 5

APPROACHES TO CROWDSOURCED-BASED WAIT TIME ESTIMATES

BACKGROUND

[0001] Field of the Invention

[0002] Embodiments of the present invention relate generally to navigation systems and, more specifically, to approaches to crowdsourced-based wait time estimates.

[0003] Description of the Related Art

[0004] A wide variety of planning tools are used to facilitate efficient time management. For example, a navigation tool may predict the quickest route to reach a point-of-interest, allowing users to minimize travel time. Further, some navigation tools allow users to search for different types of businesses and compare the distances and/or travel times between a current location and those different identified businesses. Irrespective of the specific planning information that is provided by the planning tool (i.e., an optimized route to travel, travel times to different identified businesses, etc.), such tools typically rely on predictive models to estimate portions of the planning process.

[0005] In general, the effectiveness of most planning tools is limited by the accuracy of the predictive models implemented in those tools. If portions of the planning process are not adequately addressed by the predictive models included in the planning tools, then the predictive models are undermined, and the power of the planning tool is reduced. For instance, a navigation tool that does not differentiate between the travel time to a downtown office at rush hour and the travel time to the downtown office at midnight on a Monday night can base travel time estimates on irrelevant data. Consequently, those tools can provide misleading travel time estimates.

[0006] Notably, the prediction models included in conventional planning tools typically neither directly address wait time requirements nor incorporate wait time estimates (e.g., lengths of time expected to wait in queues for services) into overall time estimates. Since many commonly planned events involve estimating wait times at points-of-sale (e.g., shopping for groceries, purchasing tickets, getting an oil change, etc.), the usefulness of conventional planning tools is limited. For instance, if the planning requirement is "estimate the quickest plan to see an emergency room doctor," then a planning tool that does not include a predictive model for wait time fails to consider the differences between wait times at trauma centers and general hospitals. Consequently, the accuracy of the planning tool is undermined.

[0007] If a user desires wait-time guidance at a particular destination, such as a grocery store, then the user must resort to manual approaches for determining those wait times. For example, the user might have to call the destination and verbally query the workers regarding the wait time. Alternatively, some destinations and service providers provide general guidelines for wait times on their websites. For instance, airports may provide estimated wait times at security lines or for delayed flights.

[0008] While such manual techniques enable users to obtain some amount of information relevant to wait times, such manual effort is tedious for users and also can increase the time required for overall planning to unacceptable levels. Further, the manually-obtained information is not necessarily reliable or accurate and, therefore, may need to be updated frequently.

[0009] As the foregoing illustrates, more effective techniques for estimating wait times would be useful.

SUMMARY

[0010] One embodiment of the present invention sets forth a computer-implemented method for predicting wait times at points-of-interest. The method includes receiving data points from a server machine, where each data point reflects at least one crowdsourced measured wait time and is associated with any one of several different points-of interest; receiving a request to predict a wait time at a first point-of-interest that is included in the several different points-of-interest; selecting a first data point included in the data points based on the first point-of-interest; and determining a predicted wait time based on the first data point.

[0011] Further embodiments provide, among other things, a system and a non-transitory computer-readable medium configured to implement the method set forth above.

[0012] At least one advantage of the disclosed techniques is that a user may obtain predicted wait times at points-of-interest based on previously measured wait times experienced by any number of other users. Using the predicted wait times, the user may knowledgeably select among various planning options, such as which grocery store to visit. For instance, and without limitation, the user may select a planning option that optimizes the predicted wait time or a planning option that optimizes an overall errand time (i.e., predicted travel time and predicted wait time).

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0014] FIG. **1**A illustrates a crowdsourced planning system configured to implement one or more aspects of the various embodiments;

[0015] FIG. **1**B is a more detailed illustration of the computing device of FIG. **1**A, according to various embodiments;

[0016] FIG. **2** is a is a more detailed illustration of the wait time client of FIG. **1**A, according to various embodiments;

[0017] FIG. **3** is a conceptual illustration of a queue path detected by the path tracer of FIG. **2** when operating in a point-of-sale mode, according to various embodiments;

[0018] FIG. **4** is a flow diagram of method steps for leveraging crowdsourced wait data to compute predicted wait times, according to various embodiments; and

[0019] FIG. **5** is a flow diagram of method steps for backtracking from a point-of-sale transaction to compute the time spent waiting in a queue, according to various embodiments.

DETAILED DESCRIPTION

[0020] In the following description, numerous specific details are set forth to provide a more thorough understanding of the present invention. However, it will be apparent to one of skill in the art that the present invention may be practiced without one or more of these specific details.

Crowdsourced Planning System

[0021] FIG. 1A illustrates a crowdsourced planning system configured to implement one or more aspects of the various embodiments. As shown, the crowdsourced planning system **100** includes, without limitation, a point-of-interest **110**, a point-of-query **180**, and a public cloud **102**. In alternate embodiments, the crowdsourced planning system **100** may include any distributed computer system instead of, or in addition to, the public cloud **102**. In yet other embodiments, the crowdsourced planning system **100** may not include the public cloud **102** and, instead, the crowdsourced planning system **100** may include a single computing unit that implements any number of processing units (e.g., central processing units and/or graphical processing units in any combination).

[0022] The point-of-interest **110** is a place (i.e., store, Amusement Park, car wash, movie theatre etc.) that is involved in one or more planning operations. Notably, at each of the points-of-interest **110** included in the crowdsourced planning system **100**, a queue may form. As used herein, a queue refers to any line of people that are waiting for an event to occur. For example, and without limitation, the point-of-interest **110** could correspond to a grocery store and the queue could correspond to the line of people that are waiting to purchase groceries. In general, the crowdsourced planning system **100** may include any number of points-of-interest **110**, and the points-of-interest **110** may change dynamically (reflecting different planning processes and/or planning options). Further, as part of the planning process, the point-of-interest **110** may be associated with one or more times-of-interest. For example, if the planning process were to involve determining the wait at a grocery store at noon, then the point-of-interest **111** could be the grocery store and the time-of-interest could be noon.

[0023] As shown, the point-of-interest **110** includes a point-of-sale system **120**. The point-of-sale-system **120** may be any device that facilitates a financial transaction, such as a cash register. In alternate embodiments, the point-of-interest **110** may not include a point-of-sale system **120**. For example, in some embodiments, the point-of-interest **110** may be a service, such as an Amusement Park ride, the queue may be the wait to board the ride, and the point-of-interest **110** does not include the point-of-sale system **120**. Typically, if the point-of-interest **110** includes the point-of-sale system **120**, then a point-of-sale corresponds to the point-of-interest **110** and a time-of-sale corresponds to the time-of-interest.

[0024] The point-of-query **180** is a place that corresponds to the location at which a request for planning guidance (i.e., a "query") is generated. For example, the point-of-query **180** could be a living room of a house and a desktop computer could generate a request for an estimated wait time for security screening at an Airport. In other embodiments, the point-of-query **180** may correspond to the location of a smartphone. In general, the point-of-query **180** is associated with a time-of-query (a time at which the request is generated) and may change locations dynamically.

[0025] The public cloud **102** provides access to encapsulated shared resources (e.g., software applications, data, etc.) over a public network, such as the Internet, to clients at the point-of-query **180** and the point-of-interest **110**. In alternate embodiments, the public cloud **102** may provide access to any type of shared resource to any number of clients at any number of stationary and mobile locations in any combination. In other embodiments, the public cloud **102** may be replaced with any type of cloud computing environment, such as a private or a hybrid cloud. As shown, the public cloud **102** includes a telematics server **170** that communicates with a navigation system **182** located at the point-of-query **180**. For example, and without limitation, a telematics server provided by a car manufacturer could provide communication and control capabilities (e.g., Global Positioning System (GPS) functionality, remote door unlocking services, etc.) to a car navigation system "on-board" a moving vehicle.

[0026] In one common planning operation, the navigation system **182** included in a car communicates with the telematics server **170** to automatically create driving plans from the point-of-query **180** (i.e., current location of the car) to any number of points-of-interest **110** (e.g., grocery stores, Amusement Parks, car washes, etc.). In general, such driving plans may consider a variety of factors and options, such as time of day, local roads vs highway travel, and so forth. However, the scope of conventional, automated navigation systems is limited to travel metrics, such as travel time and travel distance, and does not typically extend to other considerations, such as wait time at a point-of-interest, that also impact the overall expended time. For example, and without limitation, some conventional navigation systems could estimate the fastest driving route to a particular type of point (e.g., a grocery store) based on a predictive model, but provide no insight into any wait times after arrival at the destination point. If the wait time at two grocery stores varies dramatically, then the fastest driving route may not correspond to the fastest total overall expended time (from the current destination to the cash register at the grocery store), and the value of the predictive model is undermined.

[0027] As illustrated by this example, predictive models included in conventional planning systems typically do not provide insight into wait times. Accordingly, some users may supplement the data automatically provided by conventional planning systems with additional, manually acquired data. For example, and without limitation, some users could call a few grocery stores to find out which grocery store "sounds" least busy. Not only is such manual supplementation time consuming, but also relies on subjective opinions of different workers at different grocery stores.

Estimating Wait Times

[0028] To address the foregoing concerns, the public cloud **102** includes a wait time server **150** that provides wait time estimates based on crowdsourced wait data **160**. The wait time server **150** provides functionality for both populating the crowdsourced wait data **160** and calculating predicted wait times for any number of the points-of-interest **110**. To create and maintain the crowdsourced wait data **160**, the wait time server **150** communicates with wait time clients **132** at the points-of-interest **110**, receives objective wait data from the wait time clients **132**, and then incorporates the wait data into the crowdsourced wait data **160**. To obtain predicted wait times, the wait time clients **132** at the points-of-query **180** communicate the wait time server **150** to determine predicted wait times at the points-of-interest **110** based on the crowdsourced wait data **160**.

[0029] As shown, the wait time client 132_0 executes on a computing device 135_0 that is included in a mobile device **130** located at the point-of-interest **110**. The wait time client 132_1 executes on a computing device 135_1 that is included in the navigation system **182** located at the point-of-query **180**. In general, any number of wait time clients **132** may execute on any number of computing devices **135** that are included in any number of mobile or stationary devices in any combination. For example, and without limitation, the wait time client **132** may execute on any type of processing unit that is included in a car navigation system, a laptop, a smartphone, and so forth. Notably, each device may operate at a variety of different locations and any number of devices may be included in the crowdsourced planning system **100**. For example, and without limitation, a smartphone may include a central processing unit and the smartphone could, at various different points in time, be located at a variety of different locations.

[0030] Based on the input the wait time client **132** receives, the wait time client **132** may interpret a location corresponding to the computing device **135** that is executing the wait time client **132** as the point-of-query **180**, the point-of-interest **110**, both, or neither. More specifically, as the wait time client **132** generates measured wait data, the wait time unit **132** relays the measured wait data and the current location—interpreted as the point-of-interest **110**—to the wait time server **150** for incorporation into the crowdsourced wait data **160**. To generate predicted wait times, the wait time server **150** processes the updated crowdsourced wait data **160** based on a wait time predictive model **165**. The wait time predictive model **165** may implement any technically feasible algorithm designed to aggregate the crowdsourced wait data **160** into discerning predicted wait data.

[0031] The wait time client **132** downloads the predicted wait data from the wait time server **150** and, upon receiving a request for a predicted wait time, the wait time unit **132** processes the request based using the current location—interpreted as the point-of-query **180**. Notably, the wait time unit **132** calculates a predicted wait time that reflects the current location in addition to any other relevant and accessible information, such as current time, based on the predicted wait data downloaded from the wait time server **150**.

[0032] In various embodiments, the wait time client **132** may provide a user interface that enables the user to specify the point-of-interest **110**. The user interface may include any amount of planning functionality. For example, and without limitation, the user interface could include a search function for specific types of businesses, a time optimization function to select the best time to run an errand based on both travel time and wait time, and so on.

[0033] To maximize opportunities to grow the crowdsourced wait data **160** and, consequently, increase the accuracy of the predicted wait times, the wait time client **132** provides various types of wait data gathering functionality. Notably, the wait time client **132** tailors the wait gathering operations to the available infrastructure and provides, without limitation, a manual entry mode, a proximity sensor mode, and a point-of-sale mode. As part of determining the measured wait time, in the manual entry mode, the wait time client **132** relies primarily on user input. In the proximity sensor mode, the wait time client **132** automatically incorporates data from sensors, such as Bluetooth Low Energy (BLE) sensors, located at the point-of-interest **110** into the measured wait time calculations.

[0034] In the point-of-sale mode, the wait time client **132** calculates the wait time based on sales transactions at the point-of-sale system **120** located at the point-of-interest **110**. In operation, the point-of-sale system **120** transmits sales transaction information to a financial server **140** located in the public cloud **102**. For example, and without limitation, a credit card reader at a grocery store checkout counter could include a credit/debit card payment client that communicates with a financial server provided by a bank and associated with the credit/debit card. In general, the financial server **140** and the point-of-sale system **120** may communicate in any technically feasible fashion. In response, the financial server **140** sends a transaction confirmation, such as a short message system SMS **145** (also known as a text message) to a device that includes the wait time client **132** (e.g., the mobile device **130**) and is located at the point-of-interest **110**. In general, the financial sever **140** may communicate with the device that includes the wait time client **132** in any manner as known in the art.

[0035] The wait time client **132** may be stored in any type of memory that may or may not be integrated with the computing device **135**. In some embodiments, the wait time client **132** may be stored in a universal serial bus (USB) flash drive that is connected to a USB port of the computing device **135**. The computing device **135** may be any type of device capable of executing application programs.

[0036] FIG. **1**B is a more detailed illustration of the computing device **135** of FIG. **1**A, according to various embodiments. As shown, computing device **135** includes, without limitation, a processing unit **190**, input/output (I/O) devices **192**, and a memory unit **194**. Memory unit **194** includes the wait time client **132** and is configured to interact with a sensor database **196**.

[0037] Processing unit **190** may be implemented as a central processing unit (CPU), digital signal processing unit (DSP), graphics processor unit (GPU), and so forth. I/O devices **192** may include input devices, output devices, and devices capable of both receiving input and providing output. Memory unit **194** may include a memory module or collection of memory modules. The wait time client **132** within the memory unit **194** may be executed by processing unit **190**. The sensor database **196** may store timestamps, gyroscope data, accelerometer data, magnetic sensor data, position data, and the like.

[0038] Computing device **135** may be implemented as a stand-alone chip, such as a microprocessor, or as part of a more comprehensive solution that is implemented as an application-specific integrated circuit (ASIC), a system-on-a-chip (SoC), and so forth. Generally, computing device **135** may be configured to coordinate the overall operation of a computer-based system, such as the mobile device **130** or the navigation system **182**. In other embodiments, the computing device **135** may be coupled to, but separate from the computer-based system. In such embodiments, the computer-based system may include a separate processor that receives data (e.g., audio streams) from and transmits data (e.g., sensor data) to the computing device **135**, which may be included in a consumer electronic device, such as a vehicle head unit, navigation system, smartphone, portable media player, personal computer, and the like. However, the embodiments disclosed herein contemplate any technically feasible system configured to implement the functionality of the wait time client **132** and/or the wait time server **150** in any combination.

Wait Time Client

[0039] FIG. **2** is a is a more detailed illustration of the wait time client **132** of FIG. **1**A, according to various embodiments. In general, the wait time client **182** is integrated as part of a mobile or stationary computer-based device, such as the mobile device **130** or the navigation system **182**. The computer-based device, among other things, provides general input data (e.g., sensor data, text messages, etc.) and client-specific input **250**, such as user interface preferences, to the wait time client **182**. The computer-based device also consumes output data, such as predicted wait time **285**, that is generated by the wait time client **182**. As part of processing input data and generating the predicted wait time **285**, the wait time client **182** communicates with the wait time server **150** transmitting measured wait data **245** and receiving predicted wait data **275**.

[0040] As shown, the wait time client **132** includes, without limitation, a predicted wait time calculator **270** and a measured wait time calculator **250**. The predicted wait time calculator **270** requests the predicted wait data **275** from the wait time server **150** and then deterministically calculates the predicted wait time **285**. In contrast, the measured wait time calculator **250** supplies the measured wait data **245** to the wait time server **150** for incorporation into the crowdsourced wait data **160**.

[0041] In alternate embodiments, the wait time client **132** may be configured to receive the predicted wait data **275** from the wait time server **150** without providing the measured wait data **245**. In such embodiments, the measured wait time calculator **240** may be omitted or the functionality provided by the measured wait time calculator **240** may be disabled via a selection mechanism, such as a “privacy” setting in a user interface. In general, alternate embodiments of the predicted wait time calculator **270** may implement any portion of the functionality described herein and the functionality may be distributed in any technically feasible fashion between any number and type of operational units in any combination.

[0042] In operation, before calculating the predicted wait time **285**, the predicted wait time calculator **270** downloads the predicted wait data **275** from the wait timer server **150**. The predicted wait time calculator **270** may perform this download in any technically feasible fashion and in response to any type of stimulus. For instance, and without limitation, the predicted wait time calculator **270** may be configured to periodically re-download the predicted wait data **275** at a configurable interval that represents a tradeoff between bandwidth usage and the data gathering dates represented by the predicted wait data **275**. Alternatively, the predicted wait time calculator **270** may be configured to download the predicted wait data **275** on-demand, such as in response to the client-specific input **250** of a “refresh database” user interface selection.

[0043] In general the predicted wait data **275** may include any number and type of wait-time-relevant predicted data that is consistent with both the wait time server **150** and the wait time client **132**. In some embodiments, the wait time predictive model **165** may process the crowdsourced wait data **160** and generate a set of data points, where each data point includes a wait end time, a predicted wait time, and a location. The wait time server **150** may transmit any requested portion of these data points (including all the data points, a single data point, or a subset of data points corresponding to a range of locations or times), to the predicted wait time calculator **270** as the predicted wait data **275**.

[0044] Subsequently, in response to client-specific input **250**, such as predicted wait time queries, the predicted wait time calculator **270** determines the predicted wait time **285** based on the predicted wait data **275**. For example, in some embodiments, the predicted wait data **275** may include data points that may specify a variety of locations and times. In such embodiments, the predicted wait time calculator **270** could perform comparison operations on the predicted wait data **275** to select the data point that is the closest match to the point-of-interest **110** and/or the time-of-interest and then assign the predicted wait time **285** based on the selected data point. In this fashion, the wait time predictive model **165** and the predicted wait time calculator **270** work together to provide the predicted wait time **285** while optimizing the available resources in the crowdsource planning system **100**, such as bandwidth.

[0045] In general, the predicted wait time calculation functionality described herein may be implemented using any type of algorithms as known in the art and distributed in any technically feasible, consistent fashion between the wait time server **150** and the wait time client **132**. For example, and without limitation, in some embodiments, the wait time client **132** may not perform any predicted wait time calculations. In such embodiments, the wait time client **132** may omit the predicted wait time calculator **270**, forgo downloading the predicted wait data **275**, and relay client-specific input **250** directly to the wait time server **150** at run-time. Such client-specific input **250** may include, without limitation, predicted wait time queries and associated information such as the point-of-interest **110**, the point-of-query **180**, the wait start time, and the like. The wait time server **150** then calculates the predicted wait time **285** corresponding to the query and transmits the predicted wait time **285** to the wait time client **132**.

[0046] In alternate embodiments, the computer-based device that executes the wait time client **132** may include additional planning capability. For example, and without limitation, the computer-based device may be the navigation system **182** and a total time calculator included in the navigation system **182** may calculate a total trip time based on both the predicted wait time **285** and a predicted travel time. In other embodiments, the computer-based device may include search functionality that enables the user to select a start location, one or more potential destinations, and or one or more expected travel windows (i.e., afternoon), and then compare the corresponding predicted wait times **285** and/or the total trip times.

[0047] In a complementary fashion to the predicted time calculator **270**, the measured wait time calculator **240** determines a wait end time **244** and a wait start time for a queue located at the point-of-interest **110**. The wait time calculator **240** then subtracts the wait start time from the wait end time **244** to determine a measured wait time **242**. After determining the measured wait time **242**, the wait time calculator transmits the measured wait data **245** to the wait time server

150. As shown, the measured wait data **245** includes, without limitation, the measured wait time **242**, the point-of-interest **110** and the wait end time **244** Upon receiving the measured wait data **245**, the wait time server **150** updates the crowdsourced wait data **160** and/or the wait time predictive model **165** to reflect the measured wait time data **245**.

[0048] In alternate embodiments, the measured wait data **245** may include any number and type of wait related data that is relevant to the wait time server **150**. For example, and without limitation, if the crowdsourced wait data **160** and the wait time predictive model **165** discriminate based on type of day (e.g., weekday, weekend, holiday, etc.) or season, then the measured wait data **245** could include such information.

[0049] In general, the granularity of each of the measured wait data **245**, the crowdsourced wait data **160** and the wait time predictive model **165** impacts the overall accuracy of the predicted wait data **275** that the wait time server **150** generates. Further, the volume of the measured wait data **245** received for each of the points-of-interest **246** correlates to the overall reliability of the predicted wait data **275**. For these reasons, the wait time client **132** is configured to gather input via the mobile device **130** in a variety of modes, including, without limitation, a manual entry mode, a proximity sensor mode, and a point-of-sale mode. In alternate embodiments, the wait time client **132** may be configured to respond to and leverage any relevant infrastructure that is available at the current location of the mobile device **130**.

[0050] In the manual entry mode, both the wait start time (i.e., the time that the queue is entered) and the wait end time **244** (the time that the queue is exited) are entered via a user interface as part of the client-specific input **250**. Upon receiving a wait start time, the measured wait time calculator **240** stores the wait start time. Subsequently, upon receiving the corresponding wait end time **244**, the measured wait time calculator **240** subtracts the stored wait start time from the wait end time **244** to determine the measured wait time **242**. The measured wait time calculator **240** then transmits the measured wait data **245** to the wait time server **150**. The measured wait data **245** includes, without limitation the measured wait time **242**, the wait end time **244**, and the point-of-interest **246**. The measured wait time calculator **240** assigns the point-of-interest **246** in any technically feasible fashion, such as entry via the user interface, search engine results, or global positioning system (GPS) data.

[0051] In the proximity sensor mode, the wait start time is detected via a sensor that is located at the entry of the queue, and the wait end time **244** is detected via another sensor that is located at the exit of the queue. The sensors may be implemented in any technically feasible fashion that enables communication with the mobile device **130** that executes the wait time client **132**. In some embodiments, the mobile device **130** may be a Bluetooth enabled device, such as a smartphone, and the sensors may be Bluetooth Low Energy (BLE) sensors that are installed at the point-of-interest **110**. The sensors may transmit information, such as the point-of-interest **110** and the type of sensor (entry sensor or exit sensor) to the mobile device **130** using any technique as known in the art. Such techniques may include a notification beacon, transmission of a “sensor-encountered” message, and so forth. For example, in some embodiments, the sensors may transmit a unique identification (ID), and the wait time server **150** is configured to associate each ID with either an entry to a queue or an exit from a queue. Further, in some embodiments, the transmission may include the time of encounter. In other embodiments, the mobile device **130** may store the time that the transmission is received as a timestamp.

[0052] Upon receiving a wait start time, the measured wait time calculator **240** stores the wait start time. Subsequently, upon receiving the corresponding wait end time **244**, the measured wait time calculator **240** subtracts the stored wait start time from the wait end time to determine the measured wait time **242**. The measured wait time calculator **240** then transmits the measured wait data **245** to the wait time server **150**. Again, the measured wait data **245** includes, without limitation, the measured wait time **242**, the wait end time **244**, and the point-of-interest **110**. The measured wait time calculator **240** assigns the point-of-interest **110** in any technically feasible fashion, such as entry via the user interface, search engine results, global positioning system (GPS) data, or predetermined BLE sensor location.

Point-of-Sale Mode

[0053] In the point-of-sale mode, the point-of-sale system **120** is located at the point-of-interest **110**, the sales payment occurs via a computerized sales transaction, and the mobile device **130** receives confirmation of the sales transaction. More specifically, in some embodiments, the sales payment may occur via a credit card/debit card reader, the financial server **140** processes the associated sales transaction and then sends the SMS **145** to the mobile device **140** confirming the sales transaction and including information on the point-of-interest **110**. In some embodiments, the SMS **145** may include the time of the sales transaction. In other embodiments, the mobile device **130** may store the time that the SMS **145** is received as the time of the sales transaction.

[0054] After processing the SMS **145**, the mobile device **130** relays the sales transaction information to the wait time client **132** (including the measured wait time calculator **240**) as part of the client-specific input **250**. The wait time client **132** interprets the sales transaction as the wait time end **244**. Further, to enable fully automatic calculation of the measured wait time, the wait time client **132** leverages the wait time end **244** in addition to tracked sensor data to compute the measured wait time **242**.

[0055] To facilitate the point-of-sale mode, the wait time client **132** and the mobile device **130** work together in a continuous fashion to store sensor data that tracks the motion of the mobile device **130** and then process the motion data. Notably, upon receiving the wait end time **244**, the wait time client **132** backtracks from the wait time end **244** to extract a queue path from end of the queue (at the point-of-sale **120**) to a start of the queue and a corresponding wait start time.

[0056] More specifically, as shown, the wait time client **132** includes a step detector **110**, a turn detector **120**, and a path tracer **230**. The step detector **110** receives accelerometer data **215** and calculates a rate of steps based on the accelerometer data **215** and the time associated with the accelerometer data **215**. The step detector **110** may be implemented in any technically feasible fashion and may be integrated into the mobile device **130**. The turn detector **120** receives the accelerometer data **215**, gyroscope data **225**, and magnetic sensor data **227** and determines when the mobile device **130** executes a turn. The turn detector **110** may be implemented in any technically feasible fashion using any sensor data available to the mobile device **130**.

[0057] Based on the rate of steps and the detected turns, the path tracer **230** backtracks from the wait time end **244** at the point-of-sale **120** to the wait time start at the entrance to the queue. The path tracer **230** implements a pattern-based heuristic to determine the queue path. In particular, the path tracer **230** is configured to recognize specific patterns of walking (i.e., rate of steps) and angles of motion (i.e., detected turns) that are characteristic of motion within a queue. In one embodiment, the pattern of walking represents a walk-stop-walk-stop pattern often observed in queues. Further, the angles of motion characteristic of movement within the queue lie within a fixed threshold that reflects the "width" of a typical queue. In alternate embodiments, the path tracer **230** may be configured to identify characteristics of motion within queues in any technically feasible fashion and based on any heuristics, including other patterns of motion and angles, and/or other sensor data.

Path Tracing

[0058] FIG. **3** is a conceptual illustration of a queue path **315** detected by the path tracer **230** of FIG. **2** in a point-of-sale mode, according to various embodiments. For explanatory purposes only, the path followed by the mobile device **130** is depicted with a heavy line that includes arrows that delineate turns.

[0059] Based on the time-stamped sensor data that is logged by the wait time client **132** and queue constraints **390**, the step detector **210**, the turn detector **220**, and the path tracer **230** backtrack from the wait end time (t_1) **244** to determine a wait start time (t_N) **330**. In operation, the step detector **210** determines the rate of steps, the turn detector **220** detects the angle of motion, and the path tracer **230** compares the rate of steps and the angle of motion (i.e., detected turns) at various points in time t_x, starting at the wait end time **244** (t_1), to the queue constraints **230**. If the rate of steps and the angle of motion comply at a specific point in time t_x with the queue constraints **230**, then the path tracer **230** continues to trace backwards. However, when the rate of steps and/or the angle of motion no longer comply with the queue constraints **230**, then the path tracer **230** considers the previously considered point in time t_{x-1} to be the wait start time (t_N) **330**

[0060] As shown, the queue constraints **230** constrain a walking angle **350** (i.e., the angle between the location of the mobile device **130** at t_{x-1} and the location of the mobile device at t_x) to lie within a range of angles defined by the queue threshold angle **360**. In addition, the queue constraints **230** constrain the velocity of the mobile device **130** to a predetermined threshold that represents the typically relatively slow motions within the queue **310**. In alternate embodiments, the queue constraints **230** are configured to represent a shape of the queue that is not straight, such as an S-shaped queue. In some embodiments, the client-specific input **250** includes a configuration parameter that specifies the shape of the queue, and the wait time client **132** is configured to select the appropriate queue constraints **230** based on this configuration parameter.

Leveraging Crowdsourced Wait Data to Compute Predicted Wait Times

[0061] FIG. **4** is a flow diagram of method steps for leveraging crowdsourced wait data to compute predicted wait times. Although the method steps are described in conjunction with the systems of FIGS. **1-3**, persons skilled in the art will understand that any system configured to implement the method steps, in any order, falls within the scope of the present invention.

[0062] As shown, a method **400** begins at step **404**, where the wait time client **132** downloads the predicted wait data **275** from the wait time server **150**. More specifically, the predicted wait time calculator **270** (included in the wait time client **132**) retrieves the predicted wait data **275** that the wait time sever **150** generates based on the crowdsourced wait data **160**. The wait time client **132** may initiate downloads of the predicted wait data **275** at any time, thereby enabling the wait time client **132** to reflect a current version of the crowdsourced wait data **160** as opposed to a dated version of the crowdsourced wait data **160**.

[0063] At step **406**, the wait time client **132** receives wait-time-relevant input, such as the client-specific input **250**, sensor data, and the SMS **145** that includes sales transaction information. For example, the wait-time-relevant input could be a client-specific query—a request entered via a user interface of the wait time client **132** for a predicted wait time (such as the wait time at a grocery store at a noon). In another example, the wait-time-relevant input may be information that provides insight into measured (i.e., experienced) wait times, such as the current location of the wait time client **132**. At step **408**, the wait time client **132** determines whether the received wait-time-relevant input corresponds to a wait time query (e.g., "what is the grocery store with the shortest wait time within 5 miles."). If, at step **408**, the wait time client **132** determines that the wait-time-relevant input is a wait time query, then the method **400** proceeds directly to step **420**. At step **408**, if the wait time client **132** determines that the wait-time-relevant input is not a wait time query, then the method **400** proceeds to step **410**.

[0064] At step **410**, the wait time client **132** evaluates the wait-time-relevant input to determine whether the wait-time-relevant input is associated with the wait end time **244**. If, at step **410**, the wait time client **132** determines that the wait-time-relevant input is associated with the wait end time **244**, then the method **400** proceeds directly to step **414**. At step **410**, if the wait time client **132** determines that the wait-time-relevant input is not associated with the wait end time **244**, then the method **400** proceeds to step **412**.

[0065] At step **412**, the wait time client **132** stores the wait-time-relevant data for processing when the wait end time **244** is determined. For example, and without limitation, if the wait-time-relevant data includes the wait start time **330**, then the wait time client **132** would store the wait start time **330**. Similarly, if the wait-time-relevant data includes the accelerometer data **215** for a specific point in time, then the wait time client **132** would store the accelerometer data **215** and the associated time in any available memory and in any form. The method **400** then returns to step **406**. The wait time client **132** continues to cycle through steps **406-412**, storing wait-time-relevant data until the wait time client **132** detects that either the wait-time-relevant data corresponds to a wait time query or is associated with the wait end time **244**.

[0066] At step **414**, the wait time client **132** processes the wait-time-relevant data that is associated with the wait end time **244**. Specifically, the wait time client **132** determines the point-of-interest **110**, the wait end time **244**, and the wait start time **330**. The wait time client **132** may determine the point-of-interest **110**, the wait end time **244**, and the wait start time **330** in any technically feasible fashion. For example, and without limitation, in a point-of-sale mode, the wait time client **132** may implement the method disclosed in FIG. **5** to determine the wait start time **330** based on the wait end time **244** and sensor data that is included in the wait-time-relevant data and stored at step **412**.

[0067] At step **416**, the measured wait time calculator **240** calculates the measured wait time **242** based on the wait end time **244** and the wait start time **330**. At step **418**, the measured wait time calculator **240** transmits the measured wait data **245** (including the measured wait time **242**, the wait end time **244**, and the point-of-interest **110**) to the wait time server **150**. As part of step **418**, the measured wait time calculator **240** may calculate and/or transmit any additional values for the measured wait data **245** to the wait time server **150**. The method **400** then returns to step **406**. The wait time client **132** continues to cycle through steps **406-418**, processing wait-time-relevant data until the wait time client **132** detects that the wait-time-relevant data corresponds to a wait time query.

[0068] At step **420**, the wait time client **132** evaluates the wait time query to determine whether the wait time query specifies the point-of-interest **110**. If, at step **420**, the wait time client **132** determines that the wait time query specifies the point-of-interest **110**, then the method **400** proceeds directly to step **424**. At step **420**, if the wait time client **132** determines that the wait time query does not specify the point-of-interest **110**, then the method **400** proceeds to step **422**. At step **422**, the wait time client **132** selects the point-of-interest **110**. The wait time client **132** may select the point-of-interest **110** in any technically feasible fashion, such as matching search result locations to predetermined locations that correspond to the points-of-interest **110** supported by the crowdsourced wait data **160**.

[0069] At step **424**, the predicted wait time calculator **270** determines the predicted wait time **285** based on the predicted wait data **275**, the anticipated wait start time **330**, and the point-of-interest **110**. In alternate embodiments, the wait time calculator **270** may consider additional wait-time-relevant data as part of computing the predicted wait time **285**. In some embodiments the wait time calculator **270** may be configured to filter the predicted wait data **275** based on a date corresponding to each data point (e.g., consider only data points obtained within the last year). At step **426**, the wait time client **132** outputs the predicted wait time **285**. The predicted wait time **285** may be utilized in any number of planning techniques. For example, and without limitation, the predicted wait time **285** may be overlaid on a map or summed with predicted travel times to determine overall trip times. The method **400** then returns to step **406**. The wait time client **132** continues to cycle through steps **406-426**, processing wait-time-relevant data based on the nature of the data.

Computing Wait Times Based on Point-of-Sale Transactions

[0070] FIG. **5** is a flow diagram of method steps for backtracking from a point-of-sale transaction to compute the time spent waiting in a queue. Although the method steps are described in conjunction with the systems of FIGS. **1-3**, persons skilled in the art will understand that any system configured to implement the method steps, in any order, falls within the scope of the present invention.

[0071] As shown, a method **500** begins at step **504**, where the path tracer **230** receives a sales transaction notification that includes the location of the point-of-sale system **120** and the transaction time. In some embodiments, the path tracer **230** may receive the sales transaction notification via the mobile device **130** when the mobile device **130** receives the SMS **145** corresponding to the sales transaction from the financial server **150**. As part of step **504**, the path tracer **230** assigns the point-of-interest **110** to correspond to the location of the point-of-sale.

[0072] At step **506**, the path tracer **230** initializes backtracking operations that start from the wait end time **244** (and the location of the point-of-sale) and end at the time (and location) at which the mobile device **130** entered the queue **130**. In particular, the path tracer **230** sets both the wait end time **244** and a "backtracked" time (i.e., the time traced back to thus-far) to the transaction time. At step **508**, the path tracer **230** evaluates the rate of steps provided by the step detector **210** and the motion detected by the turn detector **220** between the backtracked time and a previous time for which sensor data is available. As disclosed previously herein, the step detector **210** tracks the rate of steps and the turn detector **220** detects turns (i.e., motion) based on recorded and time-stamped sensor data associated with the mobile device **130**.

[0073] At step **510**, the path tracer **230** compares the rate of steps and the motion to the queue constraints **230** to determine whether the mobile device **230** was in the queue **130** at the backtracked time. Notably, the path tracer **230** is configured to recognize specific patterns of walking (i.e., rate of steps) and angles of motion (i.e., detected turns) that are characteristic of motion within a queue based on the queue constraints **230**. If, at step **510**, the path tracer **230** determines that the queue constraints **230** are met at the backtracked time, then the method **500** proceeds to step **512**. At step **512**, the path tracer **230** sets the backtracked time to the previous time and the method **500** returns to step **508**. The path tracer **230** continues to cycle through steps **508-512**, backtracking along the path of the mobile device **230** to determine the queue path **315** until the path tracer **230** determines that the queue constraints **230** are not met at the backtracked time.

[0074] At step **510**, if path tracer **230** determines that the queue constraints **230** are not met at the backtracked time, then the method **500** proceeds directly to step **514**. At step **514**, the path tracer **230** sets the wait start time **330** to the backtracked time, and the measured wait time calculator **240** calculates the measured wait time **242** based on the wait end time **244** and the wait start time **330**. At step **516**, the measured wait time calculator **240** transmits the measured wait data **245** (including the measured wait time **242**, the wait end time **244**, and the point-of-interest **110**) to the wait time server **150** for incorporation into the crowdsourced wait data **160**, and the method **500** ends.

[0075] In sum, the disclosed techniques may be used to predict wait times at various types of queues, such as lines at point-of-sale (POS) counters. A wait time client includes both a predicted wait time calculator and a measured wait time calculator. To estimate wait times at points-of-interest at times-of-interest, the predicted wait time calculator leverages a predicted wait time database that is maintained by a wait time server. In a supportive manner, the measured wait time calculator gathers and transmits measured wait data, including wait time, transaction (i.e., sale) time, and location to the wait time server. Upon receiving measured wait data, the wait time server incorporates the measured wait data into crowdsourced wait data that reflects measured wait data that the wait time server previously received. The wait time server then populates the predicted wait time data based on a predictive wait time model that processes the crowdsourced wait data. In this manner, the wait time client enables the wait time server to act as an accessible repository for crowdsourced measured wait times—aggregating measured wait times into up-to-date and realistic estimated wait times.

[0076] To increase the utility and scope of the predicted wait time database, the wait time client supports a variety of data gathering modes to measure wait times. Each data gathering mode is tailored to the available infrastructure. For example, and without limitation, the wait time client may support a manual entry mode, a proximity sensor mode, and a point-of-sale mode. Notably, in the point-of-sale mode, the wait time client evaluates a sales transaction message sent from financial institutions to determine a queue end time and queue end location (point-of-sale) and then performs backtracking operations from the end time and end location to determine the entry time to the queue. More specifically, the wait time client traces a queue path backwards from the point-of-sale based on predetermined queue movement patterns and stored sensor data, such as, and without limitation, accelerometer data and gyroscope data.

[0077] At least one advantage of the disclosed techniques is that they enable optimized planning processes based on more accurate predicted wait times at queues. Not only does the wait time client allow users to minimize wait times at queues, but the wait time application also facilitates comprehensive trip planning. For example, and without limitation, the predicted wait time provided by the wait time client may be combined with other navigation-related information, such as estimated travel time, to select a particular point-of-interest based on total trip time. Further, since the wait time client continuously provides measured wait data, the wait time client enables the wait time server to provide a dynamic, crowdsourced-based wait time model that realistically predits wait times for a wide range of points-of-interest and times-of-interest. Because the wait time client supports a variety of data gathering techniques, including one that requires no additional infrastructure, the wait time client facilitates an evolving and diverse crowdsourced predicted wait time system.

[0078] The descriptions of the various embodiments have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments.

[0079] Aspects of the present embodiments may be embodied as a system, method or computer program product. Accordingly, aspects of the present disclosure may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the present disclosure may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

[0080] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0081] Aspects of the present disclosure are described above with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the disclosure. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, enable the implementation of the functions/acts specified in the flowchart and/or block diagram block or blocks. Such processors may be, without limitation, general purpose processors, special-purpose processors, application-specific processors, or field-programmable

[0082] The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present disclosure. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function (s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, and without limitation, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

[0083] The invention has been described above with reference to specific embodiments. Persons of ordinary skill in the art, however, will understand that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. For example, and without limitation, although many of the descriptions herein refer to specific types of audiovisual equipment and sensors, persons skilled in the art will appreciate that the systems and techniques described herein are applicable to other types of performance output devices (e.g., lasers, fog machines, etc.) and sensors. The foregoing description and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

[0084] While the preceding is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

1. A computer-implemented method for predicting wait times at points-of-interest, the method comprising:

receiving a plurality of data points from a server machine, wherein each data point reflects at least one crowdsourced measured wait time and is associated with any one of several different points-of interest, and wherein at least one of the data points is determined based on a duration of time for which a path of a mobile device satisfies one or more queue pattern constraints;

receiving a request to predict a wait time at a first point-of-interest that is included in the several different points-of-interest;

selecting a first data point included in the plurality of data points based on the first point-of-interest; and

determining a predicted wait time based on the first data point.

2. The method of claim **1**, wherein selecting the first data point comprises:

identifying a subset of data points that are included in the plurality of data points and are associated with the first point-of-interest; and

selecting a data point included in the subset of data points that is associated with a start time that lies within a specified range of times.

3. The method of claim **1**, further comprising, prior to receiving the plurality of data points from the server machine:

determining that a location of the mobile device is associated with the first point-of-interest;

calculating a first wait time based on a start time and an end time, wherein both the start time and the end time are associated with the mobile device; and

causing the server machine to generate the first data point based on the start time, the first wait time, and the location of the mobile device.

4. The method of claim **3**, wherein determining at least one of the start time and the end time comprises receiving a message, and analyzing the message to determine a transaction time associated with the first point-of-interest.

5. The method of claim **4**, wherein the message is received from a proximity beacon.

6. The method of claim **4**, wherein determining the end time comprises receiving a message that corresponds to a financial transaction, and analyzing the message to determine a timestamp associated with the message.

7. The method of claim **4**, wherein determining the start time comprises:

storing sensor data indicating that the mobile device has moved;

performing one or more backtracking operations on the sensor data to determine the path from the transaction time to a previous time specified in the sensor data, wherein the mobile device moving between the transaction time and the previous time satisfies the one or more queue pattern constraints; and

setting the start time to the previous time.

8. The method of claim **1**, further comprising performing one or more search operations based on a location of a mobile device to identify the first point-of-interest.

9. The method of claim **1**, wherein determining the predicted wait time comprises:

performing one or more read operations on the first data point to determine a first predicted wait time, a first measurement time, a second predicted wait time, and a second measurement time;

determining a start time based on the request;

computing a first difference between the start time and the first measurement time, and a second difference between the start time and the second measurement time; and

if the first difference is less than the second difference, then setting the predicted wait time to the first predicted wait time; and

if the first difference is not less than the second difference, then setting the predicted wait time to the second predicted wait time.

10. A non-transitory computer-readable storage medium including instructions that, when executed by a processor, cause the processor to predict wait times at points-of-interest, the method comprising:

downloading a plurality of data points from a server machine, wherein each data point reflects at least one crowdsourced measured wait time and is associated with any one of several different points-of interest, and wherein at least one of the data points is determined based on a duration of time for which a path of a mobile device satisfies one or more queue pattern constraints;

receiving a request to predict a wait time at a first point-of-interest that is included in the several different points-of-interest;

selecting a first data point included in the plurality of data points based on the first point-of-interest; and

determining a predicted wait time based on the first data point.

11. The non-transitory computer-readable storage medium of claim **10**, wherein determining the predicted wait time comprises identifying a first predicted wait time included in the first data point based on an end time that is specified in the request.

12. The non-transitory computer-readable storage medium of claim **10**, further comprising, prior to downloading the plurality of data points from the server machine:

determining that a location of the mobile device is associated with the first point-of-interest;

calculating a first wait time based on a start time and an end time, wherein both the start time and the end time are associated with the mobile device; and

causing the server machine to generate the first data point based on the start time, the first wait time, and the location of the mobile device.

13. The non-transitory computer-readable storage medium of claim **12**, wherein determining the start time comprises;

storing sensor data indicating that the mobile device has moved;

receiving a message, and analyzing the message to determine a transaction time associated with the first point-of-interest;

performing one or more backtracking operations on the sensor data to determine the path from the transaction time to a previous time specified in the sensor data, wherein the mobile device moving between the transaction time and the previous time satisfies one or more queue pattern constraints; and

setting the start time to the previous time.

14. The non-transitory computer-readable storage medium of claim **13**, wherein the one or more queue pattern constraints include at least one of a maximum change in direction and a maximum change in velocity.

15. The non-transitory computer-readable storage medium of claim **13**, wherein at least one of the one or more backtracking operations comprises a step-detection operation.

16. The non-transitory computer-readable storage medium of claim **13**, wherein at least one of the one or more backtracking operations comprises a turn-detection operation.

17. The non-transitory computer-readable storage medium of claim **10**, further comprising estimating a travel time to the first point-of-interest and calculating a total time based on the predicted wait time and the travel time.

18. The non-transitory computer-readable storage medium of claim **10**, wherein determining the predicted wait time comprises:

performing one or more read operations on the first data point to determine a first predicted wait time, a first measurement time, a second predicted wait time, and a second measurement time;

determining an end time based on the request;

computing a first difference between the end time and the first measurement time, and a second difference between the end time and the second measurement time; and

if the first difference is less than the second difference, then setting the predicted wait time to the first predicted wait time; and

if the first difference is not less than the second difference, then setting the predicted wait time to the second predicted wait time.

19. A system configured to predict wait times, the system comprising:

a processor; and

a memory coupled to a processor and including a wait time calculator, wherein, when executed by the processor, the wait time calculator is configured to:

perform one or more communication operations with a server machine to receive and store a wait time database that reflects crowdsourced measured in the memory, wherein the wait time database includes a plurality of data points and each data point is associated with any one of several different points-in-interest, and wherein at least one of the data points is determined based on a duration of time for which a path of a mobile device satisfies one or more queue pattern constraints;

receive a request to predict a wait time at a first point-of-interest that is included in the several different points-of-interest;

perform one or more read operations on the wait time database to select a first data point included in the wait time database based on the first point-of-interest; and

determine a predicted wait time based on the first data point.

20. The system of claim **19**, wherein the wait time calculator is further configured to perform one or more search operations on data included in the request to identify the first point-of-interest.

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