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Krumm et al.

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(45) **Date of Patent: Jul. 8, 2008**

(54) **SENSING AND ANALYSIS OF AMBIENT CONTEXTUAL SIGNALS FOR DISCRIMINATING BETWEEN INDOOR AND OUTDOOR LOCATIONS**

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(73) Assignee: **Microsoft Corporation**, Redmond, WA (US)

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Related U.S. Application Data

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(51) **Int. Cl.**
G08B 23/00 (2006.01)

(52) **U.S. Cl.** **340/501**; 340/506; 340/517

(58) **Field of Classification Search** 340/500, 340/501, 506, 517, 524, 539.13, 539.22, 340/539.28, 541; 455/41.2, 550.1, 567; 715/716, 719

See application file for complete search history.

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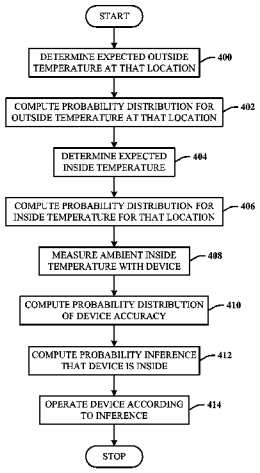
(57) **ABSTRACT**

Methods and systems that determine automatically the likelihood that a device is inside or outside of a structure or building. The system uses one or more sensors to detect ambient conditions, and make the determination. The inference can be used to save power or suppress services from certain devices, which are irrelevant, cannot be used effectively, or do not function under certain circumstances. In support thereof, the system includes one or more context sensors that measure parameters associated probabilistically with the context of a device. A context computing component considers one or more context sensors and facilitates determination of ideal actions, policies, and situations associated with the device. A service provided by the subject invention is the inference from one or more available observations the probability that the device is inside versus outside.

18 Claims, 14 Drawing Sheets



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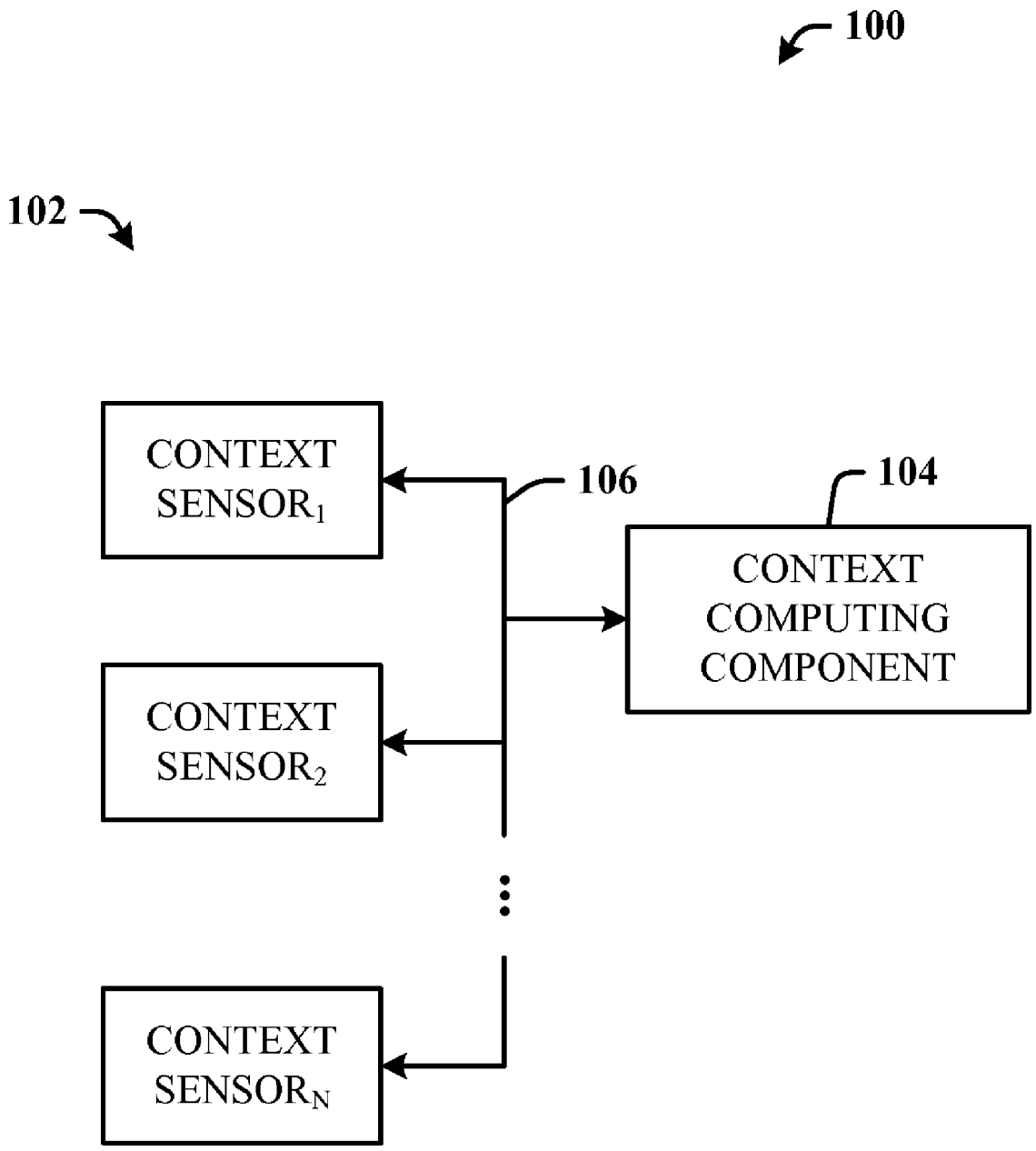
100
102
CONTEXT SENSOR$_1$
106
104
CONTEXT COMPUTING COMPONENT
CONTEXT SENSOR$_2$
CONTEXT SENSOR$_N$

FIG. 1

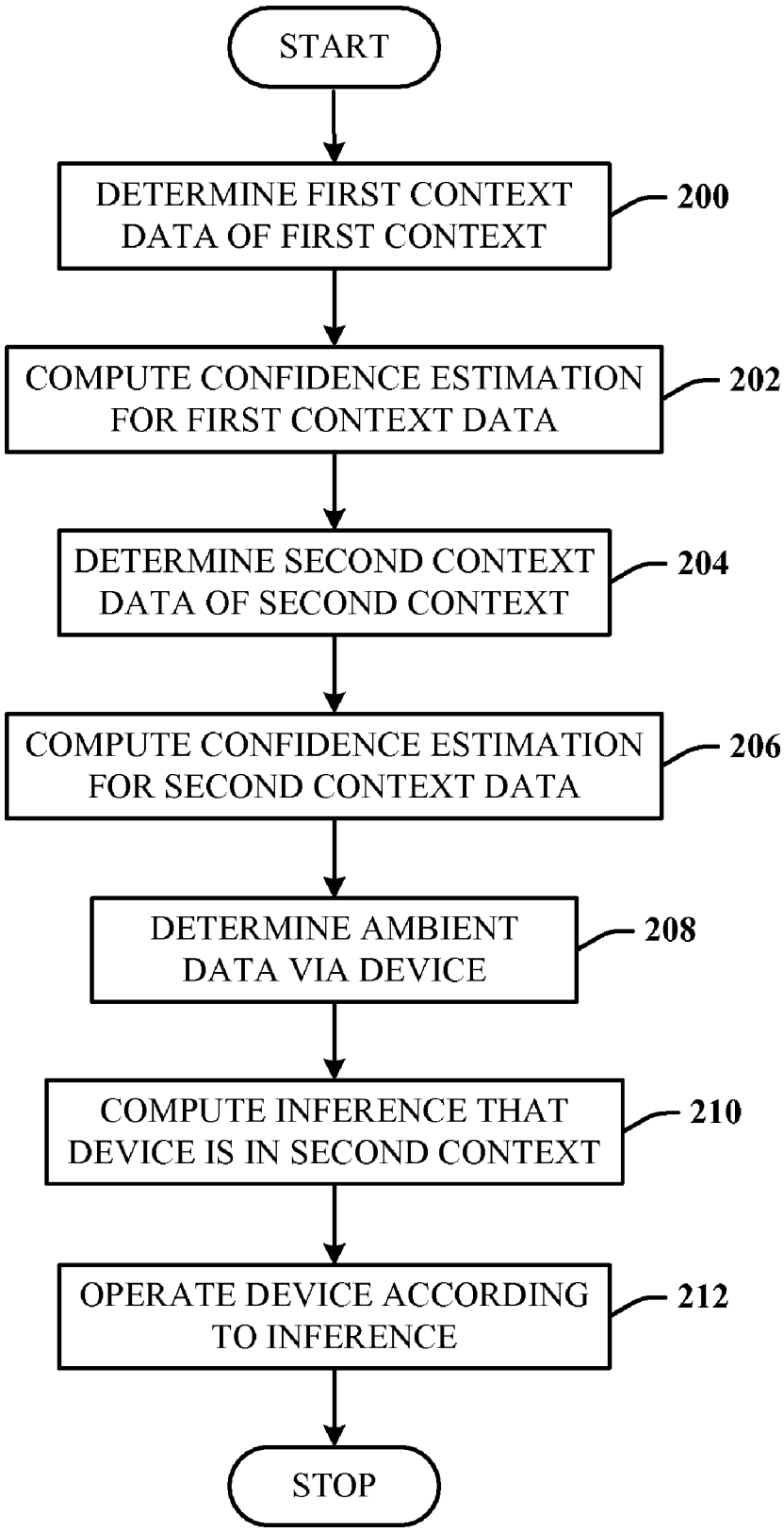
START
DETERMINE FIRST CONTEXT DATA OF FIRST CONTEXT
200
COMPUTE CONFIDENCE ESTIMATION FOR FIRST CONTEXT DATA
202
DETERMINE SECOND CONTEXT DATA OF SECOND CONTEXT
204
COMPUTE CONFIDENCE ESTIMATION FOR SECOND CONTEXT DATA
206
DETERMINE AMBIENT DATA VIA DEVICE
208
COMPUTE INFERENCE THAT DEVICE IS IN SECOND CONTEXT
210
OPERATE DEVICE ACCORDING TO INFERENCE
212
STOP

FIG. 2

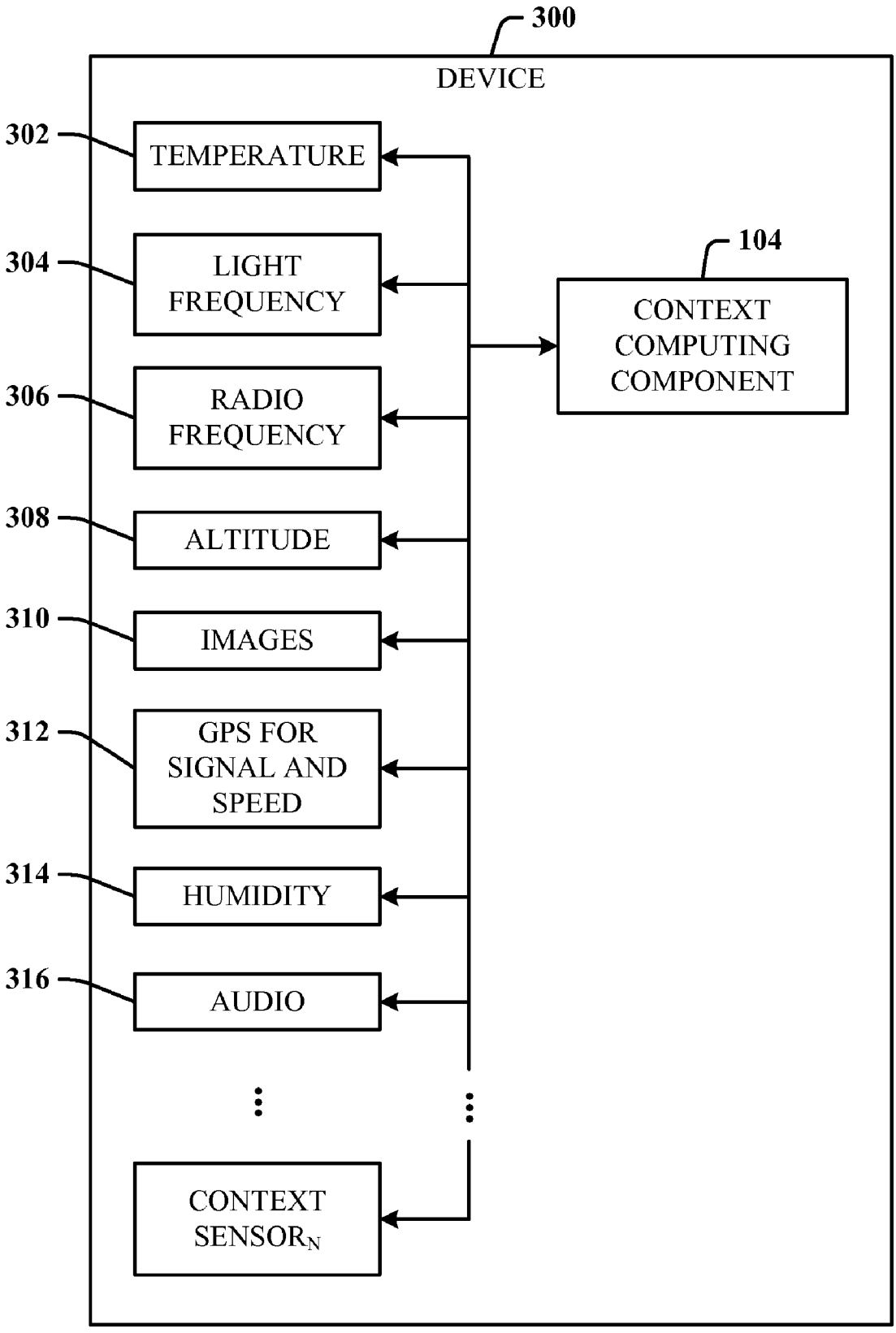
300
DEVICE
302
TEMPERATURE
304
LIGHT FREQUENCY
306
RADIO FREQUENCY
308
ALTITUDE
310
IMAGES
312
GPS FOR SIGNAL AND SPEED
314
HUMIDITY
316
AUDIO
CONTEXT SENSOR$_N$
104
CONTEXT COMPUTING COMPONENT

FIG. 3

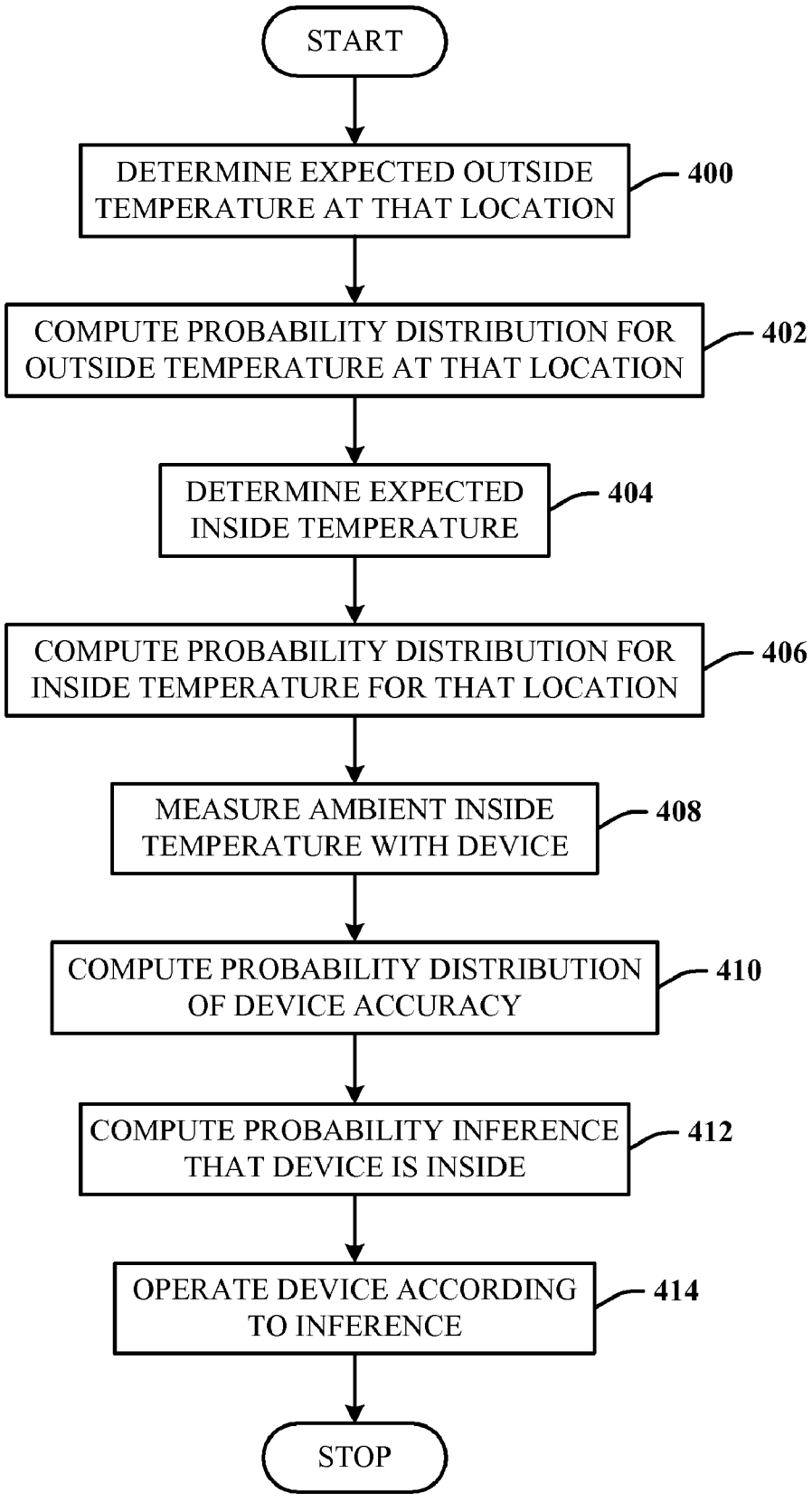
START
DETERMINE EXPECTED OUTSIDE TEMPERATURE AT THAT LOCATION
400
COMPUTE PROBABILITY DISTRIBUTION FOR OUTSIDE TEMPERATURE AT THAT LOCATION
402
DETERMINE EXPECTED INSIDE TEMPERATURE
404
COMPUTE PROBABILITY DISTRIBUTION FOR INSIDE TEMPERATURE FOR THAT LOCATION
406
MEASURE AMBIENT INSIDE TEMPERATURE WITH DEVICE
408
COMPUTE PROBABILITY DISTRIBUTION OF DEVICE ACCURACY
410
COMPUTE PROBABILITY INFERENCE THAT DEVICE IS INSIDE
412
OPERATE DEVICE ACCORDING TO INFERENCE
414
STOP

FIG. 4

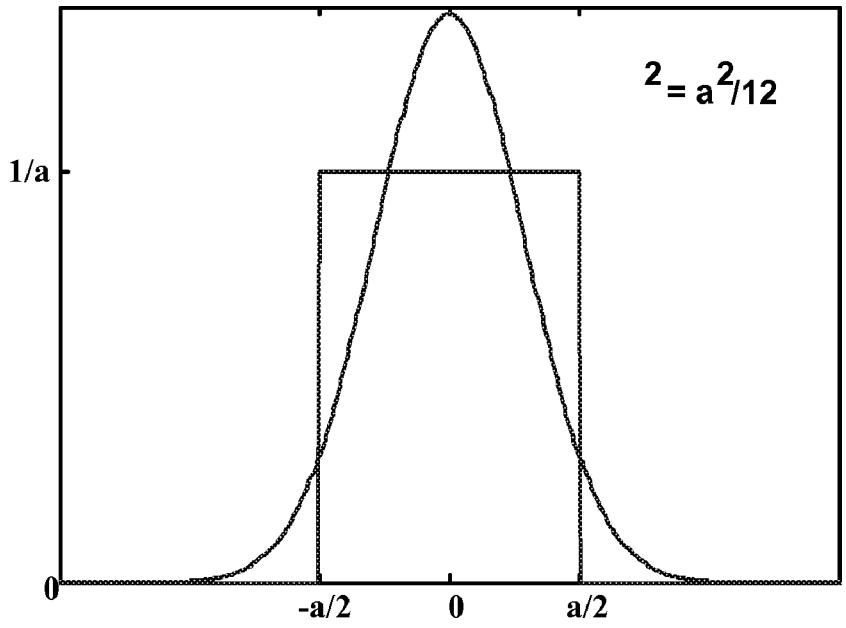
$^2 = a^2/12$
1/a
0
-a/2
0
a/2

FIG. 5

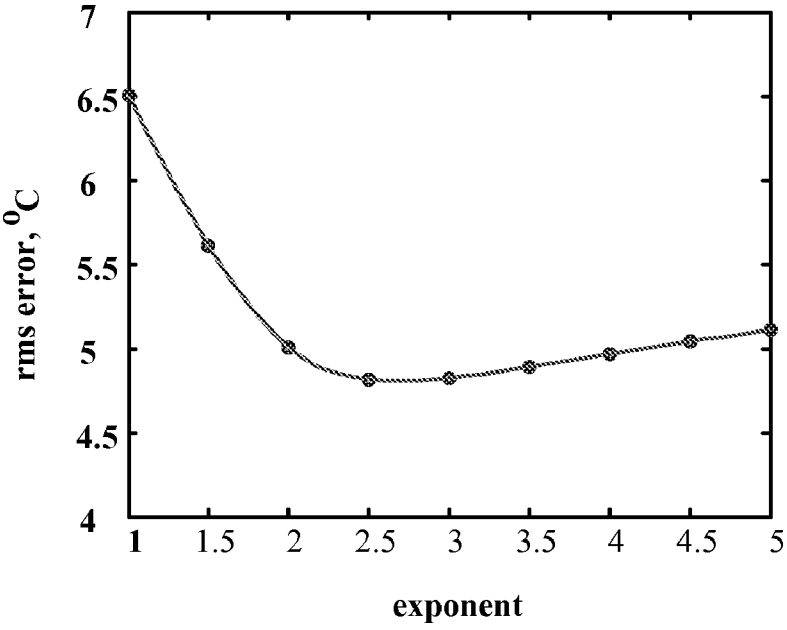
7
6.5
6
5.5
5
4.5
4
rms error, ^oC
1
1.5
2
2.5
3
3.5
4
4.5
5
exponent

FIG. 6

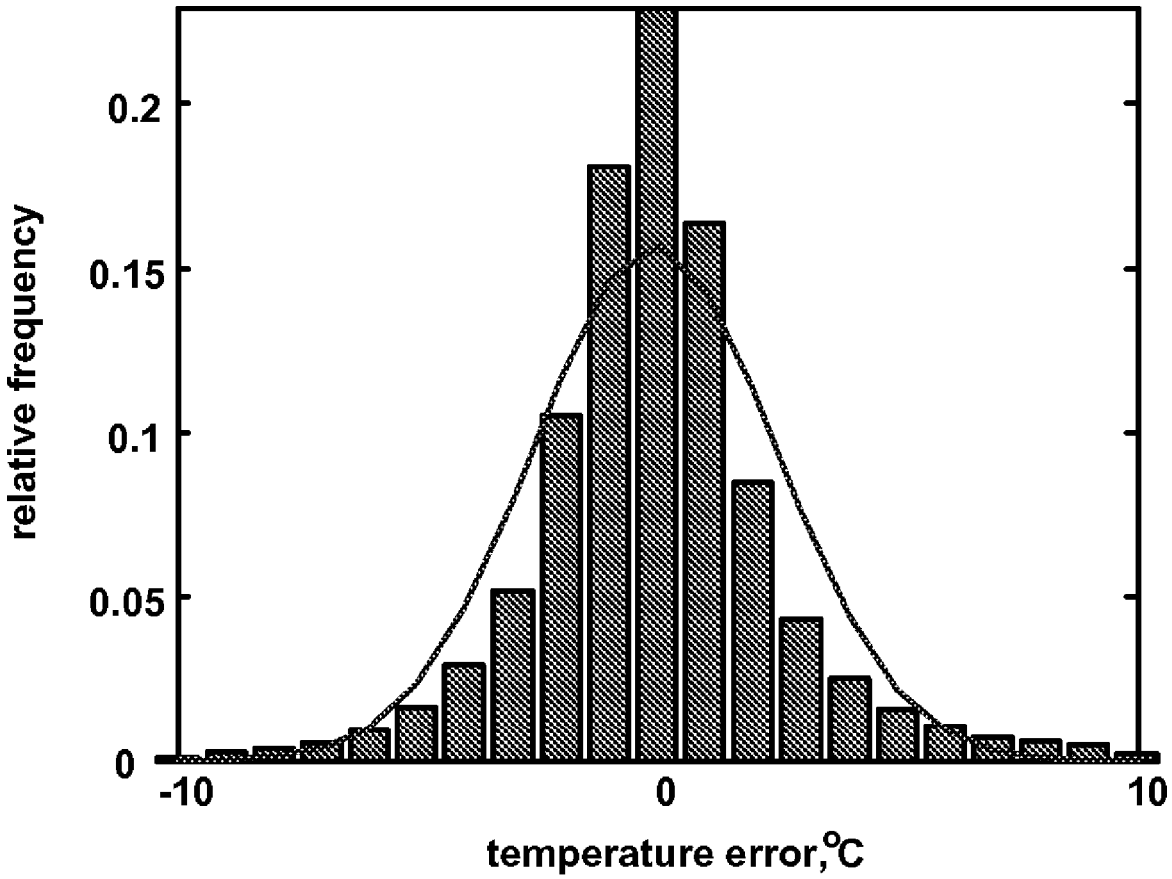
relative frequency
0.2
0.15
0.1
0.05
0
-10
0
10
temperature error,°C

FIG. 7

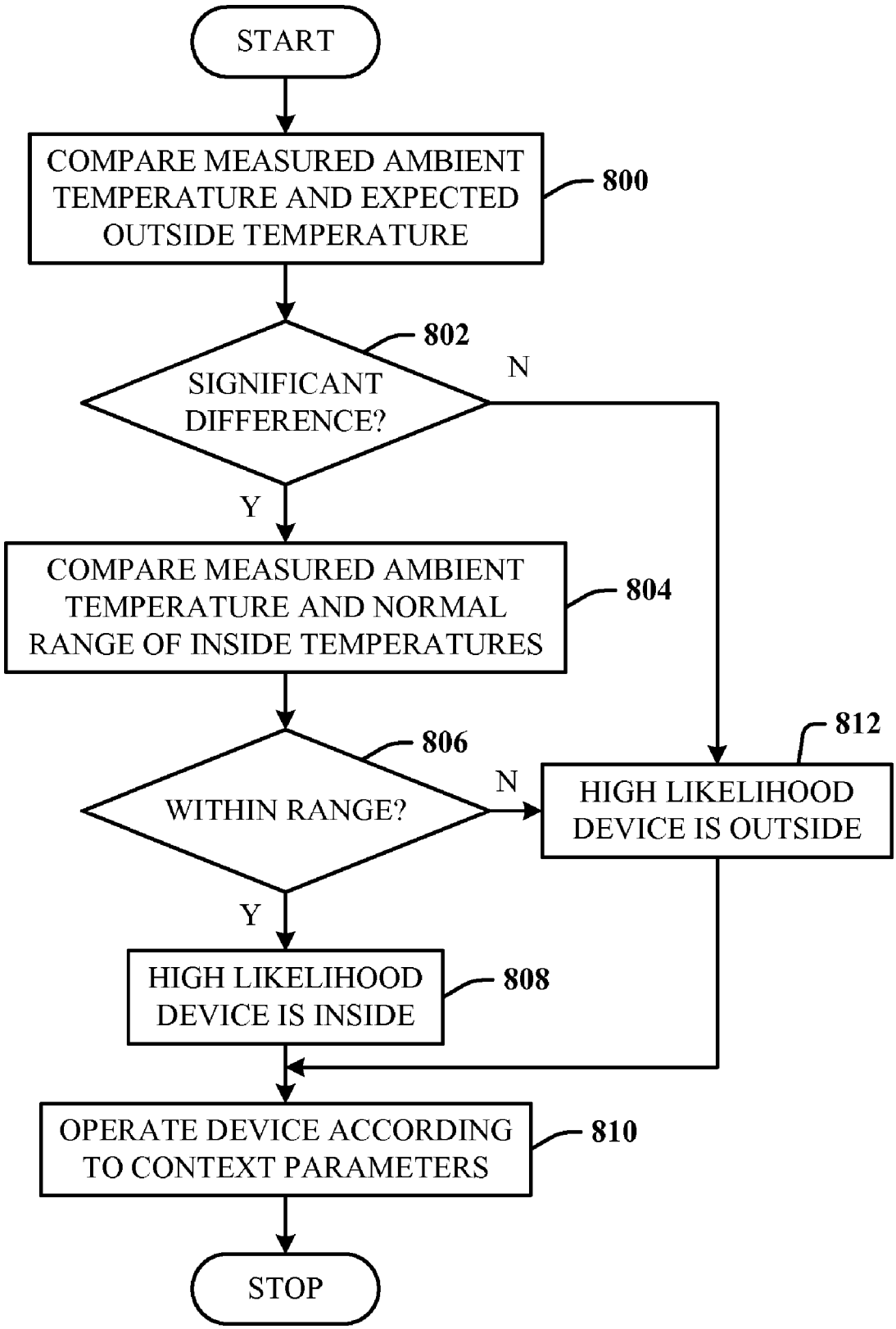
START
COMPARE MEASURED AMBIENT TEMPERATURE AND EXPECTED OUTSIDE TEMPERATURE
800
SIGNIFICANT DIFFERENCE?
802
N
Y
COMPARE MEASURED AMBIENT TEMPERATURE AND NORMAL RANGE OF INSIDE TEMPERATURES
804
WITHIN RANGE?
806
N
Y
HIGH LIKELIHOOD DEVICE IS OUTSIDE
812
HIGH LIKELIHOOD DEVICE IS INSIDE
808
OPERATE DEVICE ACCORDING TO CONTEXT PARAMETERS
810
STOP

FIG. 8

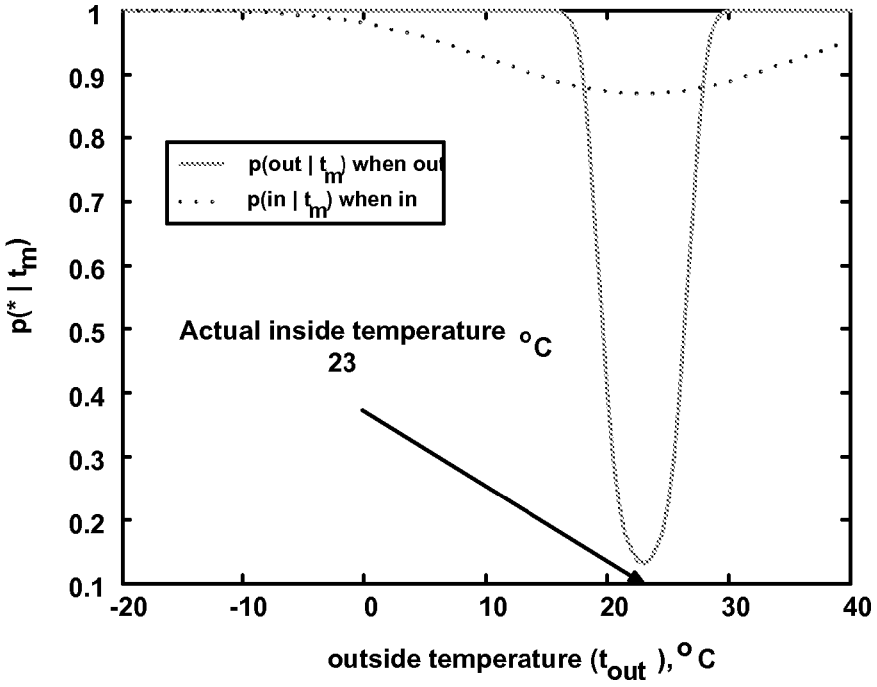
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
p(* | t_m)
p(out | t_m) when out
p(in | t_m) when in
Actual inside temperature °C
23
-20
-10
0
10
20
30
40
outside temperature (t_out), °C

FIG. 9

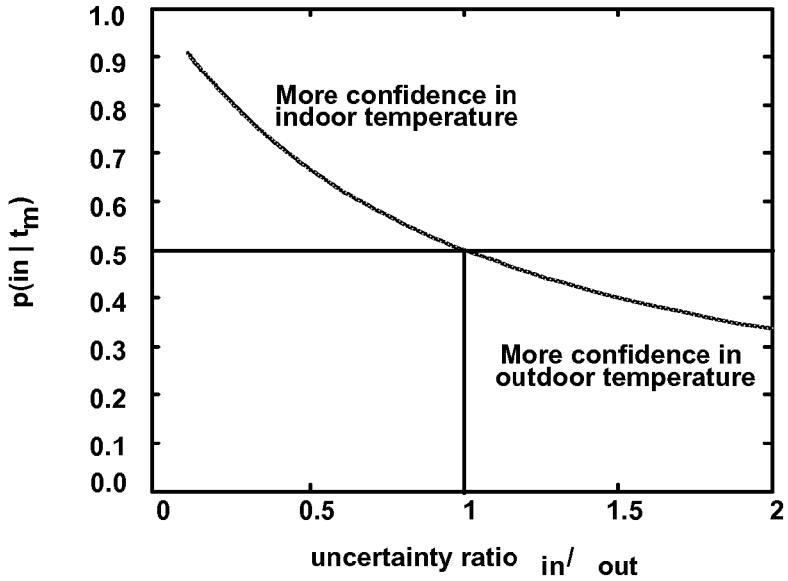
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
p(in | t_m)
More confidence in indoor temperature
More confidence in outdoor temperature
0
0.5
1
1.5
2
uncertainty ratio in/ out

FIG. 10

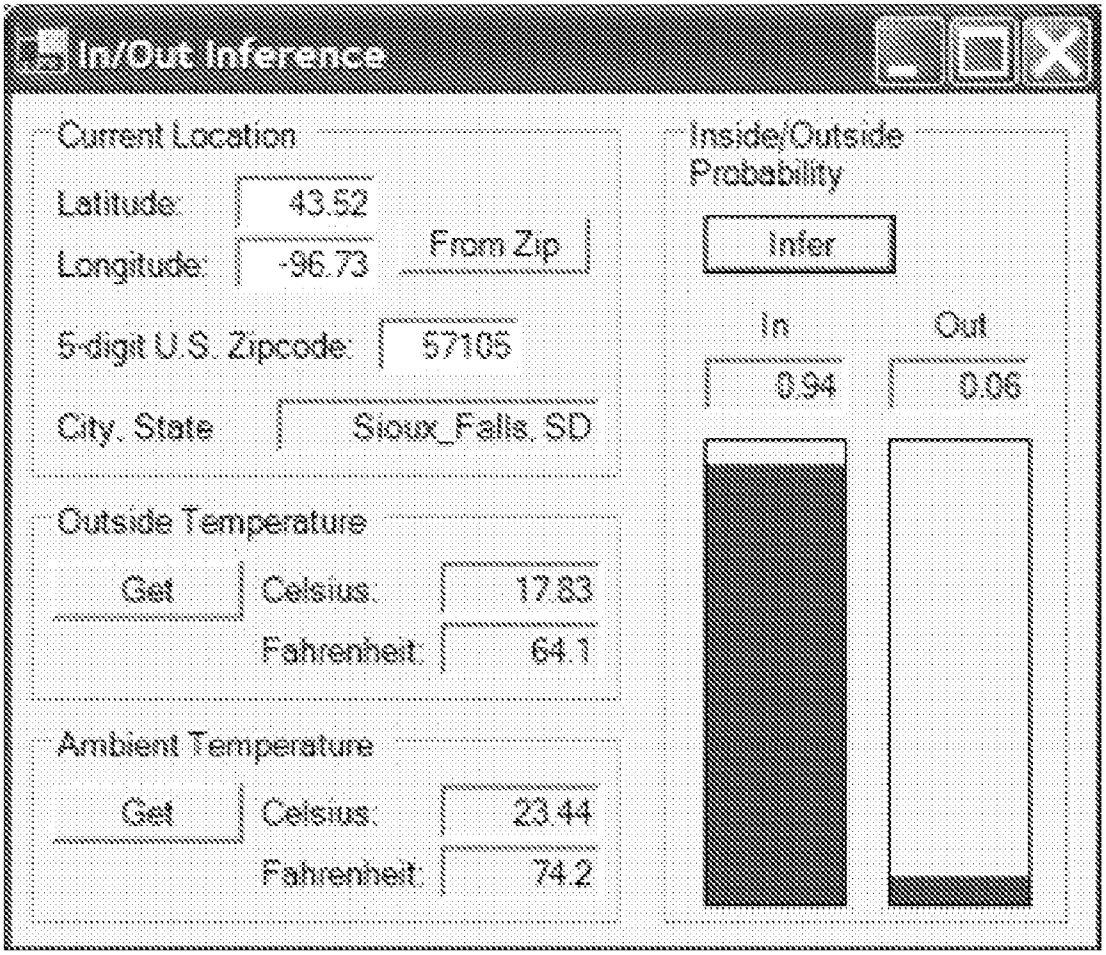
In/Out Inference
Current Location
Latitude:
43.52
Longitude:
-96.73
From Zip
5-digit U.S. Zipcode:
57105
City, State
Sioux_Falls, SD
Outside Temperature
Get
Celsius:
17.83
Fahrenheit:
64.1
Ambient Temperature
Get
Celsius:
23.44
Fahrenheit:
74.2
Inside/Outside Probability
Infer
In
Out
0.94
0.06

FIG. 11

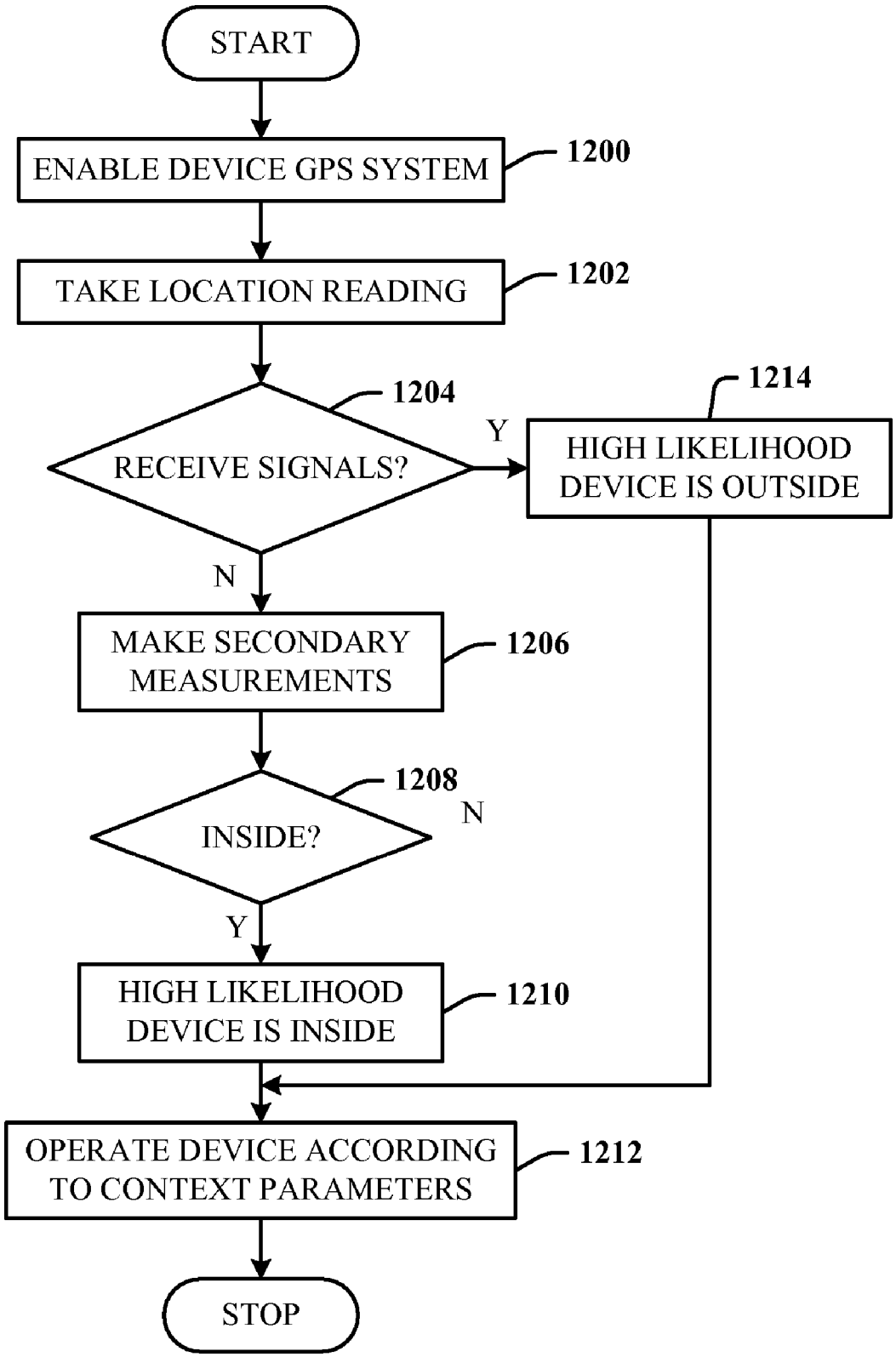
START
ENABLE DEVICE GPS SYSTEM
1200
TAKE LOCATION READING
1202
1204
RECEIVE SIGNALS?
Y
1214
HIGH LIKELIHOOD DEVICE IS OUTSIDE
N
MAKE SECONDARY MEASUREMENTS
1206
1208
INSIDE?
N
Y
HIGH LIKELIHOOD DEVICE IS INSIDE
1210
OPERATE DEVICE ACCORDING TO CONTEXT PARAMETERS
1212
STOP

FIG. 12

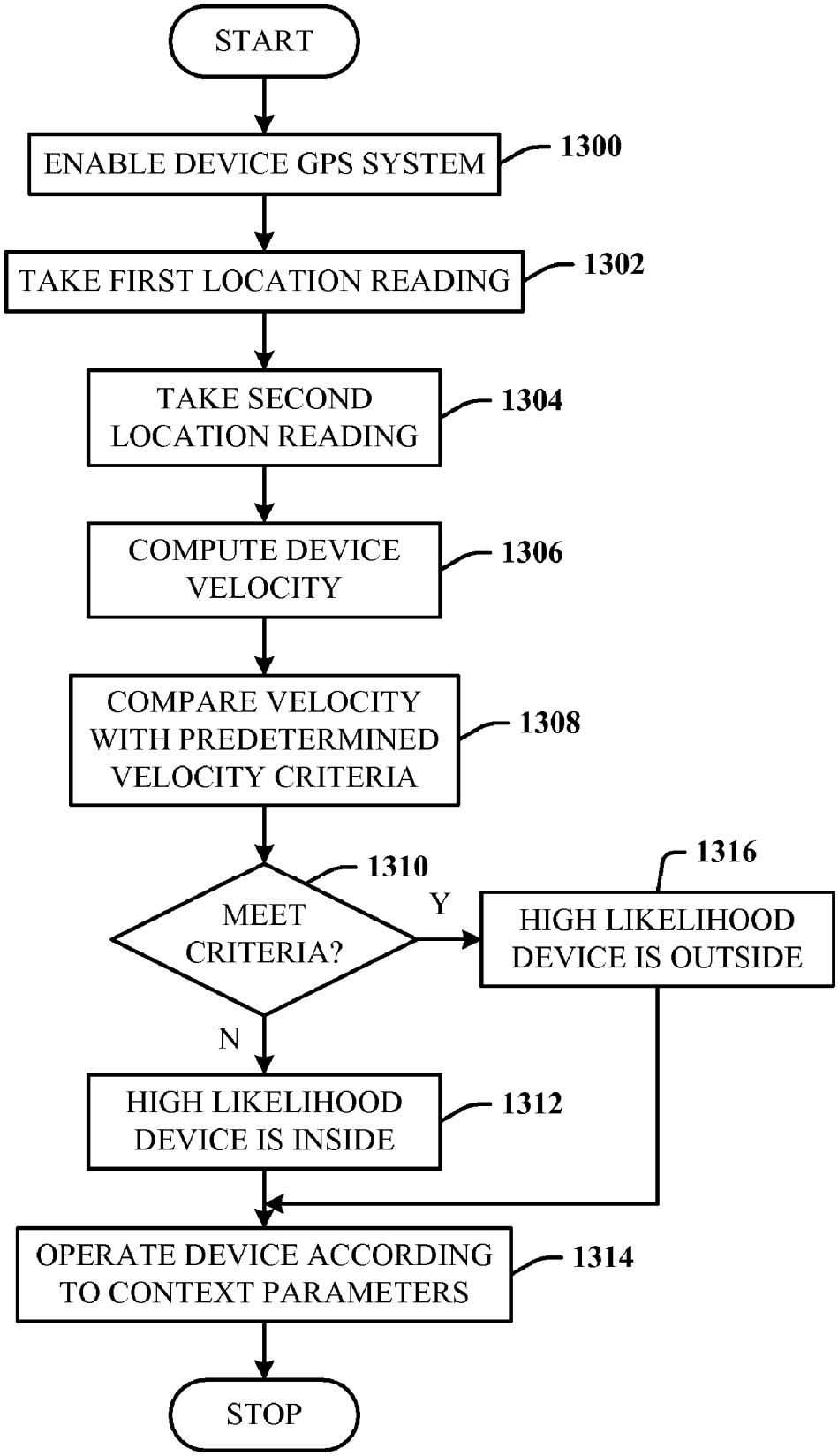
START
ENABLE DEVICE GPS SYSTEM
1300
TAKE FIRST LOCATION READING
1302
TAKE SECOND LOCATION READING
1304
COMPUTE DEVICE VELOCITY
1306
COMPARE VELOCITY WITH PREDETERMINED VELOCITY CRITERIA
1308
MEET CRITERIA?
1310
Y
N
HIGH LIKELIHOOD DEVICE IS OUTSIDE
1316
HIGH LIKELIHOOD DEVICE IS INSIDE
1312
OPERATE DEVICE ACCORDING TO CONTEXT PARAMETERS
1314
STOP

FIG. 13

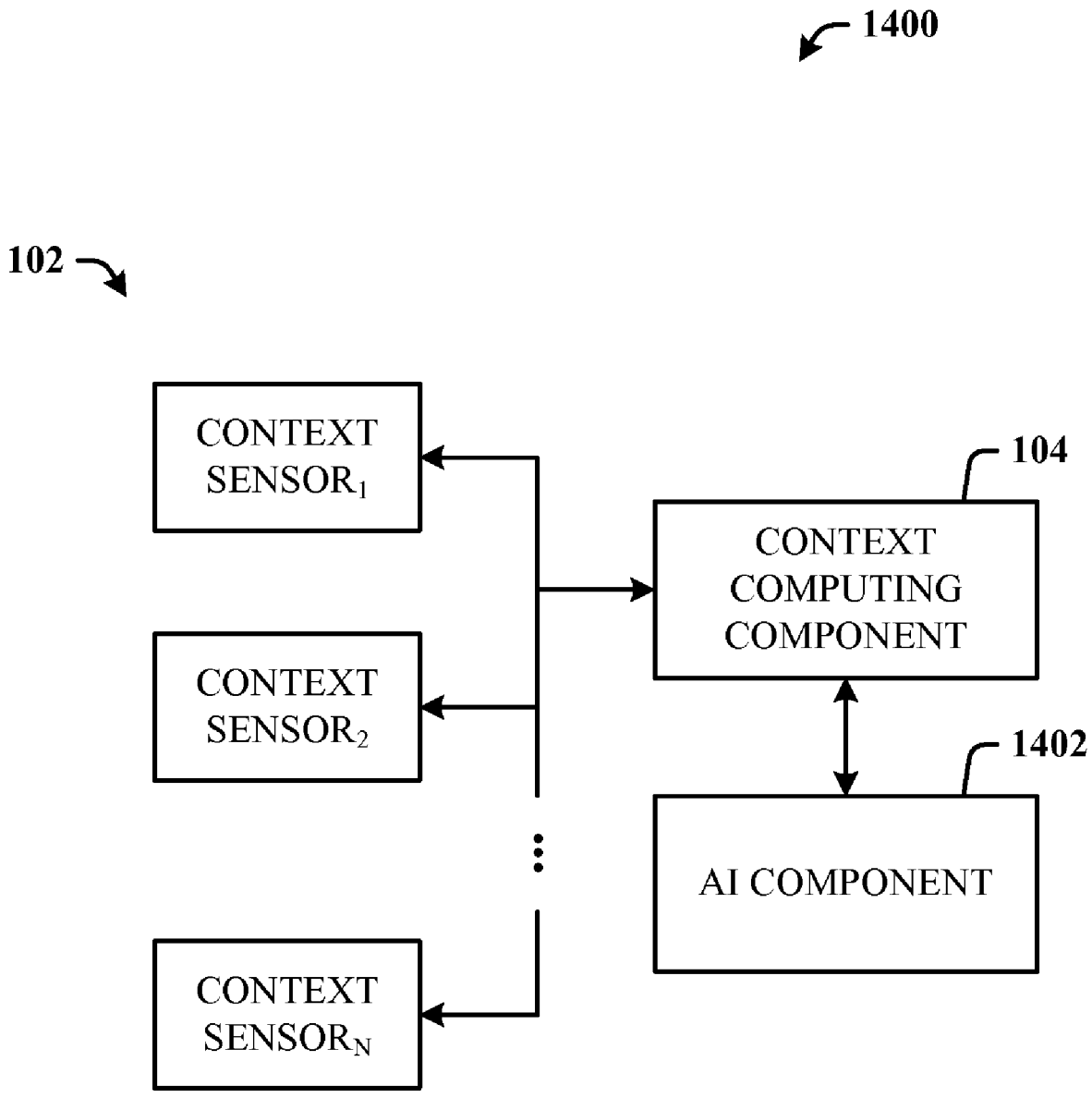
1400
102
CONTEXT SENSOR$_1$
CONTEXT SENSOR$_2$
CONTEXT SENSOR$_N$
104
CONTEXT COMPUTING COMPONENT
1402
AI COMPONENT

FIG. 14

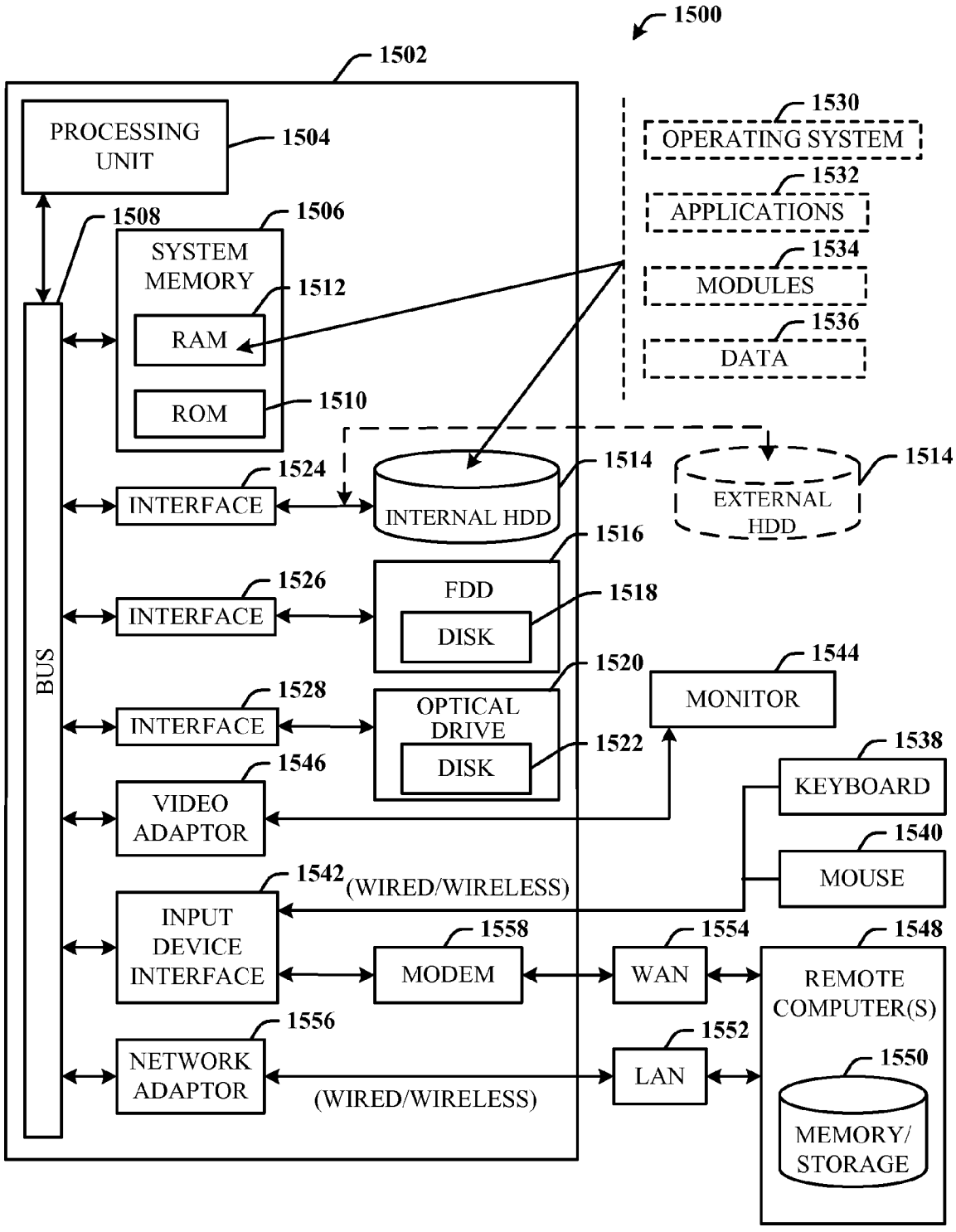
1500
1502
PROCESSING UNIT
1504
1530
OPERATING SYSTEM
1532
APPLICATIONS
1534
MODULES
1536
DATA
1508
1506
SYSTEM MEMORY
1512
RAM
ROM
1510
1524
INTERFACE
INTERNAL HDD
1514
EXTERNAL HDD
1514
1516
1526
INTERFACE
FDD
DISK
1518
BUS
1520
1544
MONITOR
1528
INTERFACE
OPTICAL DRIVE
DISK
1522
1538
KEYBOARD
1546
VIDEO ADAPTOR
1540
MOUSE
1542
(WIRED/WIRELESS)
INPUT DEVICE INTERFACE
1558
MODEM
1554
WAN
1548
REMOTE COMPUTER(S)
1556
NETWORK ADAPTOR
1552
LAN
1550
(WIRED/WIRELESS)
MEMORY/ STORAGE

FIG. 15

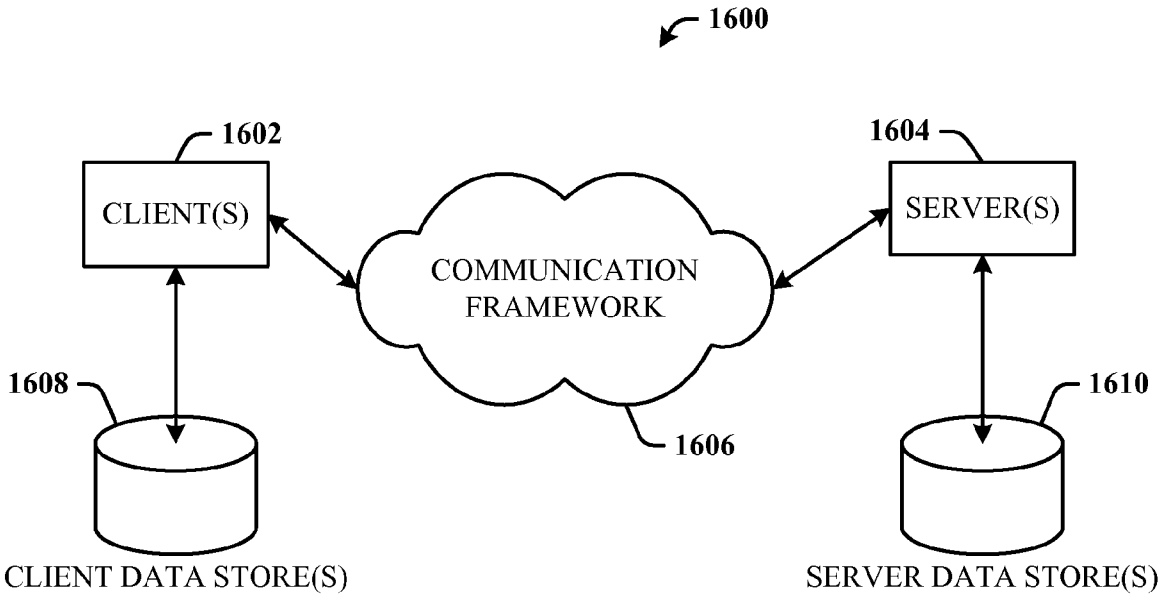
1600
1602
CLIENT(S)
1604
SERVER(S)
COMMUNICATION FRAMEWORK
1606
1608
1610
CLIENT DATA STORE(S)
SERVER DATA STORE(S)

FIG. 16

SENSING AND ANALYSIS OF AMBIENT CONTEXTUAL SIGNALS FOR DISCRIMINATING BETWEEN INDOOR AND OUTDOOR LOCATIONS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. patent application Ser. No. 10/994,550, filed on Nov. 22, 2004, now U.S. Pat. No. 7,327,245, and entitled SENSING AND ANALYSIS OF AMBIENT CONTEXTUAL SIGNALS FOR DISCRIMINATING BETWEEN INDOOR AND OUTDOOR LOCATIONS, the entirety of which is incorporated herein by reference.

TECHNICAL FIELD

This invention is related to sensing mechanisms, and more specifically, sensing mechanisms employed in portable devices to sense changes in device location.

BACKGROUND OF THE INVENTION

As computing moves off the desktop into the hands of mobile users, it is becoming more important for mobile devices to be aware of the user's context. Important pieces of context include the user's location, activities, nearby people and devices, and mode of transportation, if any. This knowledge can in turn be used by mobile devices to display reminders, to configure themselves for use with other devices, and to behave in a way that is appropriate for the surrounding environment (e.g., turn off cell phone ringer) or subcontexts of the surrounding environment such as whether particular states or transitions among states are occurring within the environment.

One significant aspect of context concerns whether or not the user (and the device) is inside or outside of a building or structure. For example, knowledge of such information can be used to facilitate determining the user's location (e.g., in a building or structure, in a particular building or structure, or in one of a set of known buildings or structures) and the user's mode of transportation (e.g., in a bus, car or airplane). Such knowledge can also be used to conserve power on systems that do not provide useful services inside buildings or outside. For example, because GPS typically fails to operate inside because satellite signals are not available inside, determination of the likelihood that a user is inside can be used to turn off a GPS system or put the system into a mode where it probes for satellite signals periodically so as to conserve the batteries of the GPS system.

One way to make an inside/outside determination would be to use a digital map of building footprints along with knowledge of the user's location or recent location. However, for most buildings such a map does not exist. Additionally, location data is not necessarily available, especially inside a structure where GPS typically fails.

In view of the foregoing, there is an unmet need for an improved technique to glean information regarding such inside/outside context of a device and/or an individual.

SUMMARY OF THE INVENTION

The following presents a simplified summary of the invention in order to provide a basic understanding of some aspects of the invention. This summary is not an extensive overview of the invention. It is not intended to identify key/critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented later.

The invention disclosed and claimed herein, in one aspect thereof, comprises architecture for automatically determining and/or inferring if a device or individual is inside or outside is provided. The system can employ one or more sensors to detect ambient conditions, and make such determination and/or inference. The system can include one or more context sensors that measure parameters of a first context of a device. A context computing component interfaces to the one or more context sensors and facilitates determination of a change from the first context to a second context. Knowledge of such context transition can for example be used to save power in certain devices, which may not be used or even function in certain states (e.g., darkness).

In another aspect of the subject invention, the system generates probability distributions which are mathematically combined to ultimately derive a probability inference that the device is inside or outside.

In yet another aspect, the sensors can include devices suitable for measuring temperature, light frequency, radio frequency (e.g., 60 Hz or 50 Hz electromagnetic signals emitted from local power lines, systems, lights, and appliances, IEEE 802.11 Wi-Fi signals, AM and FM radio, or GPS satellite signals), capturing images or image flows, location data (e.g. GPS location analysis), pressure, humidity, and audio signals.

In still another aspect thereof, a machine learning and/or inferential component enable a probabilistic and/or statistical-based analysis to prognose or infer an action that a user desires to be automatically performed based in part on the likelihood that a user is indoors or outdoors.

To the accomplishment of the foregoing and related ends, certain illustrative aspects of the invention are described herein in connection with the following description and the annexed drawings. These aspects are indicative, however, of but a few of the various ways in which the principles of the invention can be employed and the subject invention is intended to include all such aspects and their equivalents. Other advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a system that determines device context in accordance with the subject invention.

FIG. **2** illustrates a methodology of differentiating between inside and outside in accordance with the invention.

FIG. **3** illustrates shows a device that employs one or more sensors and the context computing component for inside/outside determination according to the invention.

FIG. **4** illustrates a methodology of deriving probability distributions when using temperature as a means for determining device context in accordance with the invention.

FIG. **5** illustrates the probability distribution for the temperature sensor.

FIG. **6** illustrates a graph of RMS temperature error as a function of a weighting component that gives an optimal exponent.

FIG. **7** illustrates shows a graph that represents a histogram of errors.

FIG. **8** illustrates an alternative methodology of deriving an approximation that classifies whether the device is inside or outside, in accordance with the invention.

FIG. **9** illustrates the behavior of the equation as the outside temperature varies.

FIG. **10** illustrates of a graph that simulates an outside and inside temperature both equal to the mean inside temperature.

FIG. **11** illustrates a user interface that facilitates temperature-based inside/outside determination in accordance with the invention.

FIG. **12** illustrates a methodology of using GPS to determine the inside/outside location of a device based on the GPS signal, in accordance with the invention.

FIG. **13** illustrates a methodology of using GPS to determine the inside/outside location of a device based on speed, in accordance with the invention.

FIG. **14** illustrates a context computing system that includes artificial intelligence for learning and automating features thereof in accordance with the invention.

FIG. **15** illustrates a block diagram of a computer operable to execute the disclosed architecture.

FIG. **16** illustrates a schematic block diagram of an exemplary computing environment in accordance with the subject invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention is now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the subject invention. It may be evident, however, that the invention can be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate describing the invention.

As used in this application, the terms "component" and "system" are intended to refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution. For example, a component can be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on a server and the server can be a component. One or more components can reside within a process and/or thread of execution, and a component can be localized on one computer and/or distributed between two or more computers.

As used herein, the term to "infer" or "inference" refer generally to the process of reasoning about or inferring states of the system, environment, and/or user from a set of observations as captured via events and/or data. Inference can be employed to identify a specific context or action, or can generate a probability distribution over states, for example. The inference can be probabilistic—that is, the computation of a probability distribution over states of interest based on a consideration of data and events. Inference can also refer to techniques employed for composing higher-level events from a set of events and/or data. Such inference results in the construction of new events or actions from a set of observed events and/or stored event data, whether or not the events are correlated in close temporal proximity, and whether the events and data come from one or several event and data sources.

While certain ways of displaying information to users are shown and described with respect to certain figures, those skilled in the relevant art will recognize that various other alternatives can be employed. The terms "screen," "web page," and "page" are generally used interchangeably herein. The pages or screens are stored and/or transmitted as display descriptions, as graphical user interfaces, or by other methods of depicting information on a screen (whether personal computer, PDA, mobile telephone, or other suitable device, for example) where the layout and information or content to be displayed on the page is stored in memory, database, or another storage facility.

Context Classification

A technique for inside/outside classification that exploits one or more sensor measurements on which to base such classification is described herein. For example, the fact that inside environments are normally temperature-controlled can be exploited as one means for making this determination. If a mobile device can measure ambient temperature, and if it has knowledge of or obtains the current outside temperature, it can determine or infer whether or not it is indoors or outdoors. Outside temperature information can be obtained from a database of worldwide outside temperature data maintained based on hourly updates from, for example, the American National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS). If the device's ambient temperature is within a range of normal inside temperatures, and if the outside temperature is significantly different, then there is a high probability that the device is inside. If, on the other hand, the device's ambient temperature is closer to the local outside temperature, then the device is more likely outside.

One attractive characteristic of this technique is the simplicity of the required sensing. Temperature can be measured easily with a small inexpensive sensor that draws power from the mobile device. Knowledge of outside temperature typically requires that the device obtain information as to its general location. But, typically since temperature varies marginally across relatively long geographic distances, the location estimate need not be extremely accurate. For example, the system can use location information described in terms of U.S. postal codes. In another implementation, the location information can be derived by GPS (Global Positioning System) location techniques. Such approximate location metrics can often provide temperature information suitable for making determinations described herein.

While it is clear that determining device location by temperature differentiation can be difficult in locations where the inside and outside temperatures have little differentiation, the disclosed technique still provides a high degree of correctness by reasoning mathematically about the temperature distributions, a probability of being inside, which reflects the uncertainty caused by similar inside and outside temperatures.

The certainty of inside/outside inferences is strongly related to the certainty of three different temperature distributions: measured ambient temperature from the device, expected inside temperature, and outside temperature interpolated from weather stations. These distributions are combined mathematically to create a probability estimate of being inside or outside.

It is noted other kinds of containment within indoor and outdoor locations are contemplated to enhance the accuracy of inferences about indoor and outdoor, and such considerations as the role of the sensed temperature at a device, and the typical indoor temperatures, and the current measured outdoor temperature. For example, it can be considered whether the device is likely to be inside an automobile based on the signals from accelerometers, and thus interpret appropriately the signals about the difference between typical indoor temperatures and the current outdoor temperature in a region. Likewise, the output of accelerometers, the time of day and the amount of light reaching a photosensor on a device, as well as the differences in the temperatures on different

facades of a device via the use of multiple temperature sensors are within contemplation of the subject invention to determine whether a device is in a person's pocket, thus changing the interpretation of differences between the measured outdoor temperature and indoor signals, and inferences about the overall context.

FIG. **1** illustrates a system **100** that determines device context in accordance with the subject invention. The system **100** includes one or more sensors **102** (denoted CONTEXT $SENSOR_1$,CONTEXT $SENSOR_2$, . . . , CONTEXT $SENSOR_N$) that measure physical differences between inside and outside environments. For example, one sensor can be a temperature sensing device. Another can be a pressure sensing device for sensing changes in altitude. The one or more sensors **102** communicate sensor data to a context computing component **104** over a pathway **106** for processing and deriving the probability estimate. The one or more sensors **102** and context computing component **104** can be employed in the device such that all sensing and processing is performed conveniently and quickly. Note however, that such one or more sensors **102** need not be in the same enclosure as the context computing component **104**, but can be operated in wireless communications therewith over the pathway **106**.

In one implementation of the context architecture, a GPS receiver can be automatically turned off or put into a mode where the device only turns on periodically to see if it can sense GPS signals, and if it does not sense GPS, turns itself off after the brief periodic probes, when it is determined that it is likely that the device is inside a building, because GPS does not typically work inside, thus saving power. Other sensing, via ambient sources or via specialized embedded sensing can be used to guide policies for changing a power-saving policy. For example, accelerometers can be combined with the inference and such policies as turning off a GPS receiver because the absence of sensed motion after a system is determined to be inside means that it is likely that the system is still inside. Sensing motion via accelerometers or the sensing of sudden changes in light, or changes in such ambient signals as the strength of wireless signals (e.g., IEEE 802.11), the strength of commercial AM or FM radio transmissions, or even changes in the amplitude of electromagnetic hum from nearby power systems or lines, can raise the likelihood of a context changing from inside to outside, and thus can be used to turn on a GPS system or temporarily increase the frequency of probes for GPS signals, in a device that had either been turned off or put into a low-frequency intermittent probe mode.

Additionally, knowing a person's context can be important for invoking automatic behaviors on the device. As one example, if a person is scheduled for a meeting that may or may not be attended, but the context is that he/she is outside, the person is likely not in a meeting, indicating that the person may be less busy than he or she would have been if they were attending an indoor meeting that is scheduled on their calendar. Thus, the person may be more available for receiving a telephone call on that person's cell phone.

In another example, the context architecture can be useful for adding metadata to digital photos potentially serving as a way to filter photos in a search, and as a component of higher-level context inference for ubiquitous computing. For example, an assertion about whether a picture was taken indoors or outdoors or a likelihood that a user was indoors can be encoded in metadata, and if indoors, a database of potential locations based on the latest sensed GPS location can be used to add a single or multiple candidate locations to the metadata. In one conception, such metadata can be used to allow user's to disambiguate a location for a set of pictures by changing a location guess to an assertion for a set of images. Such metadata about indoor and outdoor likelihoods can be combined with image-based classification about whether a picture represents an indoor or outdoor scene.

The availability of GPS signals is also a valuable signal about whether a user is indoors or outdoors. However, the lack of GPS signals can occur outside as well as inside because of GPS signal "shadows" caused by obstructions such as a building. The lack of GPS signals can be combined with historical maps of GPS shadows that have been logged in the past to guide the interpretation of the lack of GPS signals in inferring whether or not a device is inside or outside. Such signals can be used in conjunction with other ambient signals.

Referring now to FIG. **2**, a methodology for differentiating between inside and outside in accordance with the invention is described. While, for purposes of simplicity of explanation, the one or more methodologies shown herein, e.g., in the form of a flow chart, are depicted and described as a series of acts, it is to be understood and appreciated that the methodology(s) are not limited by the order of acts, as some acts may, in accordance with the invention, occur in a different order and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a methodology in accordance with the invention.

At **200**, context data of a first context is determined. At **202**, a confidence estimation is computed from the second context data. At **204**, context data of a second context is determined. At **206**, a confidence estimation is computed from the second context data. At **208**, the ambient data (e.g., temperature is determined via the device. At **210**, a probability estimation is computed which provides an inference of whether the device is inside or outside. At **212**, the device or its components are then operated accordingly.

FIG. **3** illustrates a device **300** that employs one or more sensors and the context computing component **104** for inside/outside determination. A variety of sensors can be used collectively and/or as subsets thereof to facilitate discriminating inside from outside. At **302**, a temperature sensor is used—inside building temperatures are normally artificially maintained in a range comfortable for their human occupants. Outside temperatures vary with location and the local weather, and can be determined by consulting updated temperature data maintained on the Internet. The device measures ambient temperature and can consult a web service to determine the outside temperature at its location.

Location data can be manually entered or determined from GPS or other location-measuring device. If the measured ambient temperature is significantly different from the outside temperature, and if the measured ambient temperature is in the range of normal inside temperatures, then the device is likely inside. If the measured ambient temperature is close to the local outside temperature, and if this temperature is significantly different from the normal range of inside temperatures, then the device is likely outside. If the measured ambient and outside temperatures are in the range of normal inside temperatures, then the inside/outside determination is uncertain.

At **304**, light frequency can be measured. The color of typical inside and outside light is different. Outside, sunlight is received directly or filtered through clouds or haze. Inside, sunlight is filtered through windows, and much inside light is generated artificially. A sensor that measures the local illumination spectrum can serve as an input to an algorithm that

reasons about typical spectra of inside and outside light to discriminate inside from outside. At **306**, radio frequency information can be sensed. Buildings are normally bathed in 60 Hz signals or "hum" (50 Hz in some countries) that is generated inadvertently by alternating current (AC) carrying wiring and devices. Except for near power lines, outside does not experience this hum as strongly. Thus, measuring the strength of 50/60 Hz hum can be used to discriminate inside from outside.

At **308**, a change in altitude can be used to determine if the device is inside or outside. A pressure sensing device (e.g., a barometer) can be used as a means for testing altitude. If the altitude differentiation changes in a relatively short period of time, the device is likely in a structure. At **310**, imaging information can be captured and processed using a camera. Inside, looking up normally gives a view of a ceiling, while outside looking up normally gives a view of the sky. Thus, computer vision techniques can be used to discriminate the color and normally structured patterns of an inside ceiling from the color and unstructured patterns of the sky based on a camera image taken from the device.

At **312**, GPS information can be utilized in at least two ways. GPS typically fails inside buildings or structures. If it does fail, this is a good clue that the device is inside, although failures also come from foliage and other overhanging objects. Additionally, two adjacent GPS readings can be used to compute the device's speed. If the speed is greater than a predetermined threshold, the device is likely not inside, but outside on a bicycle or in a car, for example.

At **314**, humidity measurements can be used. Typically, there is a marked change from inside and outside humidity. Buildings are conditioned to maintain comfort for its occupants or an environment for equipment, or both, which can also have a significant effect on the humidity. Thus, a humidity sensor can be used to differentiate between inside and outside. At **316**, audio signals can be used. Sounds unique to inside consist of droning machines like fans from HVAC, refrigerators, and computers. Unique outside sounds consist of wind, passing vehicles, and chirping birds. Processing these audio "scenes" can be used to detect the unique sounds and to discriminate inside from outside. In a more robust implementation, echoes can be sensed as a means for determining inside from outside.

Probability distributions are employed to determine a probability inference that the device is located inside or outside. One advantage of the disclosed probabilistic formulation is that the technique accurately reports its own confidence in the classification. The inside/outside inference is a function of three different temperatures: the measured ambient temperature, the outside temperature, and the inside temperature. All three are described by probability distributions that are used to compute the probability of being inside. A description of how the three probability distributions are derived is described below. Note that the probabilistic inference described herein takes a closed form if the three probability distributions are Gaussian. Thus, the distributions are modeled as such herein, although this is not a requirement.

FIG. **4** illustrates a methodology of deriving probability distributions when using temperature as a means for determining device context. At **400**, the device is moved to a location, and the expected outdoor temperature for that location is determined. As indicated supra, this can be accomplished by accessing a weather database for weather information at the location of the device. For example, the zip code at the device location can be used to retrieve weather information. At **402**, a probability distribution for the outside temperature at that location is computed. At **404**, the expected inside temperature is determined. At **406**, a probability distribution for the inside temperature at that location is computed. At **408**, the device measures the ambient inside temperature. At **410**, the probability distribution for the device accuracy is then computed. At **412**, all three distributions are used to compute a probability inference that the device is inside. At **414**, the device is operated according to the inference.

As an example of the temperature application, a thermometer was used having an advertised accuracy of ±0.28° C. over a range of −28.9° C. to 48.9° C. (−20° F. to 120° F.). The uniform distribution for this sensor over ±0.28° C. is assumed to be a Gaussian distribution with the same variance. FIG. **5** illustrates a Gaussian probability distribution with a same mean and variance which can be utilized for the temperature sensor. The variance of a uniform distribution over [a,b] is

$$\sigma^2 = \int_a^b x^2/(b-a)\,dx = (b-a)^2/12 \tag{1}$$

From the thermometer's accuracy specification, (a,b)=(−0.28° C., 0.28° C.), giving σ_m=0.162. Thus, the distribution of actual temperatures t_a is $t_a \sim N\{t_m, \sigma_m^2\}$, where t_m is the temperature measured with the mobile device, and $N\{\mu, \sigma^2\}$ represents a normal distribution.

The inside temperature of a building of interest can be measured with an inside thermometer connected to a network and used as part of the system. This requires extra infrastructure, however, so dependence herein is on the fact that building temperatures normally vary over only a small range. Buildings are usually temperature-controlled for the comfort of their occupants, with obvious exceptions for saunas, wine cellars, etc. In lieu of temperature data from a large sample of buildings, an ISO standard 7730 provides that temperatures of commercial buildings are limited to 20-24° C. in winter and 23-26° C. in summer. Thus, the temperature range (a,b)=(20° C., 26° C.) can be modeled as a normal distribution with a variance of Equation (1) above and a mean that splits the range. This results with μ_{in}=23 and σ_{in}=1.732, with inside temperature t_{in} distributed as $t_{in} \sim N\{\mu_{in}, \sigma_{in}^2\}$.

One manner to obtain the local outside temperature is to equip areas of interest with networked-connected thermometers. For instance, if a nursing home desired to monitor if any of its residents left the building, it could use a thermometer installed immediately outside. Another method is to exploit thermometers that are already in place. There are approximately 6510 weather stations located around the world. Hourly updates from these stations are gathered by the American NOAA's National Weather Service and made available as METAR reports. A server can be provided that accesses and stores the latest data from each of these stations by hourly downloading the latest METAR summary file.

As part of the inside/outside inference, the user specifies the device location in order to compute the outside temperature. Since temperature varies only slowly as a function of location, the measured location does not need be highly specific (an approximate location can provide suitable temperature data). It is sufficient to obtain the last known latitude/longitude reading from a GPS receiver or, in the U.S., the postal code which can be converted to the latitude/longitude via a web service that accesses a database of postal codes and associated latitude/longitude information.

Given a latitude/longitude reading, interpolation can be used to compute the local temperature. In one implementation, a choice of interpolation scheme is optimal inverse dis-

tance weighting. This technique interpolates temperature at a point of interest as a weighted average of all the known temperatures. The weights are the reciprocals of the distances between the known points and the point of interest, raised to some power that is computed by experiment. It is to be appreciated, however, that other interpolation schemes can be used. Mathematically, the outside temperature t_{out}* is computed as

$$t^*_{out} = \frac{\sum_{i=1}^{n} t_i / d_i^r}{\sum_{i=1}^{n} 1 / d_i^r}, \quad (2)$$

where t_i is the temperature reported from the i^{th} weather station, d_i is the distance between the point of interest and the i^{th} weather station, n is the number of weather stations, and r is the experimentally determined optimal exponent. d_i can be computed because the METAR reports give the (latitude, longitude) of each weather station.

The best r is computed based on twenty-four consecutive hours of temperature data from all the weather stations, excluding the inevitable missing reports from some stations. For each hour time slice, a leave-one-out procedure is used to estimate the interpolation error. Leaving out one weather station, all of the other weather stations are used to estimate its temperature. Taking each station and each hour in turn, an RMS interpolation error is computed. By exhaustively searching through different values of r, the minimum RMS exponent was determined to be r=2.65. FIG. **6** illustrates a graph of RMS temperature error as a function of a weighting component that gives an optimal exponent.

To estimate the error distribution of outside temperature, the same leave-one-out procedure can be used as above and a histogram of errors created. FIG. **7** depicts a graph that represents a histogram of errors. Errors above 10° C. and below −10° C., were eliminated before computing the error statistics, which amounted to about 3% of the data. This provides a better-fitting Gaussian distribution, also shown in FIG. **7**. Since this error distribution has a mean of approximately zero (actually −0.4° C.), and a standard deviation of σ_{out}=2.545, the distribution of interpolated outside temperatures is modeled as

$$t_{out} \sim N\{t^*_{out}, \sigma^2_{out}\}, \quad (3)$$

where t_{out}* is the interpolated temperature for the given location.

In one implementation, two web services can be created to facilitate access to interpolated outside temperatures. The first web service, mentioned above, converts U.S. postal codes into latitude and longitude data. A second web service can employ latitude/longitude data and return the outside temperature using for example the interpolation equation (2) above.

Based on the three temperature distributions above, a goal is to derive an equation that provides the probability of being inside based on the measured ambient temperature and interpolated outside temperature. Using Bayes' rule, the probability of being inside, given the measured ambient temperature t_m, is:

$$p(in \mid t_m) = \frac{p(t_m \mid in)p(in)}{p(t_m \mid in)p(in) + p(t_m \mid out)p(out)} \quad (4)$$

For lack of any prior assumptions, it is assumed the prior probabilities p(in)=p(out)=0.5.

Measured Temperature Conditioned on Inside. The first state conditional probability in Equation (4) is $p(t_m|in)$, which is the probability of the measured temperature t_m given that the device is inside. This is a function of the actual ambient temperature, t_a, which we do not know. The joint conditional probability distribution $p(t_m,t_a|in)$ is introduced, and the actual temperature integrated out to compute the desired probability:

$$p(t_m \mid in) = \int_{-\infty}^{\infty} p(t_m, t_a \mid in)\, dt_a = \int_{-\infty}^{\infty} p(t_a \mid in)\, p(t_m \mid t_a, in) dt_a \quad (5)$$

The distribution $p(t_a|in)$, reduces to the normal distribution governing inside temperatures:

$$p(t_a \mid in) = p(t_a) = N\{t_a; \mu_{in}, \sigma^2_{in}\} \quad (6)$$

where $N\{x; \mu, \sigma^2\}$ is the Gaussian density function:

$$N\{x; \mu, \sigma^2\} = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \quad (7)$$

The distribution $p(t_m|t_a,in)$ represents the accuracy of our thermometer, and reduces as follows:

$$p(t_m \mid t_a, in) = p(t_m \mid t_a) = N\{t_a; t_m, \sigma^2_{in}\} \quad (8)$$

Continuing from equation (5) using the resultant normals from equations (6) and (8), the closed form is provided:

$$\begin{aligned} p(t_m \mid \text{in}) &= \int_{-\infty}^{\infty} p(t_m, t_a \mid in)\, dt_a \\ &= \int_{-\infty}^{\infty} p(t_a \mid in)\, p(t_m \mid t_a, in) dt_a \\ &= \int_{-\infty}^{\infty} N\{t_a; \mu_{in}, \sigma^2_{in}\} N\{t_a; t_m, \sigma^2_m\}\, dt_a \\ &= N\{\mu_{in}; t_m, \sigma^2_{in} + \sigma^2_m\} \end{aligned} \quad (9)$$

The last step comes from an identity,

$$\int_{-\infty}^{\infty} N\{x;\mu_1,\sigma_1^2\}N\{x;\mu_2,\sigma_2^2\}dx = N\{\mu_1;\mu_2,\sigma_1^2+\sigma_2^2\} \quad (10)$$

Equation (9) is intuitively satisfying in that the maximum of $p(t_m|in)$ occurs at the mean inside temperature μ_{in}. The function broadens and falls with increases in the uncertainty of the inside temperature (σ_{in}^2) and the uncertainty of the measured temperature (σ_m^2).

Measured Temperature Conditioned on Outside. The other conditional probability from equation (4) is $p(t_m|out)$, which is the probability of the measured temperature given that the device is outside. Proceeding as above, the following closed form is derived:

$$\begin{aligned} p(t_m|out) &= \int_{-\infty}^{\infty} p(t_m, t_a|out)dt_a \\ &= \int_{-\infty}^{\infty} p(t_a|out)p(t_m|t_a, out)dt_a \\ &= \int_{-\infty}^{\infty} N\{t_a; t^*_{out}, \sigma^2_{out}\}N\{t_a; t_m, \sigma^2_m\}dt_a \\ &= N\{t^*_{out}; t_m, \sigma^2_{out}+\sigma^2_m\} \end{aligned} \quad (11)$$

Inside/Outside Probability vs. Measured Temperature. Substituting equations (9) and (11) into (4) yields a closed form for the probability of being inside given a measured temperature and an interpolated outside temperature:

$$p(in|t_m) = \frac{N\{\mu_{in}; t_m, \sigma^2_{in}+\sigma^2_m\}}{N\{\mu_{in}; t_m, \sigma^2_{in}+\sigma^2_m\} + N\{t^*_{out}; t_m, \sigma^2_{out}+\sigma^2_m\}} \quad (12)$$

And $p(out|t_m)=1-p(in|t_m)$. This is a closed form solution for computing the probability of being inside or outside based on these parameters, all in ° C.:

t_m	Temperature measured on mobile device
$\sigma_m = 0.162$	Standard deviation of measured temperature
$\mu_{in} = 23$	Mean of expected inside temperature
$\sigma_{in} = 1.732$	Standard deviation of expected inside temperature
t_{out}*	Outside temperature interpolated from weather stations
$\sigma_{out} = 2.545$	Standard deviation of outside temperature

Thus, one need only provide the measured temperature value t_m and the outside temperature value t_{out}* to arrive at the probability of the device being inside and outside.

FIG. **8** illustrates an alternative methodology of deriving an approximation that classifies whether the device is inside or outside in accordance with the invention. At **800**, the probability distributions for the measured ambient temperature and the expected outside temperature are compared. At **802**, if the difference is significant, at **804**, the probability distributions for the measured ambient temperature and the normal range of outside temperatures are compared. At **806**, if the resulting value is within a predetermined range of values, flow progresses to **808** where it is determined with a high probability that the device is inside. At **810**, the device is then operated accordingly.

At **802**, if the difference of the comparison performed at **800** is not significant, there is a high probability that the device is outside, as indicated at **812**. Moreover, if the comparison at **804** indicates that the results are not within the predetermined range of values, there is a high probability that the device is outside, as indicated at **812**. In either case, flow is to **810** to operate the device according to the context parameters.

To demonstrate equation (12) in practice, two different people and associated devices are simulated using the technique, one inside and one outside. The ambient inside temperature is provided at $t_{in}=\mu_{in}=23$, and the person inside measures it as exactly this value. FIG. **9** illustrates the behavior of the equation as the outside temperature varies from −20° C. (−4° F.) to 40° C. (104° F.), which the person outside measures exactly. The solid line shows the computed probability of the outside person being outside as the outside temperature changes. The probability remains high as long as the outside temperature is different enough from the inside temperature. As expected, the probability of being outside drops when the inside and outside temperatures are similar. The dotted line shows the computed probability of the inside person being inside. This probability also drops when the inside and outside temperatures are similar.

The simulation above confirms that the probabilities rise and fall as expected. The amount of rise and fall is a function of the temperature uncertainties. The probability of the inside person being inside never drops below 0.5, even when the inside and outside temperatures are equal. This is because the uncertainty of the outside temperature ($\sigma_{out}=2.545$) is larger than the uncertainty of the inside temperature ($\sigma_{in}=1.732$). Qualitatively, when the measured temperature is close to the expected inside temperature, the probability computation attributes more weight to the inside hypothesis, because the actual outside temperature can deviate more from the measured temperature than the inside temperature can. FIG. **10** illustrates a graph that simulates an outside and inside temperature both equal to the mean inside temperature $\mu_{in}=23$. When the ratio σ_{in}/σ_{out} is low, confidence in the inside temperature is higher, which biases the probability toward being inside. At $\sigma_{in}=\sigma_{out}$, the probability of being inside is 0.5. When σ_{in}/σ_{out} grows beyond 1.0, the probability of being inside drops below 0.5.

FIG. **11** depicts a user interface that facilitates temperature-based inside/outside determination in accordance with the invention. In the upper left the user provides the current location in the form of latitude/longitude data. Optionally, the user can input a U.S. postal code which is converted to latitude/longitude data via access to a web service. In the middle left box, the user clicks a GET button to call a temperature service for outside temperature data based on the latitude/longitude given above. In the lower left box, the user clicks a GET button to obtain an ambient temperature measurement from a connected temperature sensor. On the right, clicking an INFER button invokes the computation of equation (12) and the drawing of the bars indicating the probabilities of inside and outside. Here, the bars represent that there is a high probability that the device is inside.

FIG. **12** illustrates a methodology of using GPS to determine the inside/outside location of a device based on the GPS signal. At **1200**, GPS is enabled on the device. At **1202**, GPS is used to make a location reading of the device. At **1204**, the device determines if the location reading has been successful. If not, at **1206**, secondary measurements can be made,

although this is not necessary. If secondary measurements are made, at **1208**, the device determines if the results of the secondary measurements indicate that the device is located inside. If the secondary results indicate so, at **1210**, the system determines that there is a high probability that the device is located inside. The device is then operated according to the context parameters (being located inside), as indicated at **1212**. If, at **1204**, the GPS receiver receives signals, flow is to **1214** where the system determines that there is a high probability that the device is located outside. At **1212**, the device is then operated according to the context parameters (being located outside).

FIG. **13** illustrates a methodology of using GPS to determine the inside/outside location of a device based on speed, in accordance with the invention. At **1300**, the device GPS system is enabled to receive GPS signals. At **1302**, a first location reading is taken. Sometime later, a second location reading is taken, as indicated at **1304**. At **1306**, velocity is computed by the time differential between the location readings and the approximate distance derived from the two locations. At **1308**, the computed velocity data can be compared to predetermined criteria that indicates the device is moving faster than what would normally be considered to be inside. At **1310**, if the velocity data meets the criteria, there is a high probability that the device is located inside. Accordingly, at **1314**, the device is operated as being inside. If the velocity information does not meet the criteria, flow is to **1316** where it is determined that there is a high likelihood that the device is located outside. At **1314**, the device is then operated according to context parameters that indicate the device is outside. Note that these inferences can also be derived and utilized with the same probability analysis used for temperature hereinabove.

Referring now to FIG. **14**, a context computing system **1400** is provided that includes artificial intelligence (AI) for learning and automating features thereof in accordance with the invention. An AI component **1402** interfaces to the context computing component **104** to facilitate analysis and automation of one or more feature based on sensor data of the sensor **102** and computations of the context computing component **104**. The subject invention (e.g., in connection with selection) can employ various AI-based schemes for carrying out various aspects thereof. For example, a process for determining how many sensing devices to employ in a multi-sensor device can be facilitated via an automatic classifier system and process.

A classifier is a function that maps an input attribute vector, x=(x**1**, x**2**, x**3**, x**4**, xn), to a confidence that the input belongs to a class, that is, f(x)=confidence(class). Such classification can employ a probabilistic and/or statistical-based analysis (e.g., factoring into the analysis utilities and costs) to prognose or infer an action that a user desires to be automatically performed. A support vector machine (SVM) is an example of a classifier that can be employed. The SVM operates by finding a hypersurface in the space of possible inputs, which hypersurface attempts to split the triggering criteria from the non-triggering events. Intuitively, this makes the classification correct for testing data that is near, but not identical to training data. Other directed and undirected model classification approaches include, e.g. naïve Bayes, Bayesian networks, decision trees, neural networks, fuzzy logic models, and probabilistic classification models providing different patterns of independence can be employed. Classification as used herein also is inclusive of statistical regression that is utilized to develop models of priority.

As will be readily appreciated from the subject specification, the subject invention can employ classifiers that are explicitly trained (e.g. via a generic training data) as well as implicitly trained (e.g., via observing user behavior, receiving extrinsic information). For example, SVM's are configured via a learning or training phase within a classifier constructor and feature selection module. Thus, the classifier(s) can be used to automatically learn and perform a number of functions.

In one implementation with GPS capability, the AI component **1402** can facilitate expedited determination of whether the device is inside or outside based on the latitude/longitude data. For example, if the latitude/longitude data through repeated processes becomes associated with a location (e.g., the user's office) where the user takes the device from outside to inside many mornings at about the same time and takes the device from inside to outside in the evening, the AI component **1402** will learn this and at the expected time (either morning or evening), and according to measurements made, infer with a high probability that the device is being carried into (or out of) the office. This can add one more layer of inference to that which is derived as describer supra.

In another implementation where the device uses multiple sensors, it may be that the readings of some of the sensors yield poor results and others more accurate results for a given climate and location. Thus, the AI component **1402** can be employed to further analyze the sensor data and decide which sensor data to believe, and which to not believe.

Referring now to FIG. **15**, there is illustrated a block diagram of a computer operable to execute the disclosed architecture. In order to provide additional context for various aspects of the subject invention, FIG. **15** and the following discussion are intended to provide a brief, general description of a suitable computing environment **1500** in which the various aspects of the invention can be implemented. While the invention has been described above in the general context of computer-executable instructions that may run on one or more computers, those skilled in the art will recognize that the invention also can be implemented in combination with other program modules and/or as a combination of hardware and software.

Generally, program modules include routines, programs, components, data structures, etc., that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the inventive methods can be practiced with other computer system configurations, including single-processor or multiprocessor computer systems, minicomputers, mainframe computers, as well as personal computers, hand-held computing devices, microprocessor-based or programmable consumer electronics, and the like, each of which can be operatively coupled to one or more associated devices.

The illustrated aspects of the invention may also be practiced in distributed computing environments where certain tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules can be located in both local and remote memory storage devices.

A computer typically includes a variety of computer-readable media. Computer-readable media can be any available media that can be accessed by the computer and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media can comprise computer storage media and communication media. Computer storage media includes both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage

media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital video disk (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by the computer.

Communication media typically embodies computer-readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism, and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Combinations of the any of the above should also be included within the scope of computer-readable media.

With reference again to FIG. **15**, there is illustrated an exemplary environment **1500** for implementing various aspects of the invention that includes a computer **1502**, the computer **1502** including a processing unit **1504**, a system memory **1506** and a system bus **1508**. The system bus **1508** couples system components including, but not limited to, the system memory **1506** to the processing unit **1504**. The processing unit **1504** can be any of various commercially available processors. Dual microprocessors and other multi-processor architectures may also be employed as the processing unit **1504**.

The system bus **1508** can be any of several types of bus structure that may further interconnect to a memory bus (with or without a memory controller), a peripheral bus, and a local bus using any of a variety of commercially available bus architectures. The system memory **1506** includes read only memory (ROM) **1510** and random access memory (RAM) **1512**. A basic input/output system (BIOS) is stored in a non-volatile memory **1510** such as ROM, EPROM, EEPROM, which BIOS contains the basic routines that help to transfer information between elements within the computer **1502**, such as during start-up. The RAM **1512** can also include a high-speed RAM such as static RAM for caching data.

The computer **1502** further includes an internal hard disk drive (HDD) **1514** (e.g., EIDE, SATA), which internal hard disk drive **1514** may also be configured for external use in a suitable chassis (not shown), a magnetic floppy disk drive (FDD) **1516**, (e.g., to read from or write to a removable diskette **1518**) and an optical disk drive **1520**, (e.g., reading a CD-ROM disk **1522** or, to read from or write to other high capacity optical media such as the DVD). The hard disk drive **1514**, magnetic disk drive **1516** and optical disk drive **1520** can be connected to the system bus **1508** by a hard disk drive interface **1524**, a magnetic disk drive interface **1526** and an optical drive interface **1528**, respectively. The interface **1524** for external drive implementations includes at least one or both of Universal Serial Bus (USB) and IEEE 1394 interface technologies.

The drives and their associated computer-readable media provide nonvolatile storage of data, data structures, computer-executable instructions, and so forth. For the computer **1502**, the drives and media accommodate the storage of any data in a suitable digital format. Although the description of computer-readable media above refers to a HDD, a removable magnetic diskette, and a removable optical media such as a CD or DVD, it should be appreciated by those skilled in the art that other types of media which are readable by a computer, such as zip drives, magnetic cassettes, flash memory cards, cartridges, and the like, may also be used in the exemplary operating environment, and further, that any such media may contain computer-executable instructions for performing the methods of the invention.

A number of program modules can be stored in the drives and RAM **1512**, including an operating system **1530**, one or more application programs **1532**, other program modules **1534** and program data **1536**. All or portions of the operating system, applications, modules, and/or data can also be cached in the RAM **1512**. It is appreciated that the invention can be implemented with various commercially available operating systems or combinations of operating systems.

A user can enter commands and information into the computer **1502** through one or more wired/wireless input devices, e.g. a keyboard **1538** and a pointing device, such as a mouse **1540**. Other input devices (not shown) may include a microphone, an IR remote control, a joystick, a game pad, a stylus pen, touch screen, or the like. These and other input devices are often connected to the processing unit **1504** through an input device interface **1542** that is coupled to the system bus **1508**, but can be connected by other interfaces, such as a parallel port, an IEEE 1394 serial port, a game port, a USB port, an IR interface, etc.

A monitor **1544** or other type of display device is also connected to the system bus **1508** via an interface, such as a video adapter **1546**. In addition to the monitor **1544**, a computer typically includes other peripheral output devices (not shown), such as speakers, printers, etc.

The computer **1502** may operate in a networked environment using logical connections via wired and/or wireless communications to one or more remote computers, such as a remote computer(s) **1548**. The remote computer(s) **1548** can be a workstation, a server computer, a router, a personal computer, portable computer, microprocessor-based entertainment appliance, a peer device or other common network node, and typically includes many or all of the elements described relative to the computer **1502**, although, for purposes of brevity, only a memory storage device **1550** is illustrated. The logical connections depicted include wired/wireless connectivity to a local area network (LAN) **1552** and/or larger networks, e.g., a wide area network (WAN) **1554**. Such LAN and WAN networking environments are commonplace in offices, and companies, and facilitate enterprise-wide computer networks, such as intranets, all of which may connect to a global communication network, e.g., the Internet.

When used in a LAN networking environment, the computer **1502** is connected to the local network **1552** through a wired and/or wireless communication network interface or adapter **1556**. The adaptor **1556** may facilitate wired or wireless communication to the LAN **1552**, which may also include a wireless access point disposed thereon for communicating with the wireless adaptor **1556**.

When used in a WAN networking environment, the computer **1502** can include a modem **1558**, or is connected to a communications server on the WAN **1554**, or has other means for establishing communications over the WAN **1554**, such as by way of the Internet. The modem **1558**, which can be internal or external and a wired or wireless device, is connected to the system bus **1508** via the serial port interface **1542**. In a networked environment, program modules depicted relative to the computer **1502**, or portions thereof, can be stored in the remote memory/storage device **1550**. It will be appreciated that the network connections shown are exemplary and other means of establishing a communications link between the computers can be used.

The computer **1502** is operable to communicate with any wireless devices or entities operatively disposed in wireless communication, e.g., a printer, scanner, desktop and/or portable computer, portable data assistant, communications satellite, any piece of equipment or location associated with a wirelessly detectable tag (e.g. a kiosk, news stand, restroom), and telephone. This includes at least Wi-Fi and Bluetooth™ wireless technologies. Thus, the communication can be a predefined structure as with a conventional network or simply an ad hoc communication between at least two devices.

Wi-Fi, or Wireless Fidelity, allows connection to the Internet from a couch at home, a bed in a hotel room, or a conference room at work, without wires. Wi-Fi is a wireless technology similar to that used in a cell phone that enables such devices, e.g. computers, to send and receive data insides and out; anywhere within the range of a base station. Wi-Fi networks use radio technologies called IEEE 802.11 (a, b, g, etc.) to provide secure, reliable, fast wireless connectivity. A Wi-Fi network can be used to connect computers to each other, to the Internet, and to wired networks (which use IEEE 802.3 or Ethernet). Wi-Fi networks operate in the unlicensed 2.4 and 5 GHz radio bands, at an 11 Mbps (802.11a) or 54 Mbps (802.11b) data rate, for example, or with products that contain both bands (dual band), so the networks can provide real-world performance similar to the basic 10BaseT wired Ethernet networks used in many offices.

Referring now to FIG. **16**, there is illustrated a schematic block diagram of an exemplary computing environment **1600** in accordance with the subject invention. The system **1600** includes one or more client(s) **1602**. The client(s) **1602** can be hardware and/or software (e.g. threads, processes, computing devices). The client(s) **1602** can house cookie(s) and/or associated contextual information by employing the invention, for example.

The system **1600** also includes one or more server(s) **1604**. The server(s) **1604** can also be hardware and/or software (e.g., threads, processes, computing devices). The servers **1604** can house threads to perform transformations by employing the invention, for example. One possible communication between a client **1602** and a server **1604** can be in the form of a data packet adapted to be transmitted between two or more computer processes. The data packet may include a cookie and/or associated contextual information, for example. The system **1600** includes a communication framework **1606** (e.g., a global communication network such as the Internet) that can be employed to facilitate communications between the client(s) **1602** and the server(s) **1604**.

Communications can be facilitated via a wired (including optical fiber) and/or wireless technology. The client(s) **1602** are operatively connected to one or more client data store(s) **1608** that can be employed to store information local to the client(s) **1602** (e.g., cookie(s) and/or associated contextual information). Similarly, the server(s) **1604** are operatively connected to one or more server data store(s) **1610** that can be employed to store information local to the servers **1604**.

What has been described above includes examples of the invention. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the subject invention, but one of ordinary skill in the art may recognize that many further combinations and permutations of the invention are possible. Accordingly, the invention is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. Furthermore, to the extent that the term "includes" is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term "comprising" as "comprising" is interpreted when employed as a transitional word in a claim.

What is claimed is:

1. A system that facilitates determination of a device context, comprising:

a context sensor that measures a parameter of a first context of a device; and

a context computing component that interfaces to the context sensor and facilitates determination of a change from the first context to a second context, wherein knowledge of such context transition is used to save power in certain devices by powering the devices off; and

wherein the context sensor is part of a sensing system that includes a GPS subsystem which is activated periodically to sense GPS signals, where the absence of GPS signals facilitates powering the GPS subsystem into a mode where the GPS subsystem only turns on periodically to probe for GPS signals and if no signals are sensed, the GPS subsystem is turned off after the periodic probes.

2. The system of claim **1**, wherein the context sensor senses at least one of temperature, humidity, and pressure.

3. The system of claim **1**, wherein the context sensor senses at least one of electromagnetic wave frequency and images.

4. The system of claim **1**, wherein the context computing component infers that the device is inside or outside.

5. The system of claim **1**, wherein the context sensor includes a GPS (Global Positioning System) receiver that facilitates determining the first context of the device based on receiving a GPS signal.

6. The system of claim **1**, wherein the context sensor includes a GPS receiver that facilitates determining speed of the device based on receiving GPS location signals from at least two locations.

7. The system of claim **1**, wherein the parameter measured by the context sensor powers on at least one of a GPS subsystem of the device and the device.

8. The system of claim **1**, wherein the parameter indicates that a user of the device is available for interactive communications.

9. The system of claim **1**, wherein data the represents the change from the first context to the second context is used to add metadata to a digital photograph.

10. The system of claim **9**, wherein the metadata is used to filter the digital photograph from a plurality of photographs during a search process.

11. The system of claim **9**, wherein the metadata includes information related to whether the photograph was taken indoors or outdoors.

12. The system of claim **1**, further comprising an artificial intelligence component that employs a probabilistic and/or statistical-based analysis to prognose or infer an action that a user desires to be automatically performed.

13. A computer readable medium having computer-executable instructions for performing a method of determining context of a portable computing device, comprising:

measuring a first parameter of a first context of the portable computing device;

determining a second parameter of a second context of the portable computing device; and

computing a probability inference based on the first and second parameters that the portable computing device moved from the first context to the second context and turning off a component of the device based on the inference;

wherein location information is longitude/latitude data that is automatically accessed via a network and entered to facilitate determination of the device context.

14. The computer readable medium of claim **13**, further comprising accessing at least one of GPS and weather information to derive the probability inference.

15. A method of determining context of a portable computing device, comprising:

determining a probability distribution of a first temperature of a first context of the portable computing device;

measuring a second temperature of a second context of the portable computing device; and

computing a probability inference based on the first and second temperatures that the portable computing device moved from the first context to the second context, wherein the probability inference is determined from at least one of a measured ambient temperature, and expected temperature inside a structure, and a temperature outside the structure derived from interpolation, and wherein the temperature outside the structure is derived by accessing longitude/latitude data.

16. The method of claim **15**, wherein the first temperature is determined outside of a structure by accessing weather information associated with a geographic location of the first context.

17. The method of claim **15**, wherein the first temperature is determined outside of a structure by interpolating weather information obtained by accessing weather stations.

18. The method of claim **15**, further comprising deriving a probability distribution for an expected third temperature of the second context.

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