US008620841B1

(12) **United States Patent**
Filson et al.

(10) **Patent No.: US 8,620,841 B1**
(45) **Date of Patent: Dec. 31, 2013**

(54) **DYNAMIC DISTRIBUTED-SENSOR THERMOSTAT NETWORK FOR FORECASTING EXTERNAL EVENTS**

(75) Inventors: **John B. Filson**, Mountain View, CA (US); **Eric B. Daniels**, East Palo Alto, CA (US); **Adam Mittleman**, Redwood City, CA (US); **Sierra L. Nelmes**, Rocklin, CA (US); **Yoky Matsuoka**, Palo Alto, CA (US)

(73) Assignee: **Nest Labs, Inc.**, Palo Alto, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/601,890**

(22) Filed: **Aug. 31, 2012**

(51) **Int. Cl.**
G06F 15/18 (2006.01)

(52) **U.S. Cl.**
USPC **706/12**

(58) **Field of Classification Search**
USPC 706/12, 45
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,223,831	A	9/1980	Szarka
4,335,847	A	6/1982	Levine
4,646,964	A	3/1987	Parker et al.
4,656,835	A	4/1987	Kidder et al.
4,657,179	A	4/1987	Aggers et al.
4,685,614	A	8/1987	Levine
4,742,475	A	5/1988	Kaiser et al.
4,751,961	A	6/1988	Levine et al.
4,948,040	A	8/1990	Kobayashi et al.
5,088,645	A	2/1992	Bell
5,211,332	A	5/1993	Adams
5,224,648	A	7/1993	Simon et al.
5,240,178	A	8/1993	Dewolf et al.
5,348,078	A	9/1994	Dushane et al.
5,381,950	A	1/1995	Aldridge
5,395,042	A	3/1995	Riley et al.
5,476,221	A	12/1995	Seymour
5,499,196	A	3/1996	Pacheco

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2202008	C	2/2000
EP	196069	B1	12/1991

(Continued)

OTHER PUBLICATIONS

Yan et al. Research on event prediction in time-series data, 2004, IEEE, pp. 2874-2878.*

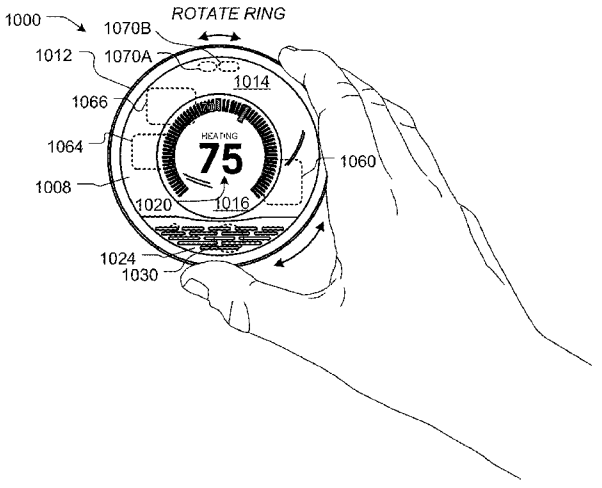
(Continued)

Primary Examiner — David Vincent
(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton, LLP

(57) **ABSTRACT**

Systems and methods for forecasting events can be provided. A measurement database can store sensor measurements, each having been provided by a non-portable electronic device with a primary purpose unrelated to collecting measurements from a type of sensor that collected the measurement. A measurement set identifier can select a set of measurements. The electronic devices associated with the set of measurements can be in close geographical proximity relative to their geographical proximity to other devices. An inter-device correlator can access the set and collectively analyze the measurements. An event detector can determine whether an event occurred. An event forecaster can forecast a future event property. An alert engine can identify one or more entities to be alerted of the future event property, generate at least one alert identifying the future event property, and transmit the at least one alert to the identified one or more entities.

18 Claims, 13 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,533,668	A	7/1996	Erikson	
5,544,036	A	8/1996	Brown, Jr. et al.	
5,555,927	A	9/1996	Shah	
5,595,342	A	1/1997	McNair et al.	
5,611,484	A	3/1997	Uhrich	
5,635,896	A	6/1997	Tinsley et al.	
5,644,173	A	7/1997	Elliason et al.	
5,646,349	A	7/1997	Twigg et al.	
5,761,083	A	6/1998	Brown, Jr. et al.	
5,802,467	A	9/1998	Salazar et al.	
5,839,654	A	11/1998	Weber	
5,902,183	A	5/1999	D'Souza	
5,909,378	A	6/1999	De Milleville	
5,926,776	A	7/1999	Glorioso et al.	
5,977,964	A	11/1999	Williams et al.	
6,062,482	A	5/2000	Gauthier et al.	
6,098,893	A	8/2000	Berglund et al.	
6,116,512	A	9/2000	Dushane et al.	
6,216,956	B1	4/2001	Ehlers et al.	
6,349,883	B1	2/2002	Simmons et al.	
6,356,204	B1	3/2002	Guindi	
6,385,510	B1	5/2002	Hoog et al.	
6,453,687	B2	9/2002	Sharood et al.	
6,519,509	B1	2/2003	Nierlich et al.	
6,548,967	B1 *	4/2003	Dowling et al.	315/318
6,574,581	B1	6/2003	Bohrer et al.	
6,604,023	B1	8/2003	Brown et al.	
6,619,055	B1	9/2003	Addy	
6,619,555	B2	9/2003	Rosen	
6,622,115	B1	9/2003	Brown et al.	
6,622,925	B2	9/2003	Carner et al.	
6,645,066	B2	11/2003	Gutta et al.	
6,769,482	B2	8/2004	Wagner et al.	
6,798,341	B1	9/2004	Eckel et al.	
6,851,621	B1	2/2005	Wacker et al.	
6,891,838	B1	5/2005	Petite et al.	
6,909,921	B1	6/2005	Bilger	
6,975,958	B2	12/2005	Bohrer et al.	
6,983,889	B2	1/2006	Alles	
6,997,390	B2	2/2006	Alles	
7,024,336	B2	4/2006	Salsbury et al.	
7,055,759	B2	6/2006	Wacker et al.	
7,135,965	B2	11/2006	Chapman, Jr. et al.	
7,156,316	B2	1/2007	Kates	
7,168,627	B2	1/2007	Kates	
7,289,887	B2	10/2007	Rodgers	
7,360,370	B2	4/2008	Shah et al.	
RE40,437	E	7/2008	Rosen	
7,434,742	B2	10/2008	Mueller et al.	
7,460,690	B2	12/2008	Cohen et al.	
7,469,550	B2	12/2008	Chapman, Jr. et al.	
7,537,171	B2	5/2009	Mueller et al.	
7,558,648	B2	7/2009	Hoglund et al.	
7,571,865	B2	8/2009	Nicodem et al.	
7,605,714	B2	10/2009	Thompson et al.	
7,644,869	B2	1/2010	Hoglund et al.	
7,702,424	B2	4/2010	Cannon et al.	
7,703,694	B2	4/2010	Mueller et al.	
D614,976	S	5/2010	Skafdrup et al.	
7,784,704	B2	8/2010	Harter	
7,802,618	B2	9/2010	Simon et al.	
7,832,465	B2	11/2010	Zou et al.	
7,837,128	B2	11/2010	Helt et al.	
7,847,681	B2	12/2010	Singhal et al.	
7,848,900	B2	12/2010	Steinberg et al.	
7,854,389	B2	12/2010	Ahmed	
7,904,209	B2	3/2011	Podgorny et al.	
7,904,830	B2	3/2011	Hoglund et al.	
8,010,237	B2	8/2011	Cheung	
8,019,567	B2	9/2011	Steinberg	
8,090,477	B1	1/2012	Steinberg	
8,131,497	B2	3/2012	Steinberg	
8,180,492	B2	5/2012	Steinberg	
8,195,313	B1 *	6/2012	Fadell et al.	700/83
2001/0033481	A1 *	10/2001	Chien	362/34
2003/0231001	A1	12/2003	Bruning	
2004/0249479	A1	12/2004	Shorrock	
2005/0043907	A1	2/2005	Eckel et al.	
2005/0128067	A1	6/2005	Zakrewski	
2005/0189429	A1	9/2005	Breeden	
2005/0194456	A1	9/2005	Tessier et al.	
2005/0270151	A1	12/2005	Winick	
2005/0280421	A1	12/2005	Yomoda et al.	
2006/0105697	A1	5/2006	Aronstam et al.	
2006/0149395	A1	7/2006	Archacki et al.	
2006/0186214	A1	8/2006	Simon et al.	
2006/0196953	A1	9/2006	Simon et al.	
2006/0208099	A1	9/2006	Chapman et al.	
2007/0052537	A1 *	3/2007	Stults et al.	340/540
2007/0114295	A1	5/2007	Jenkins	
2007/0131787	A1	6/2007	Rossi et al.	
2007/0228183	A1	10/2007	Kennedy et al.	
2008/0015740	A1	1/2008	Osann	
2008/0015742	A1	1/2008	Kulyk et al.	
2008/0077474	A1 *	3/2008	Dumas et al.	705/10
2008/0099568	A1	5/2008	Nicodem et al.	
2008/0128523	A1	6/2008	Hoglund et al.	
2008/0161977	A1	7/2008	Takach et al.	
2008/0185450	A1	8/2008	Kwon et al.	
2008/0191045	A1	8/2008	Harter	
2008/0317292	A1	12/2008	Baker et al.	
2009/0045263	A1	2/2009	Mueller et al.	
2009/0171862	A1	7/2009	Harrod et al.	
2009/0194601	A1	8/2009	Flohr	
2009/0236433	A1	9/2009	Mueller et al.	
2009/0243836	A1 *	10/2009	McSheffrey	340/524
2009/0243842	A1	10/2009	Mitchell et al.	
2009/0254225	A1	10/2009	Boucher et al.	
2009/0259713	A1	10/2009	Blumrich et al.	
2009/0261174	A1	10/2009	Butler et al.	
2010/0000239	A1	1/2010	Lifson et al.	
2010/0006660	A1	1/2010	Leen et al.	
2010/0019051	A1	1/2010	Rosen	
2010/0025483	A1	2/2010	Hoeynck et al.	
2010/0070084	A1	3/2010	Steinberg et al.	
2010/0070086	A1	3/2010	Harrod et al.	
2010/0070234	A1	3/2010	Steinberg et al.	
2010/0084482	A1	4/2010	Kennedy et al.	
2010/0168924	A1	7/2010	Tessier et al.	
2010/0211224	A1	8/2010	Keeling et al.	
2010/0250009	A1	9/2010	Lifson et al.	
2010/0261465	A1	10/2010	Rhoads et al.	
2010/0262298	A1	10/2010	Johnson et al.	
2010/0262299	A1	10/2010	Cheung	
2010/0280667	A1	11/2010	Steinberg	
2010/0289643	A1	11/2010	Trundle et al.	
2010/0305771	A1	12/2010	Rodgers	
2010/0308119	A1	12/2010	Steinberg et al.	
2010/0318227	A1	12/2010	Steinberg et al.	
2011/0001812	A1	1/2011	Kang et al.	
2011/0046792	A1	2/2011	Imes et al.	
2011/0046805	A1	2/2011	Bedros et al.	
2011/0046806	A1	2/2011	Nagel et al.	
2011/0054699	A1	3/2011	Imes et al.	
2011/0077896	A1	3/2011	Steinberg	
2011/0130636	A1 *	6/2011	Daniel et al.	600/301
2011/0185895	A1	8/2011	Freen	
2011/0253796	A1	10/2011	Posa et al.	
2011/0307103	A1	12/2011	Cheung	
2012/0065935	A1	3/2012	Steinberg et al.	
2012/0085831	A1	4/2012	Kopp	
2012/0158350	A1	6/2012	Steinberg	
2012/0221151	A1	8/2012	Steinberg	
2012/0262303	A1 *	10/2012	Fahey	340/870.02

FOREIGN PATENT DOCUMENTS

EP	1275037	B1	2/2006
JP	59106311	A	6/1984
JP	01252850	A	10/1989
JP	09298780	A	11/1997

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

JP	10023565	A	1/1998
WO	2008054938	A2	5/2008

OTHER PUBLICATIONS

Zhang et al., Forecasting with artificial neural networks: The state of the art, 1998, Elsevier, pp. 1-28.*
Author Unknown, Aprilaire Electronic Thermostats Model 8355 User's Manual, Research Products Corporation, 2000, 16 pages.
Author Unknown, Braeburn 5300 Installer Guide, Braeburn Systems, LLC, 2009, 10 pages.
Author Unknown, Braeburn Model 5200, Braeburn Systems, LLC, 2011, 11 pages.
Author Unknown, Ecobee Smart Si Thermostat Installation Manual, Ecobee, 2012, 40 pages.
Author Unknown, Ecobee Smart Si Thermostat User Manual, Ecobee, 2012, 44 pages.
Author Unknown, Ecobee Smart Thermostat Installation Manual, 2011, 20 pages.
Author Unknown, Ecobee Smart Thermostat User Manual, 2010, 20 pages.
Author Unknown, Electric Heat Lock Out on Heat Pumps, Washington State University Extension Energy Program, Apr. 2010, pp. 1-3.
Author Unknown, Honeywell Installation Guide FocusPRO TH6000 Series, Honeywell International, Inc., 2012, 24 pages.
Author Unknown, Honeywell Operating Manual FocusPRO TH6000 Series, Honeywell International, Inc., 2011, 80 pages.
Author Unknown, Honeywell Prestige IAQ Product Data, Honeywell International, Inc., 2012, 126 pages.
Author Unknown, Honeywell Prestige THX9321-9421 Operating Manual, Honeywell International, Inc., 2011, 120 pages.
Author Unknown, Hunter Internet Thermostat Installation Guide, Hunter Fan Co., 2012, 8 pages.
Author Unknown, Lennox ComfortSense 5000 Owners Guide, Lennox Industries, Inc., 2007, 32 pages.
Author Unknown, Lennox ComfortSense 7000 Owners Guide, Lennox Industries, Inc., 2009, 15 pages.
Author Unknown, Lennox iComfort Manual, Lennox Industries, Inc., 2010, 20 pages.
Author Unknown, NetX RP32-WiFi Network Thermostat Specification Sheet, Network Thermostat, 2012, 2 pages.
Author Unknown, RobertShaw Product Manual 9620, Maple Chase Company, 2001, 14 pages.
Author Unknown, RobertShaw Product Manual 9825i2, Maple Chase Company, 2006, 36 pages.
Author Unknown, SYSTXCCUIZ01-V Infinity Control Installation Instructions, Carrier Corp, 2012, 20 pages.
Author Unknown, T8611G Chronotherm IB Deluxe Programmable Heat Pump Thermostat Product Data, Honeywell International Inc., 1997, 24 pages.
Author Unknown, TB-PAC, TB-PHP, Base Series Programmable Thermostats, Carrier Corp., 2012, 8 pages.
Author Unknown, The Perfect Climate Comfort Center PC8900A W8900A-C Product Data Sheet, Honeywell International Inc, 2001, 44 pages.
Author Unknown, Trane Communicating Thermostats for Fan Coil, Trane, 2011, 32 pages.
Author Unknown, Trane Communicating Thermostats for Heat Pump Control, Trane, 2011, 32 pages.
Author Unknown, Trane Install XL600 Installation Manual, Trane, 2006, 16 pages.
Author Unknown, Trane XL950 Installation Guide, Trane, 2011, 20 pages.
Author Unknown, Venstar T2900Manual, Venstar, Inc., 2008, 113 pages.
Author Unknown, VisionPRO TH8000 Series Installation Guide, Honeywell International, Inc., 2012, 12 pages.
Author Unknown, VisionPRO TH8000 Series Operating Manual, Honeywell International, Inc., 2012, 96 pages.
Author Unknown, VisionPRO Wi-Fi Programmable Thermostat, Honeywell International, Inc., 2012, 48 pages.
Allen et al., Real-Time Earthquake Detection and Hazard Assessment by ElarmS Across California, Geophysical Research Letters, vol. 36, L00B08, 2009, pp. 1-6.
Arens et al., Demand Response Enabling Technology Development, Phase I Report: Jun. 2003-Nov. 2005, Jul. 27, P:/DemandRes/UC Papers/DR-Phase1Report-Final Draft Apr. 24-26.doc, University of California Berkeley, pp. 1-108.
Arens et al., New Thermostat Demand Response Enabling Technology, Poster, University of California Berkeley, Jun. 10, 2004.
Bourke, Server Load Balancing, O'Reilly & Associates, Inc., Aug. 2001, 182 pages.
Deleeuw, Ecobee WiFi Enabled Smart Thermostat Part 2: The Features Review, Retrieved from <URL: http://www.homenetworkenabled.com/content.php?136-ecobee-WiFi-enabled-Smart-Thermostat-Part-2-The-Features-review>, Dec. 2, 2011, 5 pages.
Gao et al., The Self-Programming Thermostat: Optimizing Setback Schedules Based on Home Occupancy Patterns, in Proceedings of the First ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings, Nov. 3, 2009, 6 pages.
Loisos et al., Buildings End-Use Energy Efficiency: Alternatives to Compressor Cooling, California Energy Commission, Public Interest Energy Research, Jan. 2000, 80 pages.
Lu et al., The Smart Thermostat: Using Occupancy Sensors to Save Energy in Homes, in Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems, Nov. 3-5, 2010, pp. 211-224.
Mozer, The Neural Network House: An Environmental that Adapts to it's Inhabitants, AAAI Technical Report SS-98-02, 1998, pp. 110-114.
International Search Report and Written Opinion mailed Nov. 2, 2012 in Application No. PCT/US2012/053502 filed Aug. 31, 2012.
Sakaki et al., Earthquake Shakes Twitter Users: Real-time Event Detection by Social Sensors, in Proceedings of the Nineteenth International WWW Conference, Apr. 26-30, 2010, 10 pages.
White et al., A Conceptual Model for Simulation Load Balancing, Proc. 1998 Spring Simulation Interoperability Workshop, 1998, 7 pages.
Honeywell Prestige THX9321 and TXH9421 Product Data 68/0311, Honeywell International, Inc., Jan. 2012, 126 pages.
Introducing the New Smart Si Thermostat, Datasheet [online]. Ecobee, Mar. 2012 [retrieved on Feb. 25, 2013]. Retrieved from the Internet: <URL: https://www.ecobee.com/solutions/home/smart-si/>.
Lux PSPU732T Manual, LUX Products Corporation, Jan. 2009, 48 pages.
NetX RP32-Wifi Network Thermostat Consumer Brochure, Network Thermostat, May 2011, 2 pages.
Venstar T5800 Manual, Venstar, Inc., Sep. 2011, 63 pages.
White Rodgers (Emerson) Model 1F81-261 Installation and Operating Instructions, White Rodgers, Apr. 2010, 8 pages.
White Rodgers (Emerson) Model IF98EZ-1621 Homeowner's User Guide, White Rodgers, Jan. 2012, 28 pages.

* cited by examiner

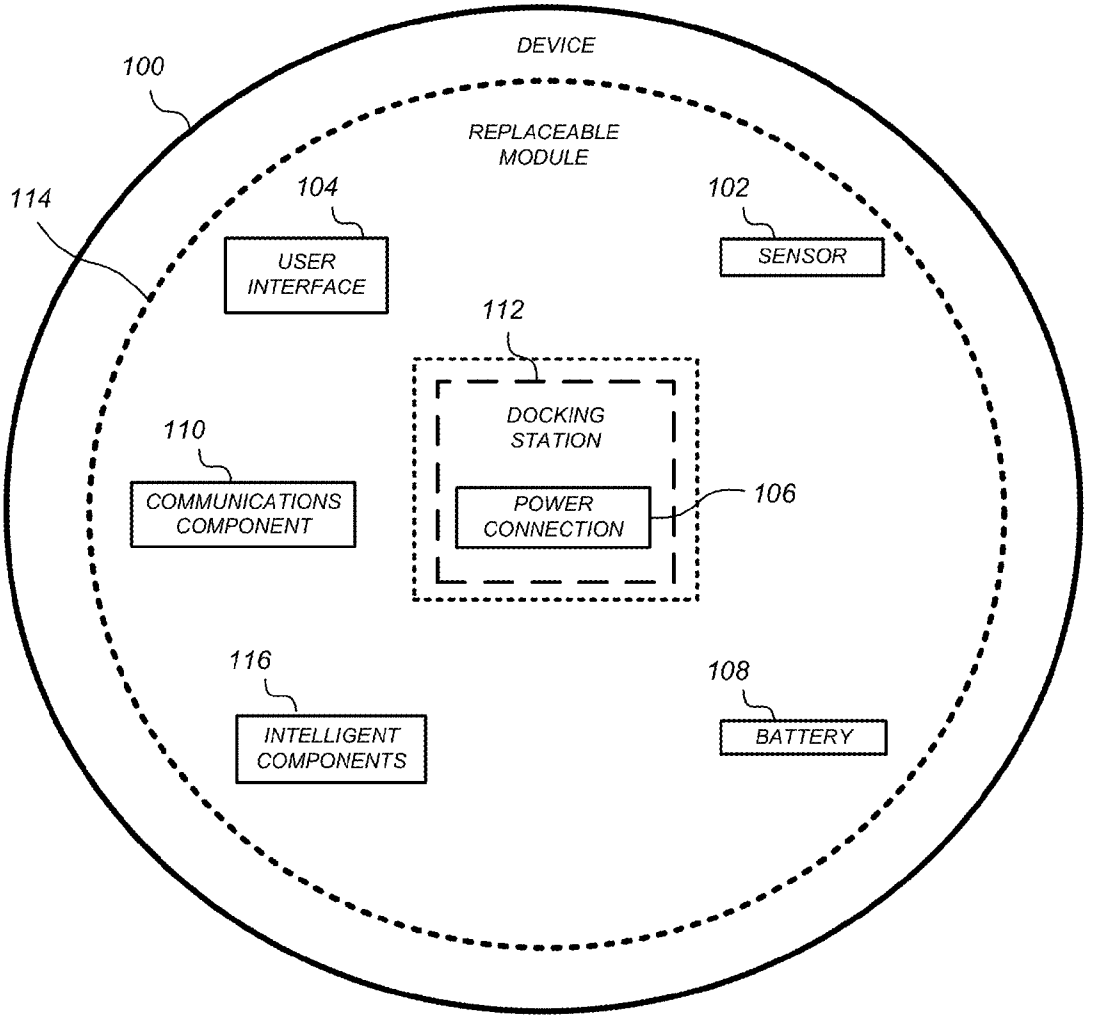

DEVICE
100
REPLACEABLE MODULE
114
104
USER INTERFACE
102
SENSOR
112
DOCKING STATION
110
COMMUNICATIONS COMPONENT
POWER CONNECTION
106
116
INTELLIGENT COMPONENTS
108
BATTERY

FIG. 1

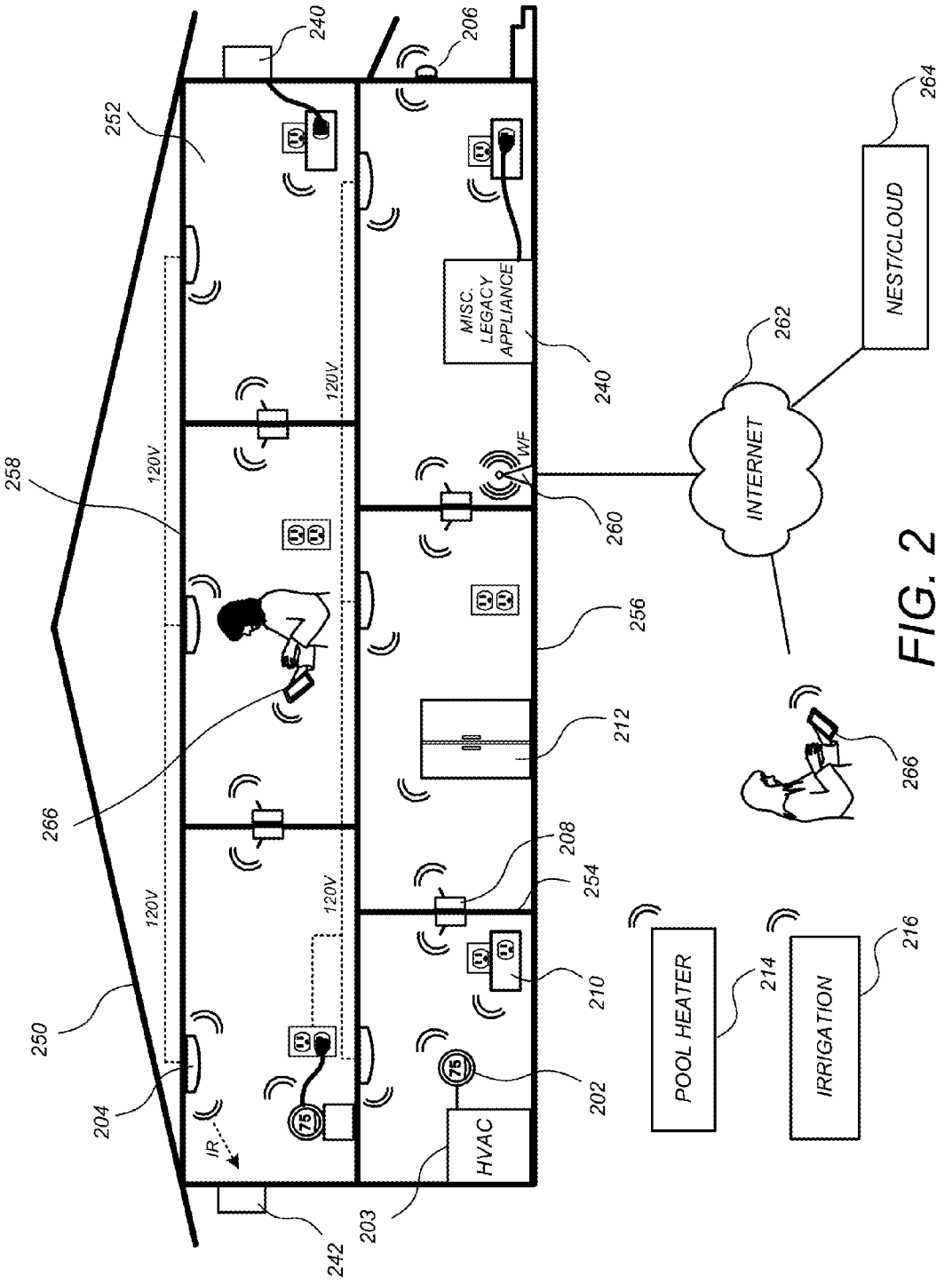

240
206
252
MISC. LEGACY APPLIANCE
240
120V
258
120V
WF
260
INTERNET
262
NEST/CLOUD
264
256
266
212
266
208
254
120V
250
210
POOL HEATER
214
IRRIGATION
216
204
IR
202
HVAC
203
242

FIG. 2

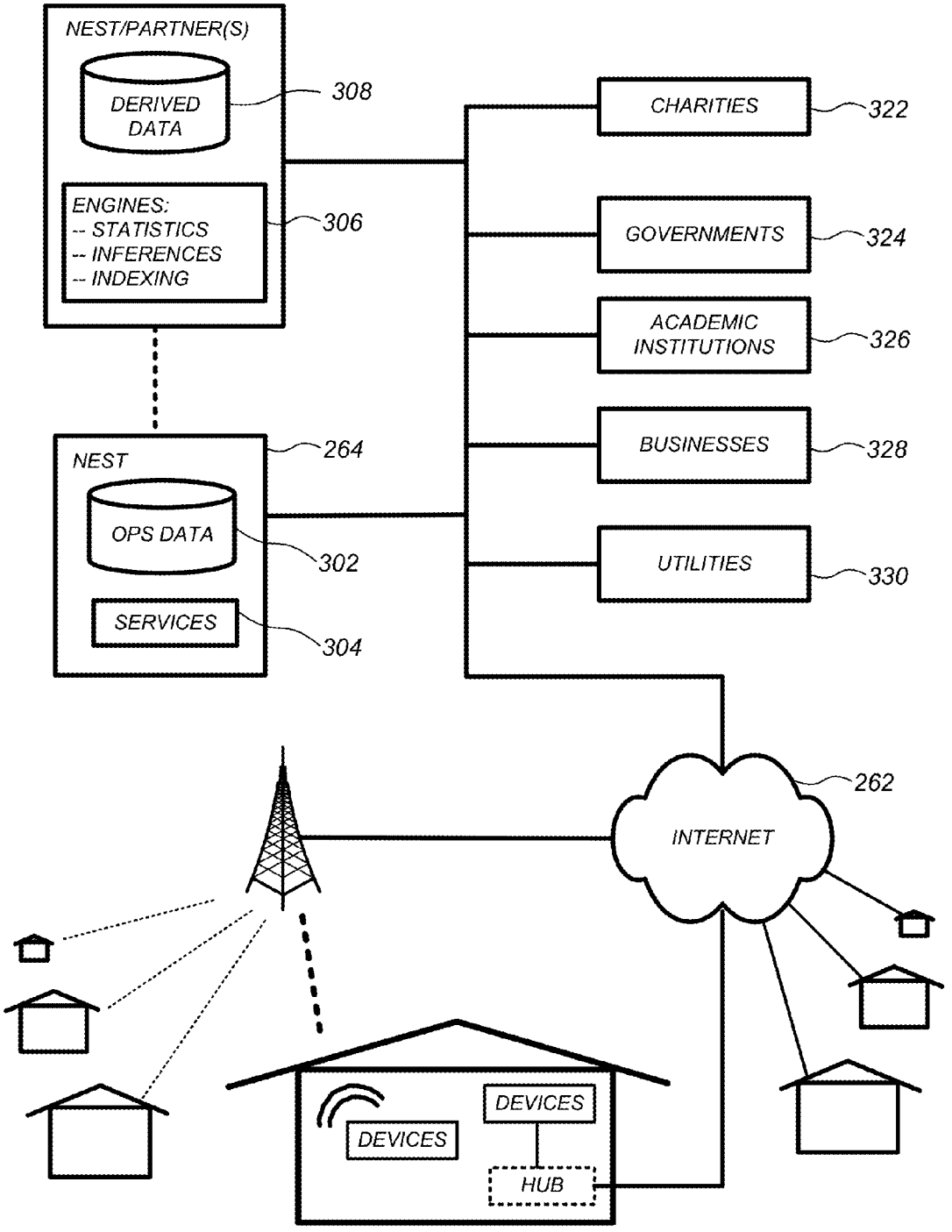

NEST/PARTNER(S)
DERIVED DATA
308
ENGINES:
-- STATISTICS
-- INFERENCES
-- INDEXING
306
NEST
264
OPS DATA
302
SERVICES
304
CHARITIES
322
GOVERNMENTS
324
ACADEMIC INSTITUTIONS
326
BUSINESSES
328
UTILITIES
330
INTERNET
262
DEVICES
DEVICES
HUB

FIG. 3

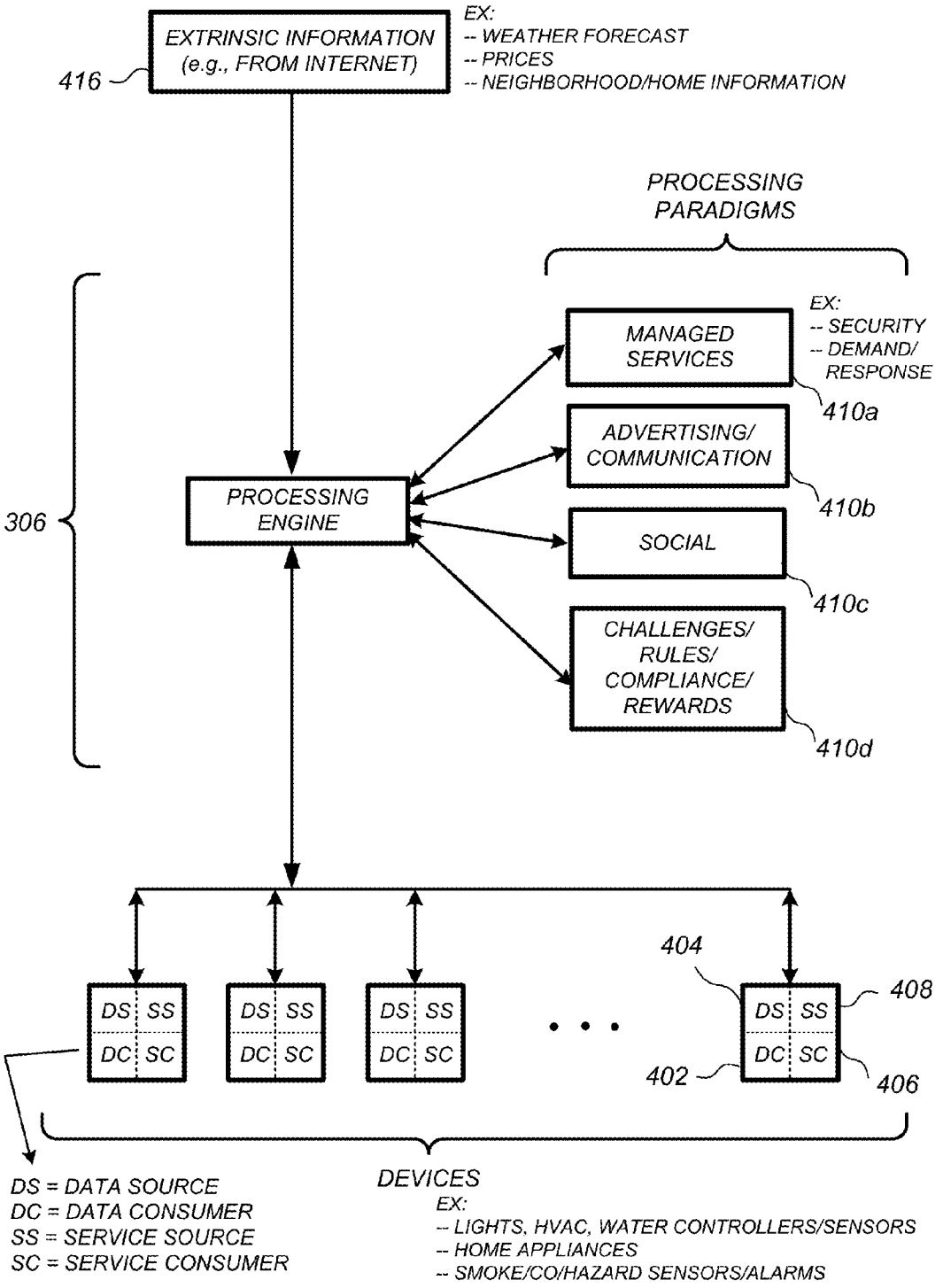

EXTRINSIC INFORMATION (e.g., FROM INTERNET)
416
EX:
-- WEATHER FORECAST
-- PRICES
-- NEIGHBORHOOD/HOME INFORMATION
PROCESSING PARADIGMS
306
PROCESSING ENGINE
MANAGED SERVICES
EX:
-- SECURITY
-- DEMAND/ RESPONSE
410a
ADVERTISING/ COMMUNICATION
410b
SOCIAL
410c
CHALLENGES/ RULES/ COMPLIANCE/ REWARDS
410d
404
408
DS SS
DC SC
402
406
DS = DATA SOURCE
DC = DATA CONSUMER
SS = SERVICE SOURCE
SC = SERVICE CONSUMER
DEVICES
EX:
-- LIGHTS, HVAC, WATER CONTROLLERS/SENSORS
-- HOME APPLIANCES
-- SMOKE/CO/HAZARD SENSORS/ALARMS

FIG. 4

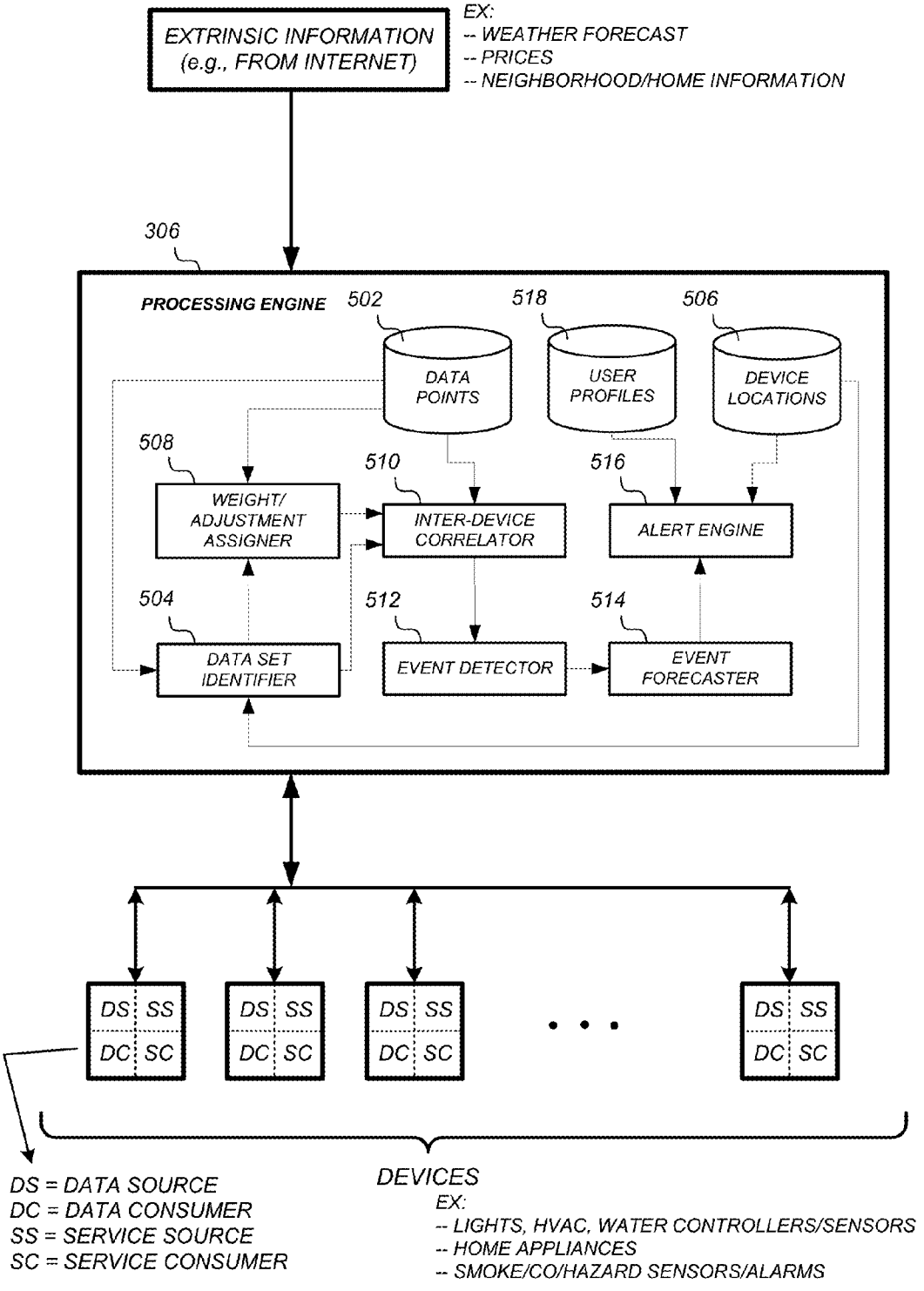

EXTRINSIC INFORMATION (e.g., FROM INTERNET)
EX:
-- WEATHER FORECAST
-- PRICES
-- NEIGHBORHOOD/HOME INFORMATION
306
PROCESSING ENGINE
502
518
506
DATA POINTS
USER PROFILES
DEVICE LOCATIONS
508
510
516
WEIGHT/ ADJUSTMENT ASSIGNER
INTER-DEVICE CORRELATOR
ALERT ENGINE
504
512
514
DATA SET IDENTIFIER
EVENT DETECTOR
EVENT FORECASTER
DS SS DC SC
DS SS DC SC
DS SS DC SC
DS SS DC SC
DS = DATA SOURCE
DC = DATA CONSUMER
SS = SERVICE SOURCE
SC = SERVICE CONSUMER
DEVICES
EX:
-- LIGHTS, HVAC, WATER CONTROLLERS/SENSORS
-- HOME APPLIANCES
-- SMOKE/CO/HAZARD SENSORS/ALARMS

FIG. 5

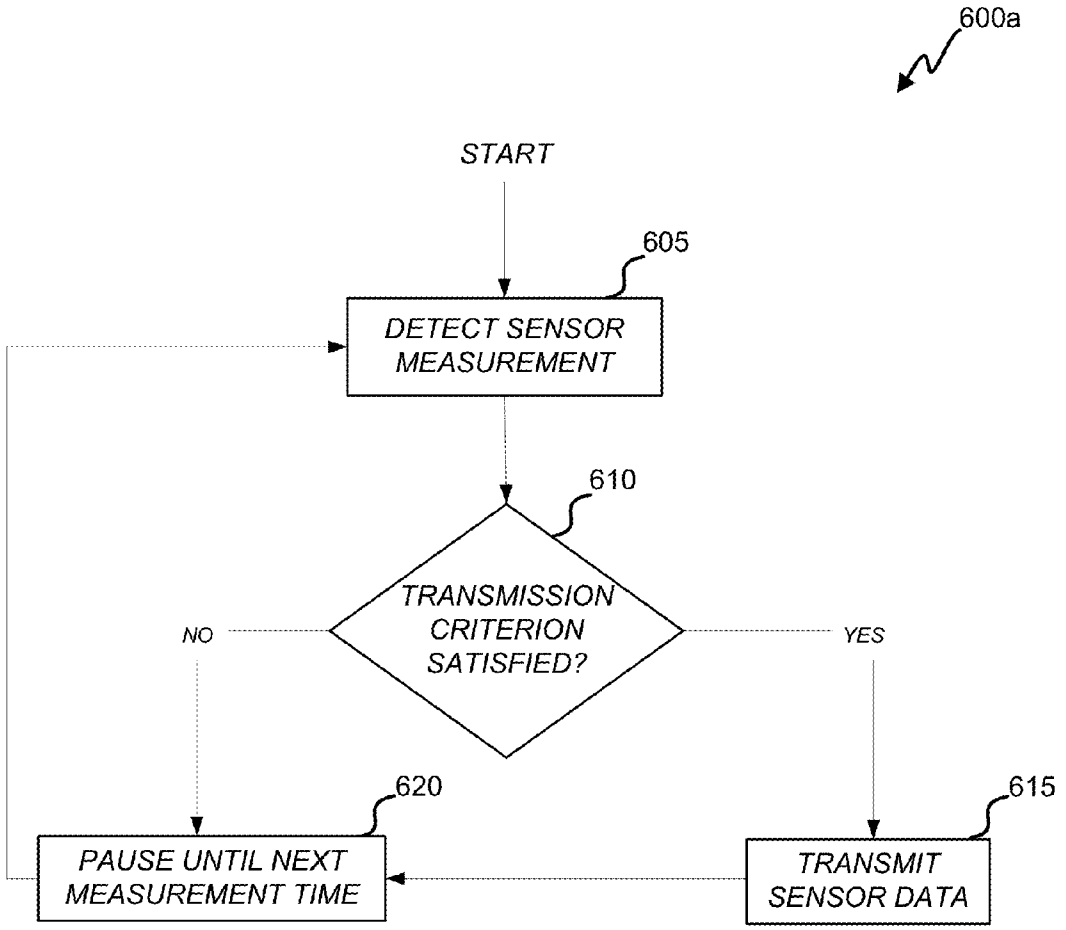

600a
START
605
DETECT SENSOR MEASUREMENT
610
TRANSMISSION CRITERION SATISFIED?
NO
YES
620
PAUSE UNTIL NEXT MEASUREMENT TIME
615
TRANSMIT SENSOR DATA

FIG. 6A

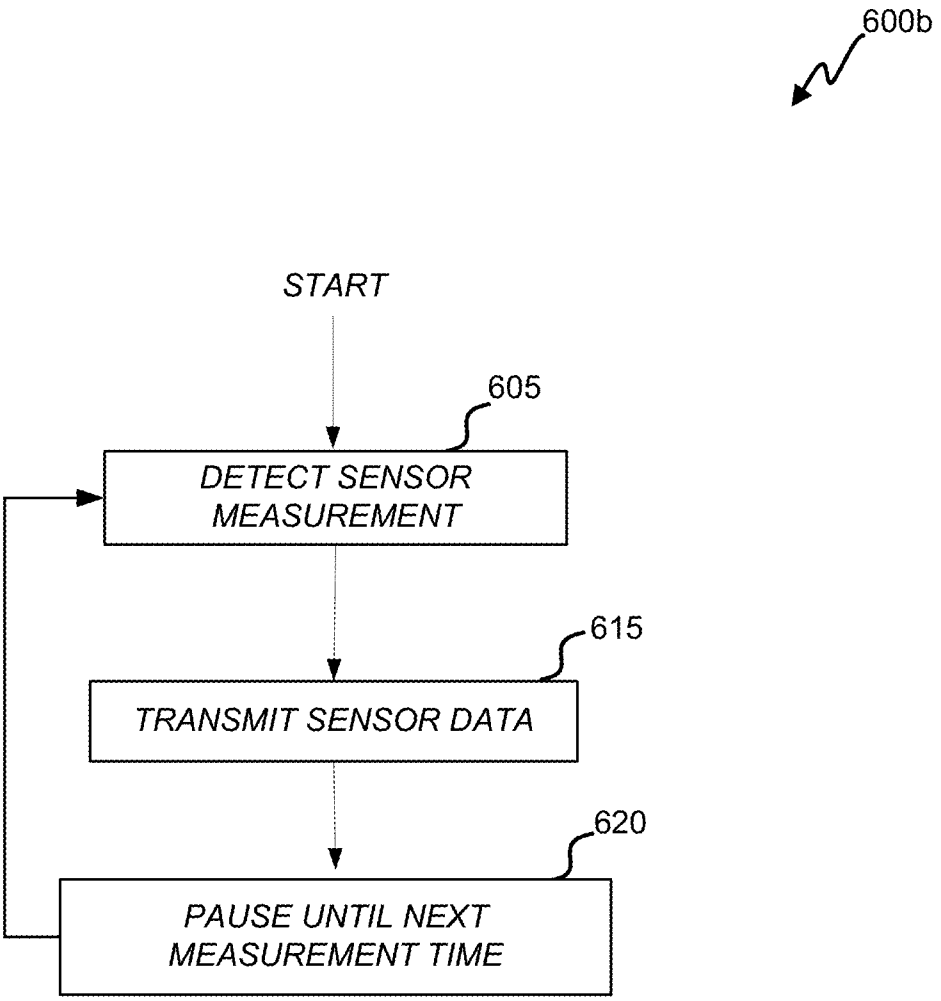

600b
START
605
DETECT SENSOR MEASUREMENT
615
TRANSMIT SENSOR DATA
620
PAUSE UNTIL NEXT MEASUREMENT TIME

FIG. 6B

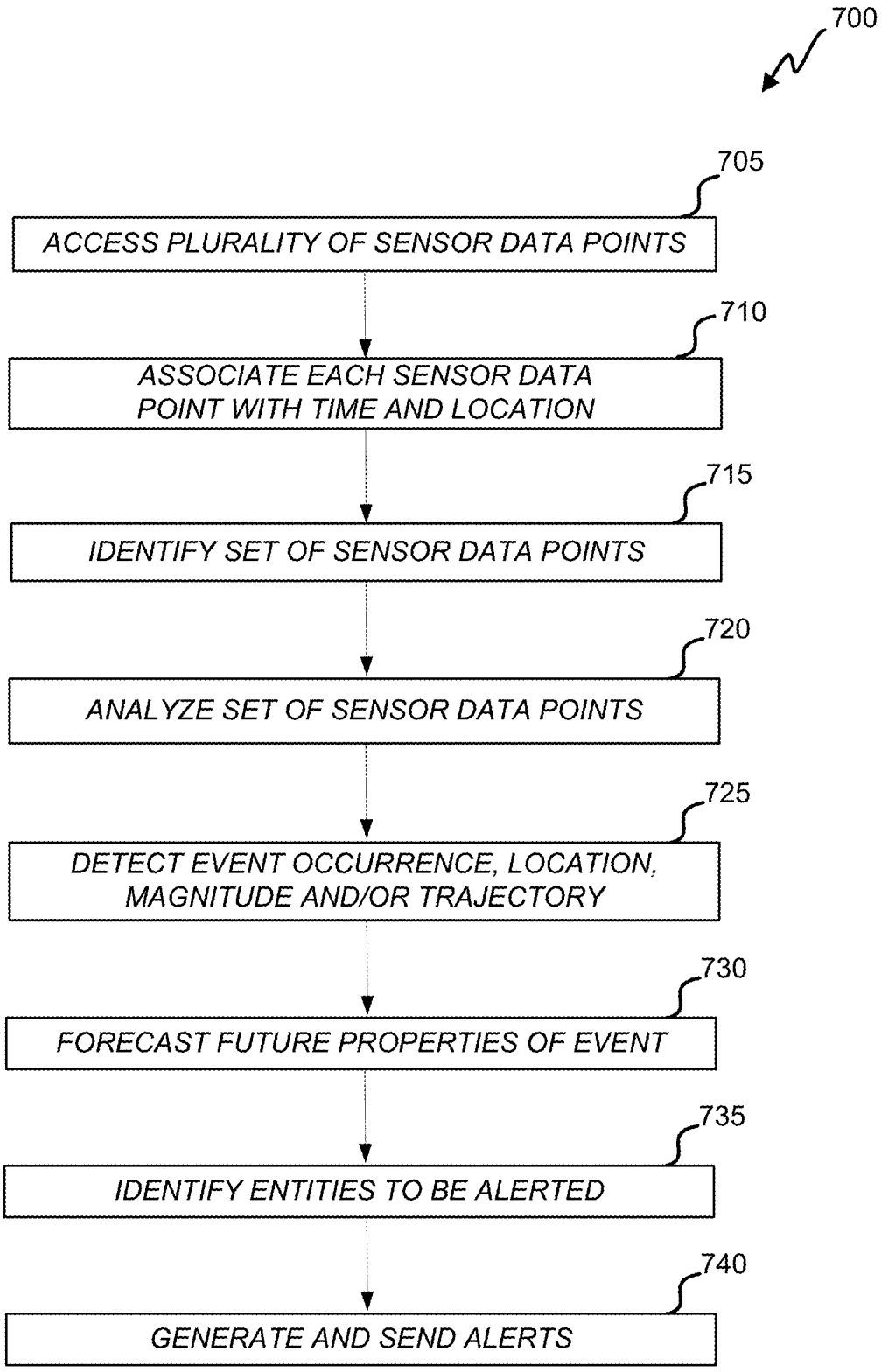

700
705
ACCESS PLURALITY OF SENSOR DATA POINTS
710
ASSOCIATE EACH SENSOR DATA POINT WITH TIME AND LOCATION
715
IDENTIFY SET OF SENSOR DATA POINTS
720
ANALYZE SET OF SENSOR DATA POINTS
725
DETECT EVENT OCCURRENCE, LOCATION, MAGNITUDE AND/OR TRAJECTORY
730
FORECAST FUTURE PROPERTIES OF EVENT
735
IDENTIFY ENTITIES TO BE ALERTED
740
GENERATE AND SEND ALERTS

FIG. 7

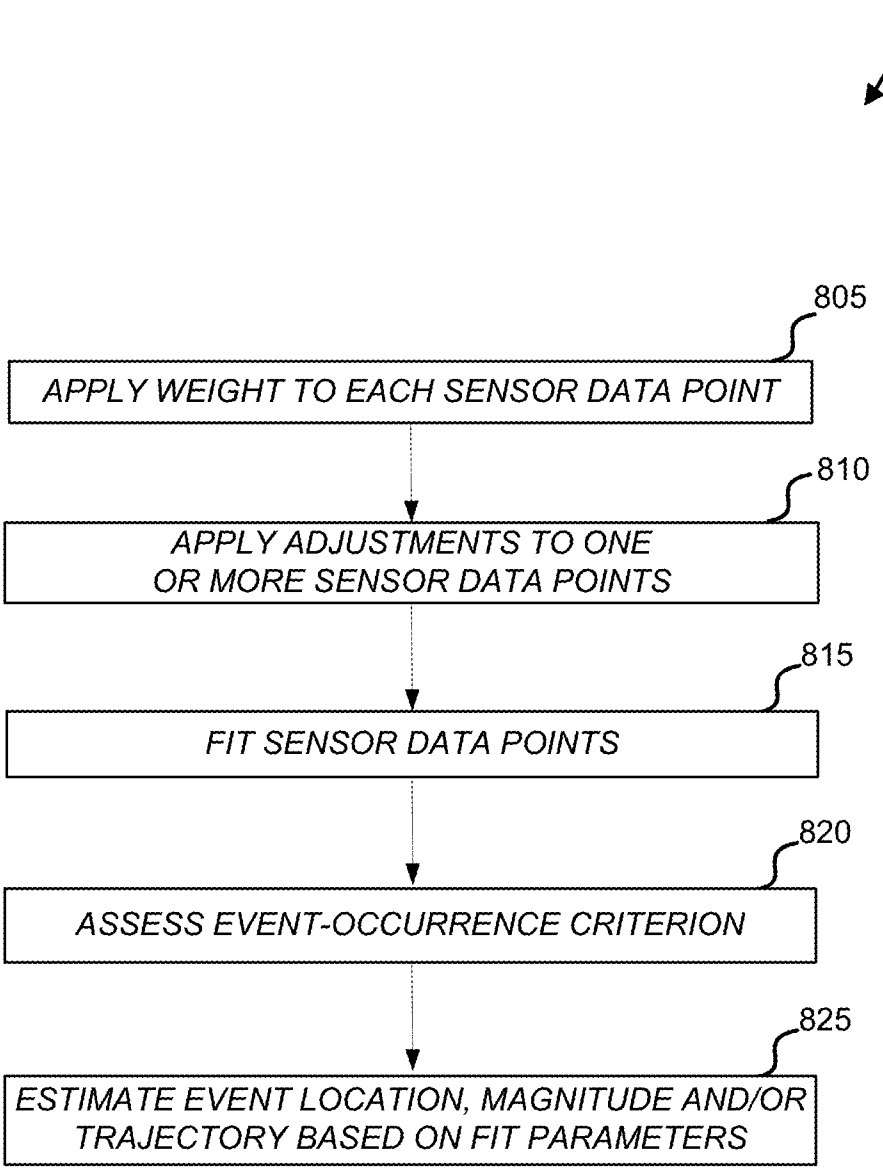

800
805
APPLY WEIGHT TO EACH SENSOR DATA POINT
810
APPLY ADJUSTMENTS TO ONE OR MORE SENSOR DATA POINTS
815
FIT SENSOR DATA POINTS
820
ASSESS EVENT-OCCURRENCE CRITERION
825
ESTIMATE EVENT LOCATION, MAGNITUDE AND/OR TRAJECTORY BASED ON FIT PARAMETERS

FIG. 8

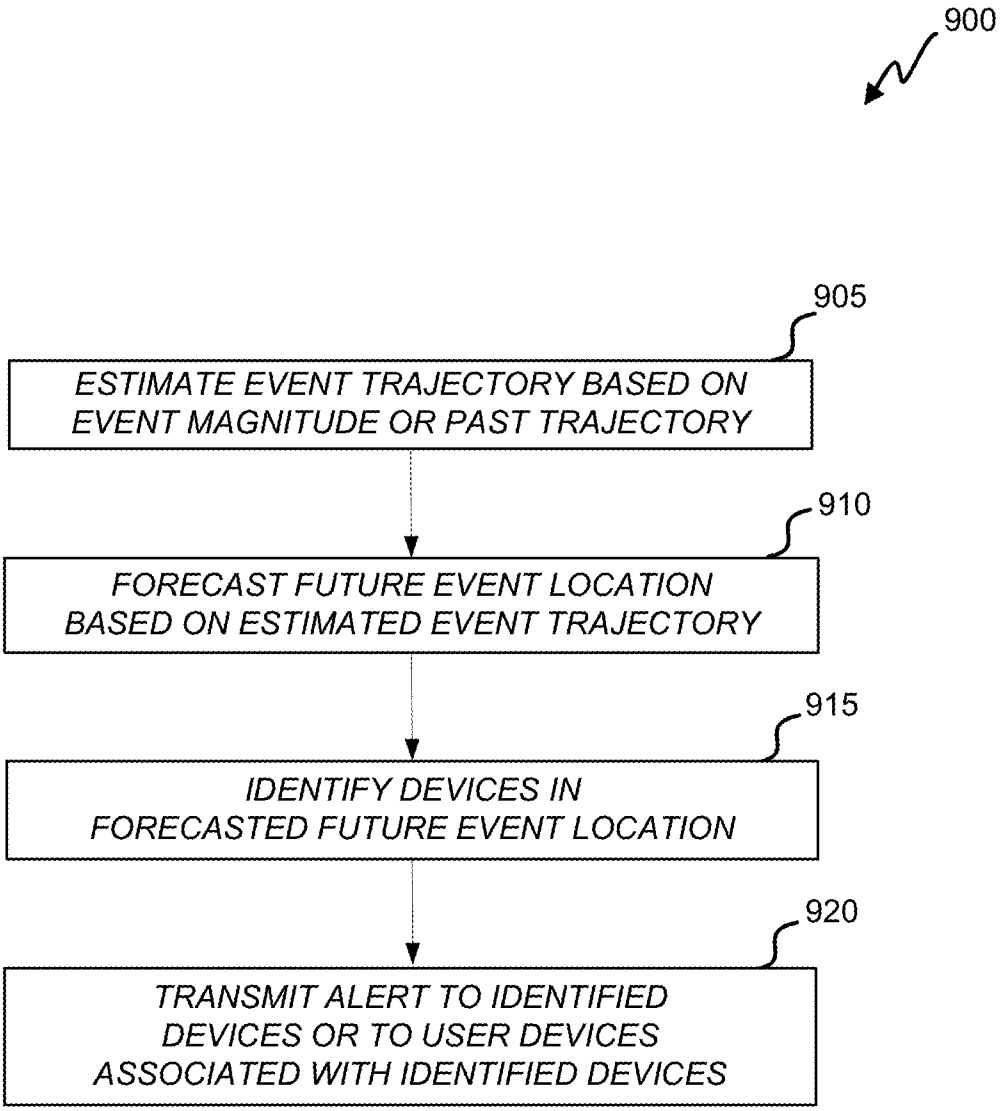

900
905
ESTIMATE EVENT TRAJECTORY BASED ON EVENT MAGNITUDE OR PAST TRAJECTORY
910
FORECAST FUTURE EVENT LOCATION BASED ON ESTIMATED EVENT TRAJECTORY
915
IDENTIFY DEVICES IN FORECASTED FUTURE EVENT LOCATION
920
TRANSMIT ALERT TO IDENTIFIED DEVICES OR TO USER DEVICES ASSOCIATED WITH IDENTIFIED DEVICES

FIG. 9

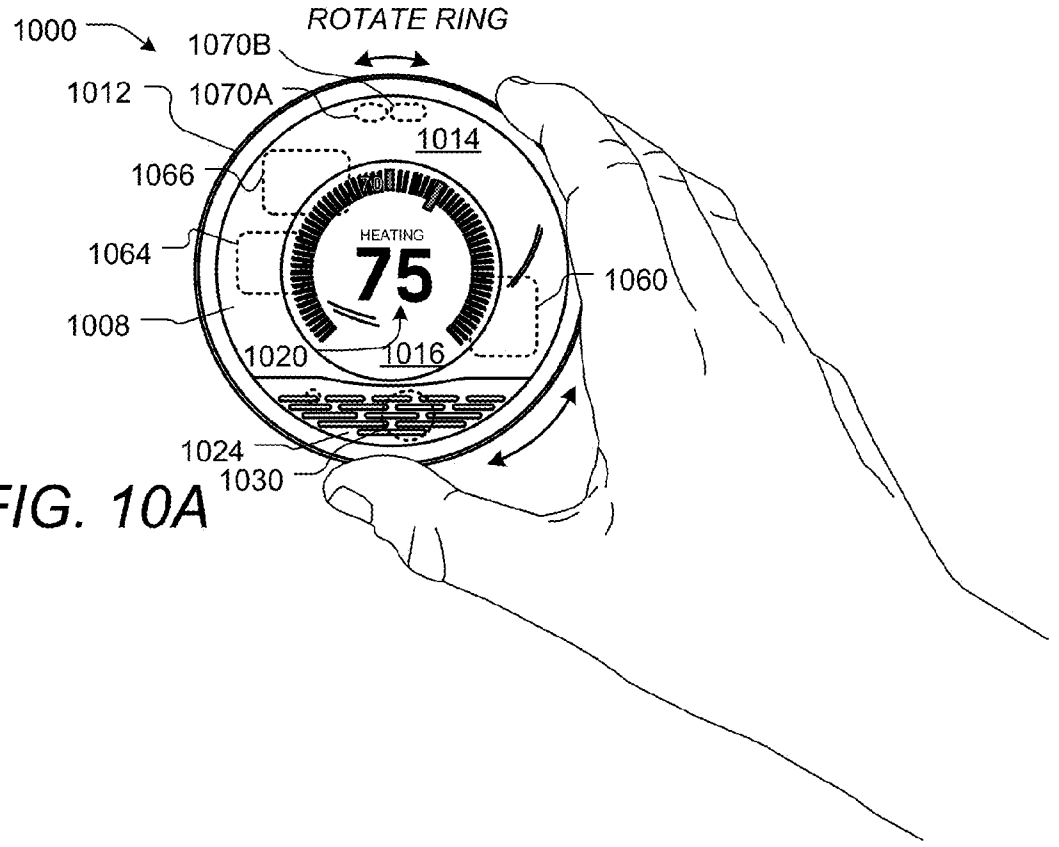


FIG. 10A

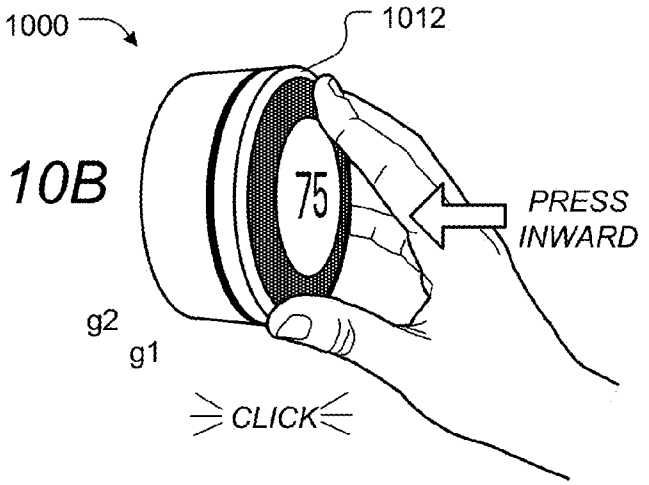


FIG. 10B

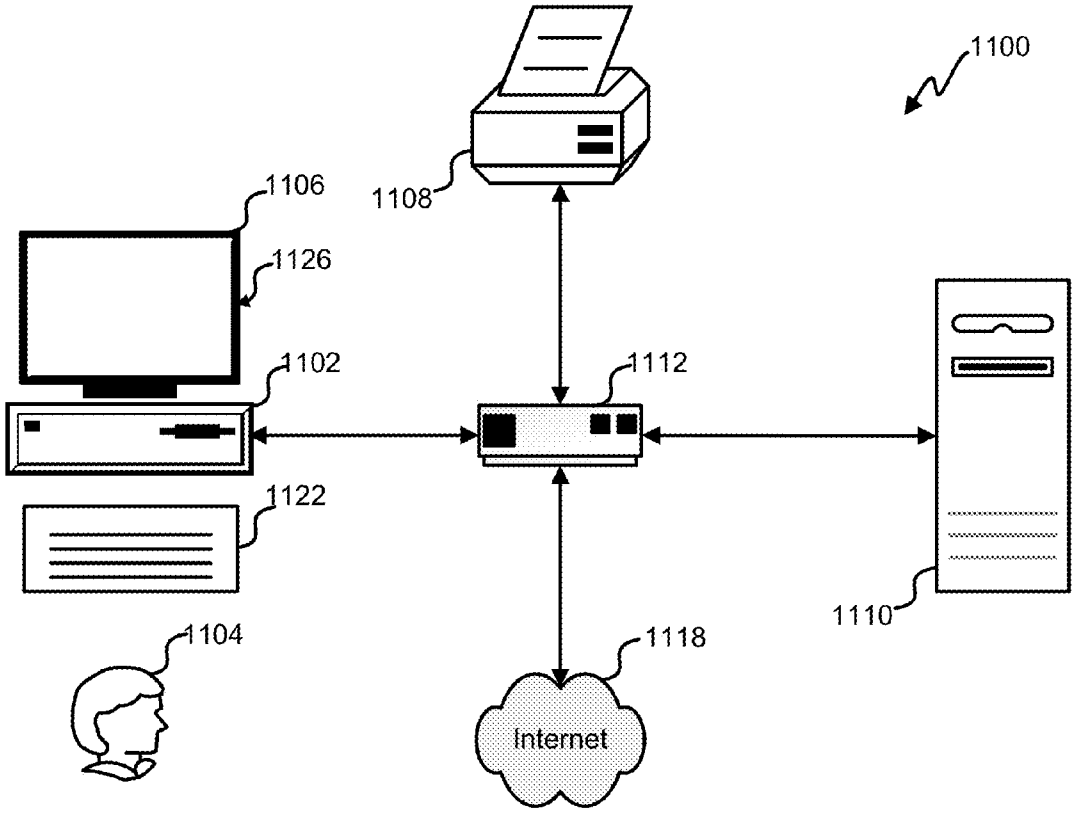


FIG. 11

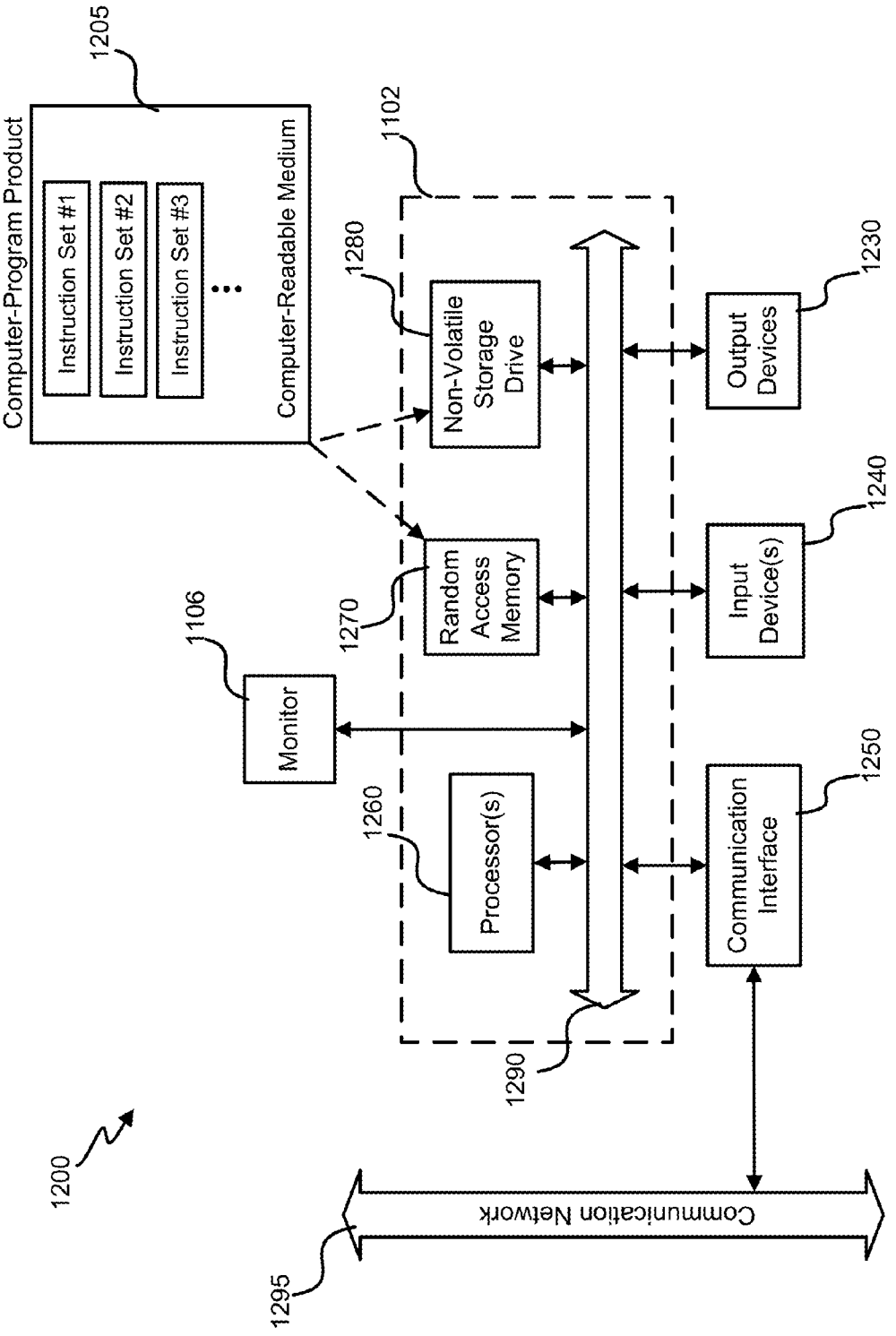

1205
Computer-Program Product
Instruction Set #1
Instruction Set #2
Instruction Set #3
...
Computer-Readable Medium
1102
1280
Non-Volatile Storage Drive
1230
Output Devices
1240
Input Device(s)
1270
Random Access Memory
1106
Monitor
1260
Processor(s)
1250
Communication Interface
1290
1200
1295
Communication Network

FIG. 12

DYNAMIC DISTRIBUTED-SENSOR THERMOSTAT NETWORK FOR FORECASTING EXTERNAL EVENTS

FIELD

This patent specification relates to systems, methods, and related computer program products for aggregating measurements obtained from a dynamic network of sensors in order to forecast external events. More particularly, this patent specification relates to a dynamic process of identifying a set of sensors (e.g., each being housed within a thermostat) applicable to an event's forecast, aggregating measurements from the set of sensors, and forecasting a future characteristic of the event based on the aggregated measurements.

BACKGROUND

Accurate and timely prediction of impending future events can be useful and beneficial in many ways. For example, predicting where and when severe weather events will strike can provide residents with the warning necessary to protect themselves and their belongings from the damage. As another example, timely prediction of impending earthquake events, even if provided only a few seconds in advance, can prevent injury or death by allowing recipients of earthquake alarm to move quickly to a safer location or position before the onset of the earthquake. Even predictions dealing with less severe events can result in substantial advantages. For example, if a person's actions can be reliably predicted, other related people can more efficiently plan their activities and/or particular conveniences can be appropriately timed to be ready upon the person's arrival at a location. Utilization of such advantages could improve productivity, safety, and comfort on many different scales and in many different ways.

Despite these strong advantages, producing reliable predictions remains a difficult task. There are many unknowns that influence a future event, and frequently, contributing variables are also unknown. Thus, weather predictions are frequently erroneous, natural disasters frequently strike without warning, and substantial time is wasted waiting on certain events, such as the arrival of others, or preparing an environment only after such others actually arrive.

SUMMARY

Provided according to one or more embodiments are systems, methods, computer program products, and related business methods for utilizing measurements obtained from a set of distributed sensors to predict events. Each sensor within a network of sensors can collect data and transmit the data to a central server. The central server can identify the set of sensors from the network of sensors by, e.g., identifying sensors within a geographical region, identifying sensors that transmitted data within a time period and/or identifying sensors that transmitted a particular type of data. The central server can then aggregate data across the set of sensors, estimate characteristics of a current event (e.g., its existence, severity, or movement), and predict characteristics of the event in the future. The central server can then transmit information about the predicted characteristic to one or more devices associated with users likely to be affected by or interested in the future event.

As a specific example, a building can include one or more smart devices, such as a thermostat, hazard-detection unit (e.g., smoke detector and/or carbon-monoxide detector), light switch, wall-plug interface, security system, or appliance. A network of devices can include smart devices across multiple rooms, across multiple buildings, across cities, etc. Within a given network, the devices can include different device types or same or similar device types. Each device within the network can include one or more sensors (e.g., to detect motion of the sensor, motion of an external object, temperature, humidity, or pressure). Data indicative of the sensor measurements can be conditionally transmitted (e.g., upon detection of an abnormal event) or regularly transmitted by a respective device to a central server. The central server can correlate the data across a set of devices in order to estimate whether readings are due to a sensor malfunction, a stationary event, or a moving event. For example, accelerometer readings from a set of devices within a locality (e.g., within a zip code) can be used to estimate whether an earthquake is occurring, temperature readings from a set of devices within a locality (e.g., within a city) can be used to estimate weather patterns, and motion-detection readings from a set of devices within a locality (within a set of rooms) can be used to estimate a trajectory of a person within a building. The central server can then predict characteristics of a future event (e.g., its location and/or strength), and can send alerts to other devices within a region predicted to be affected. The other devices can then alert users of the event or can automatically implement device settings to prepare for the event.

According to one or more preferred embodiments directed particularly to earthquake detection and prediction, it has been found particularly advantageous to embed one or more accelerometers or similar movement sensors within one or more network-connected smart-home devices that are each affixed to a home structure or that otherwise have normally stationary dispositions within the home. It has been found that network-connected thermostats and network-connected hazard detectors are two particularly useful smart-home devices within which to embed such sensors, although many other examples (network-connected light switches, network-connected doorbells, network-connected home appliances) are also within the scope of the present teachings. According to a preferred embodiment, the smart-home, accelerometer-equipped (or other motion-sensing-equipped) devices within any particular local geographic area (such as a ZIP code) are programmed and configured to quickly report the occurrence of their individual sensed movements to a common central server, such as a cloud-based server system, which is, in turn, is programmed and configured to perform correlation calculations on the received data to detect the occurrence of an earthquake event and, where applicable, promptly detect a geographical speed and trajectory of the earthquake event. Alarms or other advance warnings can then be promptly communicated to persons geographically located in the path of the earthquake event or to first responders. In one particularly advantageous embodiment, the same smart-home devices within which the accelerometers/movement sensors are embedded are also equipped to receive these warnings and to quickly provide audible and/or visual earthquake alarms to home occupants. Even if provided only seconds before the earthquake arrival, a valuable service is provided because these seconds can be used by the occupant to move to a safer location or position.

Especially for scenarios in which the network-connected smart-home devices (such as network-connected thermostats, network-connected hazard detectors, etc.) constitute even modestly popular consumer items, there is thereby functionally formed a "crowdsourced" earthquake detection network that can be orders of magnitude larger than known official earthquake detection networks in terms of the number of accelerometer/movement sensor nodes provided. More-

over, by virtue of correlations that can be performed for localized neighborhoods or geographies, the crowdsourced earthquake detection network can be highly robust against false alarms. Thus, for example, while one house in a neighborhood might be shaking due to romping teenagers or a nearby passing truck, which might trigger a sensed earthquake detection event when considered in isolation, the fact that other homes in the community are not shaking will be factored in by the correlations performed by the central server and the false-alarm condition will be avoided.

It is to be appreciated that, while crowdsourced earthquake detection based on a population of accelerometer-equipped, network-connected smart-home devices represents one particularly useful and advantageous embodiment, the scope of the present teachings is applicable across a broad variety of scenarios, including those discussed further herein, in which a population of smart-home devices is provided that are each equipped with one or more sensors, and the outputs of those sensors are received and processed in a groupwise manner to achieve one or more useful "crowdsourced" intelligence results. Not unimportantly, according to one or more of the preferred embodiments, the relative ubiquity of the sensor network that is key to the effective crowdsourced intelligence is fostered primarily by the popularity, attractiveness, and/or essential underlying functionality of the smart-home devices within which the sensors are embedded, rather than their functionality as part of the crowdsourced detection network. For example, for the particular exemplary scenario of a crowdsourced earthquake detection network, the accelerometers/movement sensors may be preferably embedded in a smart-home device comprising an elegant, visually appealing, intelligent, network-connected, self-programming thermostat such as that described in the commonly assigned US08195313B1, which is hereby incorporated by reference in its entirety for all purposes. Notably, the popularity and increasing ubiquity of the smart-home device of US08195313B1 is driven by its consumer appeal, along with the fact that every home usually needs at least one thermostat. While being a greatly beneficial by-product of the device'subiquity when adapted and configured according to the present teachings, the fact that the device can be made part of a life-saving crowdsourced earthquake detection network according to the present teachings need not itself be the central reason for that ubiquity.

In some embodiments, an event-forecasting system is provided. A measurement database can store a plurality of sensor measurements, each sensor measurement having been provided by a non-portable electronic device. A primary purpose of each respective electronic device can be unrelated to collecting measurements from a type of sensor that collected the sensor measurement. A measurement set identifier can select a set of sensor measurements from the plurality of sensor measurements in the measurement database. The electronic devices associated with the set of sensor measurements can be in close geographical proximity relative to their geographical proximity to other devices. An inter-device correlator can access the selected set of sensor measurements and collectively analyze the sensor measurements. An event detector can determine whether an event has occurred based on the results of the collective analysis. The determination that an event has occurred can require that a criterion involving at least two of the sensor measurements be satisfied. An event forecaster can forecast a future event property. The future event property can be forecasted based on a same or different collective analysis of the sensor measurements. An alert engine can identify one or more entities to be alerted of the future event property, can generate at least one alert identifying the future event property, and can transmit the at least one alert to the identified one or more entities.

In some embodiments, a method for forecasting events is provided. A plurality of sensor measurements in a measurement database can be stored, each sensor measurement having been provided by a mounted electronic device. A primary purpose of at least one respective electronic device can be not related to collecting measurements from a type of sensor that collected the sensor measurement. A set of sensor measurements from the plurality of sensor measurements in the measurement database can be selected. The electronic devices associated with the set of sensor measurements can be in close geographical proximity relative to their geographical proximity to other devices. The sensor measurements can be collectively analyzed to determine whether a large-scale event was occurring. The determination that a large-scale event was occurring can require consistency between at least two of the sensor measurements. A future event property can be forecasted. The future event property can be forecasted based on a same or different collective analysis of the sensor measurements. One or more entities to be alerted of the future event property can be identified. At least one alert identifying the future event property can be generated, and the at least one alert can be transmitted to the identified one or more entities.

In some embodiments, a crowdsourced event detection network is provided that includes a population of non-portable smart-home devices. Each smart-home device can have a primary function as one of a thermostat, a hazard detector, a wall switch, an entertainment device, a lighting device, and a home appliance. Each smart-home device can include a housing and at least one sensor coupled to the housing. The at least one sensor can be configured to sense at least one environmental characteristic or condition that is generally unrelated to the primary function of the smart-home device. Each smart-home device can further include a data transmission component configured to transmit first information representative of said least one sensed environmental characteristic or condition for reception by an aggregating processor. The aggregating processor can be configured and programmed to receive the first information from each of a plurality of the smart-home devices and to forecast a future event based on a collective analysis thereof. The aggregating processor can be further configured and programmed to identify one or more entities to be alerted of the forecasted future event and to transmit second information representative of the forecasted future event to the identified one or more entities.

BRIEF DESCRIPTION OF THE DRAWINGS

The inventive body of work will be readily understood by referring to the following detailed description in conjunction with the accompanying drawings, in which:

FIG. **1** illustrates an example of general device components which can be included in an intelligent, network-connected device;

FIG. **2** illustrates an example of a smart home environment within which one or more of the devices, methods, systems, services, and/or computer program products described further herein can be applicable;

FIG. **3** illustrates a network-level view of an extensible devices and services platform with which a smart home environment can be integrated;

FIG. **4** illustrates an abstracted functional view of the extensible devices and services platform of FIG. **3**;

FIG. **5** illustrates components of processing engine according to an embodiment of the invention;

FIGS. **6**A and **6**B illustrate flowcharts for processes **600***a* of transmitting data from a device **100** to a remote server in accordance with an embodiment of the invention;

FIG. **7** illustrates a flowchart for a process of analyzing sensor data points to forecast event properties;

FIG. **8** illustrates a flowchart for a process of analyzing sensor data points to detect event properties;

FIG. **9** illustrates a flowchart for a process of forecasting event properties and sending alerts;

FIGS. **10**A-**10**B illustrate an example of a thermostat device that may be used to collect sensor measurements;

FIG. **11** illustrates a block diagram of an embodiment of a computer system; and

FIG. **12** illustrates a block diagram of an embodiment of a special-purpose computer.

DETAILED DESCRIPTION OF THE INVENTION

Provided according to one or more embodiments are systems, methods, computer program products, and related business methods for utilizing measurements obtained from a set of distributed sensors to predict events. Each sensor within a network of sensors can collect data and transmit the data to a central server. As used herein, central server refers to any of a variety of different processing devices and/or groups of processing devices that are capable of receiving data derived from the sensors and processing the received information. As would be readily appreciated by the skilled artisan, it is not required that the one or more processors forming the central server be located in any particular geographical location relative to the sensors or to each other. While in one embodiment the central server can be implemented in cloud-based computing and storage environment such as the EC2 (Elastic Compute Cloud) offering from Amazon.com of Seattle, Wash., it is to be appreciated that the central server can be implemented on any of a variety of different hardware and software platforms, ranging from concentrated single-location computing devices to distributed networks of computing devices, including virtualized computing devices. The central server can identify the set of sensors from the network of sensors by, e.g., identifying sensors within a geographical region, identifying sensors that have transmitted data within a time period and/or identifying sensors that have transmitted a particular type of data. The central server can then aggregate data across the set of sensors, estimate characteristics of a current event (e.g., its existence, severity, or movement), and predict characteristics of the event in the future. The central server can then transmit information about the predicted characteristic to one or more devices associated with users likely to be affected by or interested in the future event.

Embodiments described further herein are but representative examples of devices, methods, systems, services, and/or computer program products that can be used in conjunction with an extensible devices and services platform that, while being particularly applicable and advantageous in the smart home context, is generally applicable to any type of enclosure or group of enclosures (e.g., offices, factories or retail stores), vessels (e.g., automobiles or aircraft), or other resource-consuming physical systems that will be occupied by humans or with which humans will physically or logically interact. It will be appreciated that devices referred to herein need not be within an enclosure or vessel. For example, a device can be on an exterior surface, nearby or connected to an enclosure or vessel. As another example, a device can include a portable device, such as a cell phone or laptop, that is configured to be carried by a user. Thus, although particular examples are set forth in the context of a smart home, it is to be appreciated that the scope of applicability of the described extensible devices and services platform is not so limited.

As described further herein, one or more intelligent, multi-sensing, network-connected devices can be used to promote user comfort, convenience, safety and/or cost savings. FIG. **1** illustrates an example of general device components which can be included in an intelligent, network-connected device **100** (i.e., "device"). Each of one, more or all devices **100** within a system of devices can include one or more sensors **102**, a user-interface component **104**, a power supply (e.g., including a power connection **106** and/or battery **108**), a communications component **110**, a modularity unit (e.g., including a docking station **112** and replaceable module **114**) and intelligence components **116**. Particular sensors **102**, user-interface components **104**, power-supply configurations, communications components **110**, modularity units and/or intelligence components **116** can be the same or similar across devices **100** or can vary depending on device type or model.

By way of example and not by way of limitation, one or more sensors **102** in a device **100** may be able to, e.g., detect acceleration, temperature, humidity, water, supplied power, proximity, external motion, device motion, sound signals, ultrasound signals, light signals, fire, smoke, carbon monoxide, global-positioning-satellite (GPS) signals, or radio-frequency (RF) or other electromagnetic signals or fields. Thus, for example, sensors **102** can include temperature sensor(s), humidity sensor(s), hazard-related sensor(s) or other environmental sensor(s), accelerometer(s), microphone(s), optical sensors up to and including camera(s) (e.g., charged-coupled-device or video cameras), active or passive radiation sensors, GPS receiver(s) or radio-frequency identification detector(s). While FIG. **1** illustrates an embodiment with a single sensor, many embodiments will include multiple sensors. In some instances, device **100** includes one or more primary sensors and one or more secondary sensors. The primary sensor(s) can sense data central to the core operation of the device (e.g., sensing a temperature in a thermostat or sensing smoke in a smoke detector). The secondary sensor(s) can sense other types of data (e.g., motion, light or sound), which can be used for energy-efficiency objectives or smart-operation objectives. In some instances, an average user may even be unaware of an existence of a secondary sensor.

One or more user-interface components **104** in device **100** may be configured to present information to a user via a visual display (e.g., a thin-film-transistor display or organic light-emitting-diode display) and/or an audio speaker. User-interface component **104** can also include one or more user-input components to receive information from a user, such as a touchscreen, buttons, scroll component (e.g., a movable or virtual ring component), microphone or camera (e.g., to detect gestures). In one embodiment, user-input component **104** includes a click-and-rotate annular ring component, wherein a user can interact with the component by rotating the ring (e.g., to adjust a setting) and/or by clicking the ring inwards (e.g., to select an adjusted setting or to select an option). In another embodiment, user-input component **104** includes a camera, such that gestures can be detected (e.g., to indicate that a power or alarm state of a device is to be changed).

A power-supply component in device **100** may include a power connection **106** and/or local battery **108**. For example, power connection **106** can connect device **100** to a power source such as a line voltage source. In some instances, connection **106** to an AC power source can be used to repeatedly charge a (e.g., rechargeable) local battery **108**, such that bat-

tery **108** can later be used to supply power if needed in the event of an AC power disconnection or other power deficiency scenario.

A communications component **110** in device **100** can include a component that enables device **100** to communicate with a central server or a remote device, such as another device described herein or a portable user device. Communications component **110** can allow device **100** to communicate via, e.g., Wi-Fi, ZigBee, 3G/4G wireless, CAT6 wired Ethernet, HomePlug or other powerline communications method, telephone, or optical fiber, by way of non-limiting examples. Communications component **110** can include a wireless card, an Ethernet plug, or nother transceiver connection.

A modularity unit in device **100** can include a static physical connection, and a replaceable module **114**. Thus, the modularity unit can provide the capability to upgrade replaceable module **114** without completely reinstalling device **100** (e.g., to preserve wiring). The static physical connection can include a docking station **112** (which may also be termed an interface box) that can attach to a building structure. For example, docking station **112** could be mounted to a wall via screws or stuck onto a ceiling via adhesive. Docking station **112** can, in some instances, extend through part of the building structure. For example, docking station **112** can connect to wiring (e.g., to 120V line voltage wires) behind the wall via a hole made through a wall's sheetrock. Docking station **112** can include circuitry such as power-connection circuitry **106** and/or AC-to-DC powering circuitry and can prevent the user from being exposed to high-voltage wires. In some instances, docking stations **112** are specific to a type or model of device, such that, e.g., a thermostat device includes a different docking station than a smoke detector device. In some instances, docking stations **112** can be shared across multiple types and/or models of devices **100**.

Replaceable module **114** of the modularity unit can include some or all sensors **102**, processors, user-interface components **104**, batteries **108**, communications components **110**, intelligence components **116** and so forth of the device. Replaceable module **114** can be configured to attach to (e.g., plug into or connect to) docking station **112**. In some instances, a set of replaceable modules **114** are produced, with the capabilities, hardware and/or software varying across the replaceable modules **114**. Users can therefore easily upgrade or replace their replaceable module **114** without having to replace all device components or to completely reinstall device **100**. For example, a user can begin with an inexpensive device including a first replaceable module with limited intelligence and software capabilities. The user can then easily upgrade the device to include a more capable replaceable module. As another example, if a user has a Model #**1** device in their basement, a Model #**2** device in their living room, and upgrades their living-room device to include a Model #**3** replaceable module, the user can move the Model #**2** replaceable module into the basement to connect to the existing docking station. The Model #**2** replaceable module may then, e.g., begin an initiation process in order to identify its new location (e.g., by requesting information from a user via a user interface).

Intelligence components **116** of the device can support one or more of a variety of different device functionalities. Intelligence components **116** generally include one or more processors configured and programmed to carry out and/or cause to be carried out one or more of the advantageous functionalities described herein. The intelligence components **116** can be implemented in the form of general-purpose processors carrying out computer code stored in local memory (e.g., flash memory, hard drive, random access memory), special-purpose processors or application-specific integrated circuits, combinations thereof, and/or using other types of hardware/firmware/software processing platforms. The intelligence components **116** can furthermore be implemented as localized versions or counterparts of algorithms carried out or governed remotely by central servers or cloud-based systems, such as by virtue of running a Java virtual machine (JVM) that executes instructions provided from a cloud server using Asynchronous Javascript and XML (AJAX) or similar protocols. By way of example, intelligence components **116** can be intelligence components **116** configured to detect when a location (e.g., a house or room) is occupied, up to and including whether it is occupied by a specific person or is occupied by a specific number of people (e.g., relative to one or more thresholds). Such detection can occur, e.g., by analyzing microphone signals, detecting user movements (e.g., in front of a device), detecting openings and closings of doors or garage doors, detecting wireless signals, detecting an IP address of a received signal, or detecting operation of one or more devices within a time window. Intelligence components **116** may include image-recognition technology to identify particular occupants or objects.

In some instances, intelligence components **116** can be configured to predict desirable settings and/or to implement those settings. For example, based on the presence detection, intelligence components **116** can adjust device settings to, e.g., conserve power when nobody is home or in a particular room or to accord with user preferences (e.g., general at-home preferences or user-specific preferences). As another example, based on the detection of a particular person, animal or object (e.g., a child, pet or lost object), intelligence components **116** can initiate an audio or visual indicator of where the person, animal or object is or can initiate an alarm or security feature if an unrecognized person is detected under certain conditions (e.g., at night or when lights are out). As yet another example, intelligence components **116** can detect hourly, weekly or even seasonal trends in user settings and adjust settings accordingly. For example, intelligence components **116** can detect that a particular device is turned on every week day at 6:30 am, or that a device setting is gradually adjusted from a high setting to lower settings over the last three hours. Intelligence components **116** can then predict that the device is to be turned on every week day at 6:30 am or that the setting should continue to gradually lower its setting over a longer time period.

In some instances, devices can interact with each other such that events detected by a first device influences actions of a second device. For example, a first device can detect that a user has pulled into a garage (e.g., by detecting motion in the garage, detecting a change in light in the garage or detecting opening of the garage door). The first device can transmit this information to a second device, such that the second device can, e.g., adjust a home temperature setting, a light setting, a music setting, and/or a security-alarm setting. As another example, a first device can detect a user approaching a front door (e.g., by detecting motion or sudden light-pattern changes). The first device can, e.g., cause a general audio or visual signal to be presented (e.g., such as sounding of a doorbell) or cause a location-specific audio or visual signal to be presented (e.g., to announce the visitor's presence within a room that a user is occupying).

FIG. **2** illustrates an example of a smart home environment within which one or more of the devices, methods, systems, services, and/or computer program products described further herein can be applicable. The depicted smart home environment includes a structure **250**, which can include, e.g., a house, office building, garage, or mobile home. It will be

appreciated that devices can also be integrated into a smart home environment that does not include an entire structure **250**, such as an apartment, condominium, or office space. Further, the smart home environment can control and/or be coupled to devices outside of the actual structure **250**. Indeed, several devices in the smart home environment need not physically be within the structure **250** at all. For example, a device controlling a pool heater or irrigation system can be located outside of the structure **250**.

The depicted structure **250** includes a plurality of rooms **252**, separated at least partly from each other via walls **254**. The walls **254** can include interior walls or exterior walls. Each room can further include a floor **256** and a ceiling **258**. Devices can be mounted on, integrated with and/or supported by a wall **254**, floor or ceiling.

The smart home depicted in FIG. **2** includes a plurality of devices, including intelligent, multi-sensing, network-connected devices that can integrate seamlessly with each other and/or with cloud-based server systems to provide any of a variety of useful smart home objectives. One, more or each of the devices illustrated in the smart home environment and/or in the figure can include one or more sensors, a user interface, a power supply, a communications component, a modularity unit and intelligent software as described with respect to FIG. **1**. Examples of devices are shown in FIG. **2**.

An intelligent, multi-sensing, network-connected thermostat **202** can detect ambient climate characteristics (e.g., temperature and/or humidity) and control a heating, ventilation and air-conditioning (HVAC) system **203**. One or more intelligent, network-connected, multi-sensing hazard detection units **204** can detect the presence of a hazardous substance and/or a hazardous condition in the home environment (e.g., smoke, fire, or carbon monoxide). One or more intelligent, multi-sensing, network-connected entryway interface devices **206**, which can be termed a "smart doorbell", can detect a person's approach to or departure from a location, control audible functionality, announce a person's approach or departure via audio or visual means, or control settings on a security system (e.g., to activate or deactivate the security system).

Each of a plurality of intelligent, multi-sensing, network-connected wall light switches **208** can detect ambient lighting conditions, detect room-occupancy states and control a power and/or dim state of one or more lights. In some instances, light switches **208** can further or alternatively control a power state or speed of a fan, such as a ceiling fan. Each of a plurality of intelligent, multi-sensing, network-connected wall plug interfaces **210** can detect occupancy of a room or enclosure and control supply of power to one or more wall plugs (e.g., such that power is not supplied to the plug if nobody is at home). The smart home may further include a plurality of intelligent, multi-sensing, network-connected appliances **212**, such as refrigerators, stoves and/or ovens, televisions, washers, dryers, lights (inside and/or outside the structure **250**), stereos, intercom systems, garage-door openers, floor fans, ceiling fans, whole-house fans, wall air conditioners, pool heaters **214**, irrigation systems **216**, security systems, and so forth. While descriptions of FIG. **2** can identify specific sensors and functionalities associated with specific devices, it will be appreciated that any of a variety of sensors and functionalities (such as those described throughout the specification) can be integrated into the device.

In addition to containing processing and sensing capabilities, each of the devices **202**, **204**, **206**, **208**, **210**, **212**, **214** and **216** can be capable of data communications and information sharing with any other of the devices **202**, **204**, **206**, **208**, **210**, **212**, **214** and **216** devices, as well as to any cloud server or any other device that is network-connected anywhere in the world. The devices can send and receive communications via any of a variety of custom or standard wireless protocols (Wi-Fi, ZigBee, 6LoWPAN, etc.) and/or any of a variety of custom or standard wired protocols (CAT6 Ethernet, HomePlug, etc.). The wall plug interfaces **210** can serve as wireless or wired repeaters, and/or can function as bridges between (i) devices plugged into AC outlets and communicating using Homeplug or other power line protocol, and (ii) devices that not plugged into AC outlets.

For example, a first device can communicate with a second device via a wireless router **260**. A device can further communicate with remote devices via a connection to a network, such as the Internet **262**. Through the Internet **262**, the device can communicate with a central server or a cloud-computing system **264**. The central server or cloud-computing system **264** can be associated with a manufacturer, support entity or service provider associated with the device. For one embodiment, a user may be able to contact customer support using a device itself rather than needing to use other communication means such as a telephone or Internet-connected computer. Further, software updates can be automatically sent from the central server or cloud-computing system **264** to devices (e.g., when available, when purchased, or at routine intervals).

By virtue of network connectivity, one or more of the smart-home devices of FIG. **2** can further allow a user to interact with the device even if the user is not proximate to the device. For example, a user can communicate with a device using a computer (e.g., a desktop computer, laptop computer, or tablet) or other portable electronic device (e.g., a smartphone) **266**. A webpage or app can be configured to receive communications from the user and control the device based on the communications and/or to present information about the device's operation to the user. For example, the user can view a current setpoint temperature for a device and adjust it using a computer. The user can be in the structure during this remote communication or outside the structure.

The smart home also can include a variety of non-communicating legacy appliances **140**, such as old conventional washer/dryers, refrigerators, and the like which can be controlled, albeit coarsely (ON/OFF), by virtue of the wall plug interfaces **210**. The smart home can further include a variety of partially communicating legacy appliances **242**, such as IR-controlled wall air conditioners or other IR-controlled devices, which can be controlled by IR signals provided by the hazard detection units **204** or the light switches **208**.

FIG. **3** illustrates a network-level view of an extensible devices and services platform with which the smart home of FIGS. **1** and/or **2** can be integrated. Each of the intelligent, network-connected devices from FIG. **2** can communicate with one or more remote central servers or cloud computing systems **264**. The communication can be enabled by establishing connection to the Internet **262** either directly (for example, using 3G/4G connectivity to a wireless carrier), though a hubbed network (which can be scheme ranging from a simple wireless router, for example, up to and including an intelligent, dedicated whole-home control node), or through any combination thereof.

The central server or cloud-computing system **264** can collect operation data **302** from the smart home devices. For example, the devices can routinely transmit operation data or can transmit operation data in specific instances (e.g., when requesting customer support). The central server or cloud-computing architecture **264** can further provide one or more services **304**. The services **304** can include, e.g., software update, customer support, sensor data collection/logging,

remote access, remote or distributed control, or use suggestions (e.g., based on collected operation data **304** to improve performance, reduce utility cost, etc.). Data associated with the services **304** can be stored at the central server or cloud-computing system **264** and the central server or cloud-computing system **264** can retrieve and transmit the data at an appropriate time (e.g., at regular intervals, upon receiving request from a user, etc.).

One salient feature of the described extensible devices and services platform, as illustrated in FIG. **3**, is a processing engine **306**, which can be concentrated at a single server or distributed among several different computing entities without limitation. Processing engine **306** can include engines configured to receive data from a set of devices (e.g., via the Internet or a hubbed network), to index the data, to analyze the data and/or to generate statistics based on the analysis or as part of the analysis. The analyzed data can be stored as derived data **308**. Results of the analysis or statistics can thereafter be transmitted back to a device providing ops data used to derive the results, to other devices, to a server providing a webpage to a user of the device, or to other non-device entities. For example, use statistics, use statistics relative to use of other devices, use patterns, and/or statistics summarizing sensor readings can be transmitted. The results or statistics can be provided via the Internet **262**. In this manner, processing engine **306** can be configured and programmed to derive a variety of useful information from the operational data obtained from the smart home. A single server can include one or more engines.

The derived data can be highly beneficial at a variety of different granularities for a variety of useful purposes, ranging from explicit programmed control of the devices on a per-home, per-neighborhood, or per-region basis (for example, demand-response programs for electrical utilities), to the generation of inferential abstractions that can assist on a per-home basis (for example, an inference can be drawn that the homeowner has left for vacation and so security detection equipment can be put on heightened sensitivity), to the generation of statistics and associated inferential abstractions that can be used for government or charitable purposes. For example, processing engine **306** can generate statistics about device usage across a population of devices and send the statistics to device users, service providers or other entities (e.g., that have requested or may have provided monetary compensation for the statistics). As specific illustrations, statistics can be transmitted to charities **322**, governmental entities **324** (e.g., the Food and Drug Administration or the Environmental Protection Agency), academic institutions **326** (e.g., university researchers), businesses **328** (e.g., providing device warranties or service to related equipment), or utility companies **330**. These entities can use the data to form programs to reduce energy usage, to preemptively service faulty equipment, to prepare for high service demands, to track past service performance, etc., or to perform any of a variety of beneficial functions or tasks now known or hereinafter developed.

FIG. **4** illustrates an abstracted functional view of the extensible devices and services platform of FIG. **3**, with particular reference to the processing engine **306** as well as the devices of the smart home. Even though the devices situated in the smart home will have an endless variety of different individual capabilities and limitations, they can all be thought of as sharing common characteristics in that each of them is a data consumer **402** (DC), a data source **404** (DS), a services consumer **406** (SC), and a services source **408** (SS). Advantageously, in addition to providing the essential control information needed for the devices to achieve their local and immediate objectives, the extensible devices and services platform can also be configured to harness the large amount of data that is flowing out of these devices. In addition to enhancing or optimizing the actual operation of the devices themselves with respect to their immediate functions, the extensible devices and services platform can also be directed to "repurposing" that data in a variety of automated, extensible, flexible, and/or scalable ways to achieve a variety of useful objectives. These objectives may be predefined or adaptively identified based on, e.g., usage patterns, device efficiency, and/or user input (e.g., requesting specific functionality).

For example, FIG. **4** shows processing engine **306** as including a number of paradigms **410**. Processing engine **306** can include a managed services paradigm **410***a* that monitors and manages primary or secondary device functions. The device functions can include ensuring proper operation of a device given user inputs, estimating that (e.g., and responding to) an intruder is or is attempting to be in a dwelling, detecting a failure of equipment coupled to the device (e.g., a light bulb having burned out), implementing or otherwise responding to energy demand response events, or alerting a user of a current or predicted future event or characteristic. Processing engine **306** can further include an advertising/communication paradigm **410***b* that estimates characteristics (e.g., demographic information), desires and/or products of interest of a user based on device usage. Services, promotions, products or upgrades can then be offered or automatically provided to the user. Processing engine **306** can further include a social paradigm **410***c* that uses information from a social network, provides information to a social network (for example, based on device usage), and/or processes data associated with user and/or device interactions with the social network platform. For example, a user's status as reported to their trusted contacts on the social network could be updated to indicate when they are home based on light detection, security system inactivation or device usage detectors. As another example, a user may be able to share device-usage statistics with other users. Processing engine **306** can include a challenges/rules/compliance/rewards paradigm **410***d* that informs a user of challenges, rules, compliance regulations and/or rewards and/or that uses operation data to determine whether a challenge has been met, a rule or regulation has been complied with and/or a reward has been earned. The challenges, rules or regulations can relate to efforts to conserve energy, to live safely (e.g., reducing exposure to toxins or carcinogens), to conserve money and/or equipment life, to improve health, etc.

Processing engine **306** can integrate or otherwise utilize extrinsic information **416** from extrinsic sources to improve the functioning of one or more processing paradigms. Extrinsic information **416** can be used to interpret operational data received from a device, to determine a characteristic of the environment near the device (e.g., outside a structure that the device is enclosed in), to determine services or products available to the user, to identify a social network or social-network information, to determine contact information of entities (e.g., public-service entities such as an emergency-response team, the police or a hospital) near the device, etc., to identify statistical or environmental conditions, trends or other information associated with a home or neighborhood, and so forth.

An extraordinary range and variety of benefits can be brought about by, and fit within the scope of, the described extensible devices and services platform, ranging from the ordinary to the profound. Thus, in one "ordinary" example, each bedroom of the smart home can be provided with a smoke/fire/CO alarm that includes an occupancy sensor, wherein the occupancy sensor is also capable of inferring (e.g., by virtue of motion detection, facial recognition,

audible sound patterns, etc.) whether the occupant is asleep or awake. If a serious fire event is sensed, the remote security/monitoring service or fire department is advised of how many occupants there are in each bedroom, and whether those occupants are still asleep (or immobile) or whether they have properly evacuated the bedroom. While this is, of course, a very advantageous capability accommodated by the described extensible devices and services platform, there can be substantially more "profound" examples that can truly illustrate the potential of a larger "intelligence" that can be made available. By way of perhaps a more "profound" example, the same data bedroom occupancy data that is being used for fire safety can also be "repurposed" by the processing engine **306** in the context of a social paradigm of neighborhood child development and education. Thus, for example, the same bedroom occupancy and motion data discussed in the "ordinary" example can be collected and made available for processing (properly anonymized) in which the sleep patterns of schoolchildren in a particular ZIP code can be identified and tracked. Localized variations in the sleeping patterns of the schoolchildren may be identified and correlated, for example, to different nutrition programs in local schools.

FIG. **5** illustrates components of processing engine **306** according to an embodiment of the invention. Processing engine **306** can receive data points indicative of sensor measurements from each of a plurality of devices. Each data point can include multiple values, such as a continuous-scale, discrete-scale or binary sensor measurement; a measurement time; a transmission time; a device identifier; and/or a device location identifier. For example, a data point can include one or more temperature, pressure, humidity, acceleration or motion-detection sensor readings. The data point can be stored in a data-point database **502**.

Processing engine **306** can include a data set identifier **504**, which can identify a set of data points to analyze. In various embodiments, different events can initiate the set identification For example, a data set can be identified upon receiving a data point with a concerning or unusual sensor measurement, upon receiving a request from a user or other entity for event information, or at regular intervals.

In some instances, all data within a data set is received from a same device type (e.g., all from sprinkler systems) and/or relates to measurements of a same or similar type (e.g., all including temperature data). In some instances, data within a data is received from different device types and/or relates to measurements of different types. The set of data points can include data points associated with similar locations and/or times. For example, the set of data points can include all data points associated with a same zip code and received within a particular time period (e.g., the last 30 seconds, 1 minute, 5 minutes, 10 minutes, 30 minutes, 60 minutes, 2 hours, 6 hours, 12 hours or 24 hours). As another example, the set of data points can include all data points associated with a location that is less than a fixed distance away from a location of an instant data point. To illustrate, if a data point indicates that massive acceleration is detected at Location #**1**, then the data set can include all data points associated with a location less than 1 mile away from Location #**1** and received within the last minute.

In order to identify data points associated with similar locations, data set identifier **504** can use a device-location database **506**. For example, each device of a plurality of devices can transmit one or more data points to processing engine **306** over a period of time. The data point can include a device ID and a location (e.g., determined based on user input or location-identification technology, such as GPS technology). Processing engine **306** can thereafter populate a device-location database **506** to associate each device ID with the respective location (the location including, e.g., geographical coordinates, a street address, a county, a city, and/or a zip code). Subsequently, if data set identifier **504** is attempting to identify a set of data points near a particular location (e.g., a location associated with an instant data point), data set identifier **504** can consult device-location database **505** to identify appropriate device IDs and can then search for data points within data-point database **502** that are associated with the device IDs.

A weight/adjustment assigner **508** can assign a weight and/or adjustment to each of one, more or all data-point values within the data set. The weight can be associated with an estimated reliability or a sensor or device associated with a respective data-point value. A given device can be less reliable than others, e.g., due to its age, its model, its device type, its mounting position (e.g., vertical versus horizontal), its location (e.g., upstairs versus downstairs), or stability or insulation of an enclosure surrounding or supporting the device (e.g., with older houses being more influenced by external environments than newer houses).

Weight/adjustment assigner **508** can determine a weight to be associated with a device by assessing data-point values associated with the device over a period of time. A device associated with highly variable data-point values can be assigned (depending on the embodiment) a relatively high weight to indicate that the sensor is sensitive to environmental changes and provides informative data or a relatively low weight to indicate that the sensor is likely uncalibrated or malfunctioning. In some instances, data-point values over the time period are compared to data-point values from other devices (e.g., near the instant device). A high weight can be assigned to a device with data-point values well-correlated with or predictive of data-point values of the other devices. Weights can be dynamically adjusted by, e.g., repeatedly analyzing recently received data points (e.g., by redefining an analyzed time period to be a recent time period). A weight can include, e.g., a number, such as a scaled number (e.g., between 0-1).

In some instances, it might be determined that the data-point values are likely inaccurate, but they can nonetheless be informative. In some instances, the data-point values have little to no inaccuracy but exhibit an inconsistency with other data-point values due to, e.g., different device models, sensor types, or device types. In these cases, it can be advantageous to highly weight the data-point values, but also to adjust the values. For example, a sensor can be biased to always collect biased measurements (e.g., 10 units or 10% above actual values or measurements with a nonlinear bias). Data-point value inaccuracies or inconsistencies can be due to variation across devices in a device's mounting position, a device's location, or a property of an enclosure surrounding or supporting the device.

Weight/adjustment assigner **508** can determine an adjustment to be associated with a device by assessing data-point values associated with the device over a period of time. The data-point values can be compared to data-point values of other devices or to control values. For example weight/adjustment assigner **508** can compare an average of a device's data-point value across a time period to a set value (e.g., 0 or 9.8 m/s^2 for an accelerometer reading), a value looked up from an external source (e.g., an average temperature over the time period), or a calculated value (e.g., a mean, median or mode of device-specific average values across a set of nearby devices). As another example, weight/adjustment assigner **508** can compare individual data-point values across a time

period to other values (e.g., a mean, median or mode of time-matched data-point values for a set of devices). The determined adjustment can include a single value, such as one that can be added to or multiplied to data-point values, or a more complicated function, such as a power function or logarithmic function.

Weight/adjustment assigner **508** can periodically determine weights and/or adjustments and store the weights and/or adjustments in one or more look-up tables (e.g., a weight look-up table and an adjustment look-up table). Each weight and/or adjustment can be associated with a device and/or sensor (e.g., using a device ID or sensor ID). In some instances, blank entries in the look-up table can be associated with a default assignment (e.g., a default weight or no adjustment), or the look-up table can be prepopulated with the default assignments which can thereafter be adjusted by weight/adjustment assigner.

Upon identification of a data set by data set identifier **504**, the set identification can be transmitted to an inter-device correlator **510**. In some instances, the identified set includes set properties (e.g., Device IDs: a_1-a_{10} and transmission times: b_1-b_2). Thus, the identified set includes one or more data-set criteria. Inter-device correlator **510** can then pull the data points from data-point database **502** that corresponds to the data set. In some instances, data set identifier **504** identifies a specific set of data points (e.g., Data Point IDs: $c_{1\text{-}20}$). In these instances, either data set identifier **504** can retrieve the appropriate data points from data-point database **502** and transmit them to inter-device correlator **510** or inter-device correlator **510** can itself retrieve the points.

Inter-device correlator **510** analyzes the set of data points collectively in an attempt to identify whether an event resulted in observed sensor readings. For example, an earthquake would give rise to large accelerometer readings, a power outage would give rise to low voltage-detection measurements, a tornado would give rise to low pressure measurements, or a storm and/or clouds would give rise to low outdoor light intensities. However, each of these measurements could be caused by other factors within a single device (e.g., house renovations or romping teenagers causing large accelerometer readings; intentionally turning off the power causing low voltage-detection measurements; faulty sensor readings causing low pressure measurements; or a deck covering causing low outdoor light intensities). By collectively analyzing the data points, inter-device correlator **510** can better estimate whether a very local event or a more substantial event caused the sensor readings. Consistent and correlated readings across a set of nearby devices (e.g., across a neighborhood or zip code) suggest the presence of a substantial event.

Inter-device correlator **510** can utilize any of a variety of techniques to collectively analyze the set of data points. For example, statistics can be performed to determine whether dramatic sensor readings were outliers. Similarly, clustering techniques can be used to determine whether at least a plurality of devices exhibited similar extreme sensor readings. Location- and/or time-sensitive fitting (e.g., 1-d or 2-d Gaussian fitting) can be used to characterize whether sensor readings vary in a continuous manner.

The analysis performed by inter-device correlator **510** (e.g., and data properties analyzed by inter-device correlator **510**) can include analyses used to predict an event of interest. For example, earthquake prediction techniques disclosed in Allen et al., Real-time earthquake detection and hazard assessment by ElarmS across California, *Geophysical Research Letters,* 36, 2009: 1-6, by Sakaki et al., Earthquake shakes Twitter users: real-time event detection by social sensors, *WWW* 2010, 2010: 851:860, and/or by U.S. Pat. No. 6,356,204, each of which is hereby incorporated by reference in its entirety for all purposes, can be used.

Inter-device correlator **510** can produce one or more parameters as a result of the analysis. The parameters could include, e.g., a reliability metric, an extreme sensor reading, a time and/or location associated with an extreme sensor reading, or one or more fit parameters (e.g., a Gaussian-fit amplitude, offset and/or width or a quality-of-fit metric). These parameters can be transmitted to an event detector **512**.

Based on the parameters, event detector **512** can estimate whether an event occurred, a magnitude of the event, a location of the event, a past trajectory of the event, and/or a time of the event. For example, to determine whether an event occurred, event detector **512** can compare a percentage of data points with dramatic sensor measurement values (e.g., beyond one or two standard deviations from the mean or above or below a fixed measurement threshold) to a percentage threshold, or event detector **512** can compare a quality-of-fit metric to a threshold. Event detector **512** can estimate a location and/or time of an event based on when and/or where extreme sensor readings occurred or based on an offset fit parameter. Event detector **512** can estimate a trajectory based on a tracking locations associated with dramatic measurement values over a period of time or based on time-sensitive fit parameters. Event detector **512** can estimate an event magnitude based on a single dramatic measurement value (e.g., the highest or lowest within the set), an average of dramatic measurement values (e.g., an average of the 5 highest or lowest within the set), or a fit parameter (e.g., a Gaussian-fit amplitude).

After an event has been detected, an event forecaster **514** can make predictions about future characteristics of the event. For example, event forecaster **514** can predict where the event will later move to and when it will reach that destination. Event forecaster **514** can predict one or more "affected areas" which will experience effects of given characteristics of the event. These predictions can be made based on past trajectories of the event (e.g., estimated by event detector **512**) and/or known trajectory characteristics of the type of event. Event forecaster **514** can predict future strengths or characteristic changes of the event. For example, an earthquake's strength can decrease as it spreads, and a precipitation type (e.g., snow, rain, or hail) can change as a storm moves. Event characteristics can depend on current characteristics of other areas, such as a current temperature, annual precipitation level, altitude, etc. Thus, event forecaster **514** can identify these characteristics (e.g., based on data in data points within the identified data set or other data points or from an external source) and use the characteristics in its forecasting.

An alert engine **516** can then generate and transmit alerts that are indicative of or identify the forecasted event. In some instances, alert engine **516** identifies devices in locations likely to be affected by the event in the future. Alert engine **516** can specifically receive a location zone or location criterion from event forecaster **514** and identify devices in that location based on data in the device-locations database **506**. These devices can include devices within the identified data set and/or other devices. Alerts can then be sent to the identified devices.

In some instances, alert engine **516** identifies users likely to be interested in the event. A user-profile database **518** can associate, for each user, a telephone number (e.g., a cellular phone number), an email, or a portable device ID with a device ID. Alert engine **516** can predict that a user will be interested in the event if the event is predicted to affect a location at which the device is located (e.g., a home) or if the

user is estimated to be within an area predicted to be affected (e.g., determined based on cell-phone tracking techniques). Alert engine **516** can then send alerts to the users via a telephone call, email or notification sent to a portable device.

In some instances, alert engine **516** is sent to higher-level entities, such as an emergency-control center, health-care workers, utility company, weather station, etc. These higher-level entities can themselves alert areas likely be affected by the event, attempt to reduce the event's effect, or prepare for post-event action.

An alert can explicitly or implicitly identify an event type, an indication that the event is forecasted to reach a specific location, a prediction as to when the event will reach the location, an actual and/or predicted trajectory of the event, and a past and/or predicted event magnitude. The follow lists examples of possible alerts:

- Text message sent to user's cell phone reading: "Earthquake imminent. Take cover."
- Phone message sent to user's cell phone stating: "Severe hail storm predicted to reach your house at 4:30 pm."
- Signal sent to wall thermostat that causes the thermostat to broadcast: "Tornado watch."
- Signal sent to a user's wall plug interfaces indicating that the devices should safely kill power within 1 minute due to forecasted power outage.

Alerts can be sent, e.g., over a network such as the Internet or over a cell-phone network. User preferences can indicate how they wish to be alerted (e.g., via text message, phone call, or home device alert). For fast-moving events, alerts can be pushed to users to ensure that users are provided with notice in as much advance as possible. In some instances, users can pull for alerts. For example, a user can request a local forecast or request the probability of a nearby hail storm reaching a current location or home location.

While some embodiments herein indicate or imply that processing engine **306** is located within a central server, it will be appreciated that, in some instances, other devices can include processing engine **306**. Thus, devices **100** can communicate in a peer-to-peer manner. For example, a device that detects a potentially concerning. or important event can transmit data point to one or more nearby devices (e.g., in different rooms or different buildings). The nearby devices could then determine whether a large-scale event is occurring by comparing its data to that of the other device's, and, if so, transmit alerts to yet more devices. As another example, the device can pull data points from nearby devices, determine whether a large-scale event is occurring, and, if so, transmit alerts to yet more devices. As yet another example, each device can routinely transmit data points to nearby devices, such that a device can instantly estimate whether a large-scale event is occurring.

FIG. **6**A illustrates a flowchart for a process **600***a* of transmitting data from a device **100** to a remote server in accordance with an embodiment of the invention. At block **605**, a sensor measurement is detected. In some instances, the sensor measurement is collected by the sensor at routine intervals (e.g., every minute, 5 minutes, 15 minutes, 30 minutes, hour, 2 hours, 6 hours, 12 hours or 24 hours). In some instances, the sensor measurement is only collected upon the occurrence of particular external effects. For example, device **100** can include a sensor that only detects movement if a central mass is sufficiently moved to reach a perimeter or external notch.

At block **610**, it is determined whether a transmission criterion is satisfied. The transmission criterion can relate to the sensor measurement. For example, the criterion can require the measurement to be above a threshold, below a threshold, or to have changed from a previous measurement by at least a given amount.

If the criterion is satisfied, process **600***a* can continue to block **615**, at which sensor data is transmitted. The sensor data can include a raw version of the sensor measurement or a processed version of the sensor measurement (e.g., normalized, time-averaged, or otherwise filtered or processed). The sensor data can further include, e.g., a measurement time; a transmission time; a device identifier; and/or a device location identifier. The sensor data can be transmitted wirelessly to a central server or to other devices (e.g., other nearby devices).

Following the data transmission, or if the transmission criterion is determined to not be satisfied at block **610**, process **600***a* continues to block **620**, at which the process is paused until the next measurement time. This could entail pausing the process for a defined time interval or pausing the process until another sensor measurement is detected based on an external effect. Following the pause, process **600***a* returns to block **605**.

FIG. **6**B illustrates a flowchart for another process **600***b* of transmitting data from a device **100** to a remote server in accordance with an embodiment of the invention. Process **600***b* is similar to that of process **600***a*. However, process **600***b* does not include block **610**. Thus, sensor data is reliably transmitted upon detection of the sensor measurement. This could result in regular sensor-data transmission or transmission of sensor data each time that an external effect resulted in the sensor measurement to be detected.

FIG. **7** illustrates a flowchart for a process **700** of analyzing sensor data points to forecast event properties. At block **705**, a plurality of sensor data points are accessed. In some instances, a central server receives data points for each of a plurality of devices. In some instances, a device generates at least one sensor data point based on a measurement by a local sensor and receives at least one sensor data point from another device. Thus, a data point can be accessed after it is received from another device or after it is locally generated. Each sensor data point can include a raw or processed sensor measurement value; a measurement time; a transmission time; a device identifier; and/or a device location identifier.

At block **710**, each sensor data point can be associated with a time and location. The time can include a time at which the sensor data point was generated or received or a time within the sensor data point (e.g., a measurement time). The location can include a location within the sensor data point or a location associated with a device ID in the sensor data point (e.g., determined based on associations in device-locations database **506**). In some instances, the sensor data points and the associated times and locations are stored in data-point database **502**. It will be appreciated that the plurality of data points can be accessed, associated with times and locations and/or stored at a same time or at different times (e.g., subsequent to receipt of each data point).

At block **715**, a set of sensor data points is identified (e.g., by data set identifier **504**). In some instances, this identification is precipitated by and/or conditioned on detection of an abnormal sensor measurement in a data point, a request by a user or external entity for an event-detection or event-forecast analysis, or passage of a routine time interval. The identified set of sensor data points can include those associated with a location within a same geographic region and/or those associated with a time within a same time period. The geographic region can be determined based on a location associated with a data point having an abnormal (e.g., above- or below-

threshold) sensor measurement or a location associated with a request for an event-detection or event-forecast analysis.

At block **720**, the set of sensor data points is analyzed (e.g., by inter-device correlator **510**). The analysis can include determining whether an abnormal sensor measurement is consistent or inconsistent with other sensor measurements, generating statistics, generating a model, performing a data fit, and comparing generated statistics or values to one or more thresholds.

At block **725**, it can be determined whether a particular type of event is occurring, and, if so, the event's location, magnitude and/or trajectory (e.g., by event detector **512**). The determination about the event's occurrence can be determined based on a number or percentage of data points having a characteristic sensor measurement (e.g., above-threshold or below-threshold measurements), quality-of-fit statistics, or estimated event magnitude (e.g., concluding that no event occurred if a sufficiently low magnitude is estimated). The location, magnitude and/or trajectory can be determined based on which data points were associated with the most extreme measurements, fit parameters (e.g., offset parameters) and/or time-sensitive analyses.

At block **730**, future event properties can be forecasted (e.g., by event forecaster **514**). The future event properties can include a future location and/or magnitude of the event. In some instances, the future properties indicate qualitative properties of the event, such as whether a storm will produce snow, hail or rain. The future event properties can be forecasted, e.g., based on time-sensitive analyses, using a predictive model, or based on known trajectory or propagation properties associated with the event type.

At block **735**, entities to be alerted are identified (e.g., by alert engine **516**). Block **735** can include identifying locations likely to be affected by the event in the future and identifying devices within the locations. The identified entities can then either include those devices or users associated with those devices (e.g., to be alerted via phone, text message or email). In some instances, block **735** includes identifying entities that requested general alerts (e.g., requesting an alert whenever an event is detected within a nearby area) or requesting specific alerts (e.g., recently having requested a local forecast).

At block **740**, alerts are generated and sent to the identified entities (e.g., by alert engine **516**). The alerts can include an indication that the event was detected, an estimate of the event's past location, time or magnitude, and/or an indication of the event's forecasted future (e.g., its future location, arrival time and magnitude).

FIG. **8** illustrates a flowchart for a process **800** of analyzing sensor data points to detect event properties. For example, block **720** of process **700** can include one, more or all of blocks **805**-**820** of process **800**.

At block **805**, a weight is applied to each of one, more or all sensor data points (e.g., by inter-device correlator **510**). The weight can represent or be indicative of a reliability of the sensor data point or how informative the sensor data point as to one or more event properties. In some instances, a plurality of weights are applied to each data point. For example, a first weight can be used when attempting to determine whether an event occurred or is occurring, and one or more second weights can be used to determine a magnitude, location or trajectory of the event. Thus, if a particular device's sensor reliably measured an above-threshold reading only when the event occurred, but the measurement was otherwise uninformative as to the event's magnitude, multiple weights could be useful (e.g., weighting more highly the sensor reading to first determine whether an event occurred and then weighting more lowly the sensor reading to determine event properties).

The weight can be identified by, e.g., looking up an identifier (e.g., a device or sensor identifier) in a look-up table. The look-up table can include one or more weights for the identifier. These stored weights may have been previously determined (e.g., by weight/adjustment assigner **508**), e.g., by analyzing past sensor data points with respect to known event properties, by considering whether a particular device's sensor data points reliably co-varied with other nearby device's sensor data points, and/or by assessing variability across past sensor data points. It will be appreciated that, in some instances, the weights are stored in multiple look-up tables (e.g., each relating to a different event property).

At block **810**, an adjustment is applied to one or more sensor data points (e.g., by inter-device correlator **510**). The adjustment can include a linear adjustment (e.g., such that a sensor measurement should be adjusted based on an additive or multiplicative factor) or a nonlinear adjustment. In some instances, a plurality of adjustments are applied to each data point. For example, a first adjustment can be used when attempting to determine whether an event occurred or is occurring, and one or more second adjustments can be used to determine a magnitude, location or trajectory of the event. As a specific illustration, a first adjustment could include a stepwise function that transforms a sensor measurement to "1" if it as above a threshold and "0" otherwise, and a second adjustment could include a multiplicative and additive scaling factor. In both instances, the adjustments can result in normalized sensor measurements across devices, though the first adjustment may be more useful when determining a binary condition (e.g., "Did the event occur—yes or no") and the second adjustment may be more useful when determining a continuous condition (e.g., "Where was the center of the event").

The adjustment can be identified by, e.g., looking up an identifier (e.g., a device or sensor identifier) in a look-up table. The look-up table can include one or more adjustments for the identifier. These stored adjustments may have been previously determined (e.g., by weight/adjustment assigner **508**), e.g., by analyzing past sensor data points with respect to known event properties, by considering whether a particular device's sensor data points reliably co-varied with other nearby device's sensor data points, and/or by assessing variability across past sensor data points. In some instances, a single look-up table stores both weights and adjustments. In some instances, different look-up tables store weights and adjustments. It will be appreciated that, in some instances, the adjustments are stored in multiple look-up tables (e.g., each relating to a different event property).

At block **815**, the weighted and/or adjusted sensor data points are fitted (e.g., by inter-device correlator **510**). The fit could involve fitting a one-dimensional, two-dimensional or multi-dimensional function. The function can include or consist of, e.g., a power function, a logarithmic function, a Gaussian function, and/or a trigonometric function. One or more parameters can be identified as a result of the fit. The parameters can include numeric values to be included within the fitted function (e.g., coefficients, powers, offsets, etc.) and/or one or more quality-of-fit values.

At block **820**, event-occurrence criterion is assessed (e.g., by event detector **512**). The assessment can include comparing one or more fit parameters to one or more thresholds. For example, a criterion can indicate that an event occurred if a quality-of-fit parameter exceeded a first value and an amplitude coefficient of a Gaussian function exceeded a second value. In some instances, the thresholds are not fixed, e.g., such that lower quality-of-fit parameters are acceptable when detecting the event occurrence given higher amplitude coef-

ficients. The assessment can include identifying a binary event-occurrence answer, a probability metric and/or a confidence metric. For example, a binary event-occurrence answer can include "Yes" indicating that that the event occurred, 76% indicating that there is a 76% probability that the event occurred, and/or 0.6 indicating a confidence metric on a 0-to-1 scale of the "Yes" or 76% result.

At block **825**, other event properties are estimated (e.g., by event detector **512**). The other event properties can include, e.g., a measurement-timed or initial event location (e.g., identifying its central location or its reach), a measurement-timed or initial event magnitude, a time that the event began, and/or a trajectory of the event. For example, the event properties could include that an earthquake event was estimated to have begun at 10:32 am at a location with geographic coordinates (x1, x2) and with a strength of 6.8 on the Richter scale. As another example, the event properties could include that, at 10:34 am, an earthquake event spread to neighborhoods with zip codes X_1, X_2 and X_3, with a strength of 4.4-4.8.

In some instances, a single fit can result in estimation as to whether the event occurred (at block **825**) and estimation of one or more other event properties. In some instances, two, three or more fits are used. For example, a first fit can be used during an estimation as to whether the event occurred, a second fit for the event's magnitude, and the third fit for the event's location. These fits may be simultaneously determined or successively determined.

FIG. **9** illustrates a flowchart for a process **900** of forecasting event properties and sending alerts. For example, one or more of blocks **730-740** of process **700** can include one, more or all of blocks **905-920** of process **900**.

At block **905**, an event trajectory can be estimated based on an event magnitude or past trajectory (e.g., by event forecaster **514**). For example, a spread of an earthquake initially centered on a first location may depend on the earthquake's magnitude. As another example, a reach of a tornado or storm can depend on a past trajectory of the tornado or storm. Estimating the event trajectory can include extrapolating a past trajectory. Estimating the event trajectory can also or alternatively include considering characteristics of areas near the event (e.g., land-surface properties, weather conditions, fault-line presence, or altitude).

At block **910**, a future event location is forecasted based on the estimated event trajectory (e.g., by event forecaster **514**). The future event location can include a central location (e.g., a center of a tornado or storm) or an area. For example, an earthquake can initially affect a small area around the earthquake's epicenter and can later spread to affect an asymmetrical ring-shaped area. Thus, an estimate of the ring-shaped area can be made. The estimated future event location can include, e.g., a range of geographic coordinates, a set of zip codes, or a list of cities.

At block **915**, devices in the forecasted future event location are identified (e.g., by alert engine **516**). The devices can be identified by looking up the future event location in a database (e.g., device-locations database **506**). The database can be populated with an address, coordinate set, city, and/or zip code for each device. This data can be provided by user input or by smart-device technology (e.g., that uses GPS signals).

At block **920**, alerts are transmitted to the identified devices or to user devices associated with identified devices (e.g., by alert engine **516**). For example, a user of a device can identify his phone number or email address, and a message can therefore be sent to his phone or email account. The message can identify the occurrence of the event and/or can include past or forecasted event properties.

FIGS. **10A-10B** illustrate one example of a thermostat device **1000** that may be used to collect sensor measurements. The term "thermostat" is used to represent a particular type of VSCU unit (Versatile Sensing and Control) that is particularly applicable for HVAC control in an enclosure. As used herein the term "HVAC" includes systems providing both heating and cooling, heating only, cooling only, as well as systems that provide other occupant comfort and/or conditioning functionality such as humidification, dehumidification and ventilation. Although "thermostat" and "VSCU unit" may be seen as generally interchangeable for the context of HVAC control of an enclosure, it is within the scope of the present teachings for each of the embodiments hereinabove and hereinbelow to be applied to VSCU units having control functionality over measurable characteristics other than temperature (e.g., pressure, flow rate, height, position, velocity, acceleration, capacity, power, loudness, brightness) for any of a variety of different control systems involving the governance of one or more measurable characteristics of one or more physical systems, and/or the governance of other energy or resource consuming systems such as water usage systems, air usage systems, systems involving the usage of other natural resources, and systems involving the usage of various other forms of energy.

As illustrated, thermostat **1000** includes a user-friendly interface, according to some embodiments. Thermostat **1000** includes control circuitry and is electrically connected to an HVAC system. Thermostat **1000** is wall mounted, is circular in shape, and has an outer rotatable ring **1012** for receiving user input.

Outer rotatable ring **1012** allows the user to make adjustments, such as selecting a new target temperature. For example, by rotating outer ring **1012** clockwise, a target setpoint temperature can be increased, and by rotating the outer ring **1012** counter-clockwise, the target setpoint temperature can be decreased.

A central electronic display **1016** may include, e.g., a dot-matrix layout (individually addressable) such that arbitrary shapes can be generated (rather than being a segmented layout); a combination of a dot-matrix layout and a segmented layout' or a backlit color liquid crystal display (LCD). An example of information displayed on electronic display **1016** is illustrated in FIG. **10A**, and includes central numerals **1020** that are representative of a current setpoint temperature. It will be appreciated that electronic display **1016** can display other types of information, such as information identifying or indicating an event occurrence and/or forecasting future event properties.

Thermostat **1000** has a large front face lying inside the outer ring **1012**. The front face of thermostat **1000** comprises a clear cover **1014** that according to some embodiments is polycarbonate, and a metallic portion **1024** preferably having a number of slots formed therein as shown. According to some embodiments, metallic portion **1024** has number of slot-like openings so as to facilitate the use of a passive infrared motion sensor **1030** mounted therebeneath. Metallic portion **1024** can alternatively be termed a metallic front grille portion. Further description of the metallic portion/front grille portion is provided in the commonly assigned U.S. Ser. No. 13/199,108, which is hereby incorporated by reference in its entirety for all purposes.

Motion sensing as well as other techniques can be use used in the detection and/or predict of occupancy, as is described further in the commonly assigned U.S. Ser. No. 12/881,430, which is hereby incorporated by reference in its entirety. According to some embodiments, occupancy information is used in generating an effective and efficient scheduled pro-

gram. Preferably, an active proximity sensor **1070**A is provided to detect an approaching user by infrared light reflection, and an ambient light sensor **1070**B is provided to sense visible light. Proximity sensor **1070**A can be used to detect proximity in the range of about one meter so that the thermostat **1000** can initiate "waking up" when the user is approaching the thermostat and prior to the user touching the thermostat. Ambient light sensor **1070**B can be used for a variety of intelligence-gathering purposes, such as for facilitating confirmation of occupancy when sharp rising or falling edges are detected (because it is likely that there are occupants who are turning the lights on and off), and such as for detecting long term (e.g., 24-hour) patterns of ambient light intensity for confirming and/or automatically establishing the time of day.

According to some embodiments, for the combined purposes of inspiring user confidence and further promoting visual and functional elegance, thermostat **1000** is controlled by only two types of user input, the first being a rotation of the outer ring **1012** as shown in FIG. **10**A (referenced hereafter as a "rotate ring" or "ring rotation" input), and the second being an inward push on an outer cap **1008** (see FIG. **10**B) until an audible and/or tactile "click" occurs (referenced hereafter as an "inward click" or simply "click" input). Upon detecting a user click, new options can be presented to the user. For example, a menu system can be presented, as detailed in U.S. Ser. No. 13/351,668, which is hereby incorporated by reference in its entirety for all purposes. The user can then navigate through the menu options and select menu settings using the rotation and click functionalities.

According to some embodiments, thermostat **1000** includes a processing system **1060**, display driver **1064** and a wireless communications system **1066**. Processing system **1060** is adapted to cause the display driver **1064** and display area **1016** to display information to the user, and to receiver user input via the rotatable ring **1012**. Processing system **1060**, according to some embodiments, is capable of carrying out the governance of the operation of thermostat **1000** including the user interface features described herein. Processing system **1060** is further programmed and configured to carry out other operations as described herein. For example, processing system **1060** may be programmed and configured to dynamically determine when to collect sensor measurements, when to transmit sensor measurements, and/or how to present received alerts. According to some embodiments, wireless communications system **1066** is used to communicate with, e.g., a central server, other thermostats, personal computers or portable devices (e.g., laptops or cell phones).

Referring next to FIG. **11**, an exemplary environment with which embodiments may be implemented is shown with a computer system **1100** that can be used by a user **1104** to remotely control, for example, one or more of the sensor-equipped smart-home devices according to one or more of the embodiments. The computer system **1110** can alternatively be used for carrying out one or more of the server-based processing paradigms described hereinabove, can be used as a processing device in a larger distributed virtualized computing scheme for carrying out the described processing paradigms, or for any of a variety of other purposes consistent with the present teachings. The computer system **1100** can include a computer **1102**, keyboard **1122**, a network router **1112**, a printer **1108**, and a monitor **1106**. The monitor **1106**, processor **1102** and keyboard **1122** are part of a computer system **1126**, which can be a laptop computer, desktop computer, handheld computer, mainframe computer, etc. The monitor **1106** can be a CRT, flat screen, etc.

A user **1104** can input commands into the computer **1102** using various input devices, such as a mouse, keyboard **1122**, track ball, touch screen, etc. If the computer system **1100** comprises a mainframe, a designer **1104** can access the computer **1102** using, for example, a terminal or terminal interface. Additionally, the computer system **1126** may be connected to a printer **1108** and a server **1110** using a network router **1112**, which may connect to the Internet **1118** or a WAN.

The server **1110** may, for example, be used to store additional software programs and data. In one embodiment, software implementing the systems and methods described herein can be stored on a storage medium in the server **1110**. Thus, the software can be run from the storage medium in the server **1110**. In another embodiment, software implementing the systems and methods described herein can be stored on a storage medium in the computer **1102**. Thus, the software can be run from the storage medium in the computer system **1126**. Therefore, in this embodiment, the software can be used whether or not computer **1102** is connected to network router **1112**. Printer **1108** may be connected directly to computer **1102**, in which case, the computer system **1126** can print whether or not it is connected to network router **1112**.

With reference to FIG. **12**, an embodiment of a special-purpose computer system **1200** is shown. For example, one or more of intelligent components **116**, processing engine **306** and components thereof may be a special-purpose computer system **1200**. The above methods may be implemented by computer-program products that direct a computer system to perform the actions of the above-described methods and components. Each such computer-program product may comprise sets of instructions (codes) embodied on a computer-readable medium that directs the processor of a computer system to perform corresponding actions. The instructions may be configured to run in sequential order, or in parallel (such as under different processing threads), or in a combination thereof. After loading the computer-program products on a general purpose computer system **1126**, it is transformed into the special-purpose computer system **1200**.

Special-purpose computer system **1200** comprises a computer **1102**, a monitor **1106** coupled to computer **1102**, one or more additional user output devices **1230** (optional) coupled to computer **1102**, one or more user input devices **1240** (e.g., keyboard, mouse, track ball, touch screen) coupled to computer **1102**, an optional communications interface **1250** coupled to computer **1102**, a computer-program product **1205** stored in a tangible computer-readable memory in computer **1102**. Computer-program product **1205** directs system **1200** to perform the above-described methods. Computer **1102** may include one or more processors **1260** that communicate with a number of peripheral devices via a bus subsystem **1290**. These peripheral devices may include user output device(s) **1230**, user input device(s) **1240**, communications interface **1250**, and a storage subsystem, such as random access memory (RAM) **1270** and non-volatile storage drive **1280** (e.g., disk drive, optical drive, solid state drive), which are forms of tangible computer-readable memory.

Computer-program product **1205** may be stored in non-volatile storage drive **1280** or another computer-readable medium accessible to computer **1102** and loaded into memory **1270**. Each processor **1260** may comprise a microprocessor, such as a microprocessor from Intel® or Advanced Micro Devices, Inc.®, or the like. To support computer-program product **1205**, the computer **1102** runs an operating system that handles the communications of product **1205** with the above-noted components, as well as the communications between the above-noted components in support of the computer-program product **1205**. Exemplary operating

systems include Windows® or the like from Microsoft Corporation, Solaris® from Sun Microsystems, LINUX, UNIX, and the like.

User input devices **1240** include all possible types of devices and mechanisms to input information to computer system **1102**. These may include a keyboard, a keypad, a mouse, a scanner, a digital drawing pad, a touch screen incorporated into the display, audio input devices such as voice recognition systems, microphones, and other types of input devices. In various embodiments, user input devices **1240** are typically embodied as a computer mouse, a trackball, a track pad, a joystick, wireless remote, a drawing tablet, a voice command system. User input devices **1240** typically allow a user to select objects, icons, text and the like that appear on the monitor **1106** via a command such as a click of a button or the like. User output devices **1230** include all possible types of devices and mechanisms to output information from computer **1102**. These may include a display (e.g., monitor **1106**), printers, non-visual displays such as audio output devices, etc.

Communications interface **1250** provides an interface to other communication networks and devices and may serve as an interface to receive data from and transmit data to other systems, WANs and/or the Internet **1118**. Embodiments of communications interface **1250** typically include an Ethernet card, a modem (telephone, satellite, cable, ISDN), a (asynchronous) digital subscriber line (DSL) unit, a FireWire® interface, a USB® interface, a wireless network adapter, and the like. For example, communications interface **1250** may be coupled to a computer network, to a FireWire® bus, or the like. In other embodiments, communications interface **1250** may be physically integrated on the motherboard of computer **1102**, and/or may be a software program, or the like.

RAM **1270** and non-volatile storage drive **1280** are examples of tangible computer-readable media configured to store data such as computer-program product embodiments of the present invention, including executable computer code, human-readable code, or the like. Other types of tangible computer-readable media include floppy disks, removable hard disks, optical storage media such as CD-ROMs, DVDs, bar codes, semiconductor memories such as flash memories, read-only-memories (ROMs), battery-backed volatile memories, networked storage devices, and the like. RAM **1270** and non-volatile storage drive **1280** may be configured to store the basic programming and data constructs that provide the functionality of various embodiments of the present invention, as described above.

Software instruction sets that provide the functionality of the present invention may be stored in RAM **1270** and non-volatile storage drive **1280**. These instruction sets or code may be executed by the processor(s) **1260**. RAM **1270** and non-volatile storage drive **1280** may also provide a repository to store data and data structures used in accordance with the present invention. RAM **1270** and non-volatile storage drive **1280** may include a number of memories including a main random access memory (RAM) to store of instructions and data during program execution and a read-only memory (ROM) in which fixed instructions are stored. RAM **1270** and non-volatile storage drive **1280** may include a file storage subsystem providing persistent (non-volatile) storage of program and/or data files. RAM **1270** and non-volatile storage drive **1280** may also include removable storage systems, such as removable flash memory.

Bus subsystem **1290** provides a mechanism to allow the various components and subsystems of computer **1102** communicate with each other as intended. Although bus subsystem **1290** is shown schematically as a single bus, alternative embodiments of the bus subsystem may utilize multiple busses or communication paths within the computer **1102**.

For a firmware and/or software implementation, the methodologies may be implemented with modules (e.g., procedures, functions, and so on) that perform the functions described herein. Any machine-readable medium tangibly embodying instructions may be used in implementing the methodologies described herein. For example, software codes may be stored in a memory. Memory may be implemented within the processor or external to the processor. As used herein the term "memory" refers to any type of long term, short term, volatile, nonvolatile, or other storage medium and is not to be limited to any particular type of memory or number of memories, or type of media upon which memory is stored.

Moreover, as disclosed herein, the term "storage medium" may represent one or more memories for storing data, including read only memory (ROM), random access memory (RAM), magnetic RAM, core memory, magnetic disk storage mediums, optical storage mediums, flash memory devices and/or other machine readable mediums for storing information. The term "machine-readable medium" includes, but is not limited to portable or fixed storage devices, optical storage devices, wireless channels, and/or various other storage mediums capable of storing that contain or carry instruction(s) and/or data.

EXAMPLES

Example 1

Thermostats are provided, and each thermostat includes a set of accelerometers, which detect acceleration in each of three perpendicular directions. Users purchase the thermostat, and each user mounts the thermostat on a wall in a dwelling (e.g., in his home). Each thermostat detects a local wireless network and requests a password. A respective user enters the password by rotating a rotatable ring of the thermostat to highlight appropriate letters and clicking the ring to select the highlighted letter, such that the thermostat can communicate over the Internet.

Each thermostat further requests that a user enter an address, which may be a full specific street address in some embodiments or a more general area identifier such as a ZIP code in other embodiment, at which it is located. The user again enters the address using the rotatable ring. Each thermostat then transmits a message to a central server identifying the thermostat and the address. Alternatively, once the user has paired their thermostat with an online account associated with the thermostat, the user may provide their address information using browser-based access to that online account. The central server associates each thermostat with its address in a database.

The accelerometers collect acceleration measurements every minute. If any of the three acceleration measurements (one for each spatial dimension) exceed a threshold, the thermostat transmits the acceleration measurements to a center server, along with a device identifier.

The central server, upon receiving the communication, looks up the thermostat's address and identifies other thermostats near the communication-transmitting thermostat. The central server determines that 10 of 15 other nearby thermostats have also transmitted similar communications within the last minute. This 66% transmission rate exceeds an event-occurrence threshold, and thus, the central server determines that an earthquake has occurred.

The central server identifies median acceleration measurements and estimates an earthquake magnitude based on the median. The central server assesses whether there are any similarly occurring events among other nearby populations of thermostats. The central server then forecasts other areas likely to be affected in view of the earthquake's magnitude and known properties about earthquake propagation. The central server consults the database to identify other devices in the forecasted location and transmits a signal to each of the other devices. Upon receiving the signal, each of the other devices sounds an alarm indicating that people should take cover.

Example 2

Sprinkler systems are provided. Each system includes a control box with temperature, humidity and wind detector. Users purchase the sprinkler system, and each user mounts the control box on a wall outside a dwelling (e.g., on a house exterior surface). The control box, or a separately provided device provided in conjunction with the control box, is equipped with a user interface having a similar physical look and feel to the user interface of the thermostat device described above with respect to FIGS. **10**A-**10**B. Each sprinkler system detects a local wireless network and requests a password. A respective user enters the password by rotating a rotatable ring of the control box (or other user interface device associated with the control box) of the sprinkler system to highlight appropriate letters and clicking the ring to select the highlighted letter, such that the sprinkler system can communicate over the Internet.

Each sprinkler system also receives GPS signals and identifies its geographic coordinates. The sprinkler system then transmits a message to a central server identifying the sprinkler system and the coordinates. The central server associates each sprinkler system with its coordinates in a database.

The sprinkler systems collect measurements from the temperature, humidity and wind sensors for five minutes every hour. The sprinkler system averages these measurements across the time period and transmits the averaged measurements and a device identifier to the central server.

The central server, upon receiving the communication, looks up coordinates for the sprinkler system. The central server then inputs the coordinates and the average measurements into a model. The model gradually learns about how the average measurements predicts future measurements. The learning may involve weighting sensor measurements (e.g., to reduce the influence of likely-faulty sensor readings), correlating measurement readings in a first region with later measurement readings in a second region, and considering non-measurement variables, such as the date, time of day, and topography. The model can include utilization of thermodynamic and/or aerodynamic principles.

The model outputs regular forecasts, which include forecasts for a region spanned by the plurality of sprinkler systems. The forecasts are routinely sent to meteorology centers. Further, a user of the sprinkler system can request a forecast (using the sprinkler system user interface or using a website which can receive an identifier of the sprinkler system and/or of the user). A message is transmitted to the central server, the message including an indication of the request and an identifier of the sprinkler system or the user. The central server looks up the coordinates of the sprinkler system and identifies a forecast specific to those coordinates. A message with the forecast information is then transmitted back to the user (e.g., back to the sprinkler system or over the Internet via the website), and the forecast is displayed to the user.

Example 3

A variety of devices are provided, the devices including smoke detectors, wall-plug interfaces, thermostats, and light switches. Each device includes a pressure sensor. Users purchase the devices and appropriately positions the device (e.g., mounting it to a wall). Each device may be equipped with a user interface having a similar physical look and feel to the user interface of the thermostat device described above with respect to FIGS. **10**A-**10**B. Each device detects a local wireless network and requests a password. A respective user enters the password by rotating a rotatable ring of the device to highlight appropriate letters and clicking the ring to select the highlighted letter, such that the device can communicate over the Internet.

A user of each device registers the device online using a serial number. The user also enters the address of the device location and his phone number. A central server receives this data and associates each device with its address in a first database and associates each device with a user phone number in a second database.

The central server communicates with external governmental agencies that control the official issuance of tornado watches and warning. Upon receiving a message from the agency that a tornado watch has been issued, the central server looks up devices within the tornado-watch area using the first database. The central server then sends a message to those devices requesting regular pressure-sensor data. The devices collect the measurements and communicate the measurements to the central server.

The central server routinely analyzes the pressure-sensor data and compares an average of a subset of the data (e.g., the data within an 80-90% range with 0% being the lowest received value and 100% being the highest) to a threshold. Upon detecting that the average exceeds the threshold, the central server sends an electronic alert over the Internet to the governmental agency. Further, the central server sends text messages to the smartphones associated with the devices in the tornado-watch area indicating that the server has issued an escalated tornado-watch state.

Example 4

A plurality of light switches are provided. Each light switch includes a motion detector. Users purchase the devices and mount each light switch to a wall. Within a building, each light switch communicates wirelessly with a control box that includes a processing system.

Each motion detector is continuously active. Once a motion detector detects motion, it transmits a signal to the control box identifying the light switch and indicating that motion has been detected. The control box correlates the motion detections across the light switches and identifies common patterns (e.g., a frequent successive detection sequence is one that activates the motion detector Switch #**3**, then #**5**, then #**8**). Based on these patterns, the control box estimates location information about the switches (e.g., Switch #**3** is near Switch #**5**).

The control box can later receive select motion detections and forecast future motion detections (e.g., if detections are made by Switch #**3** and then #**5**, the control box can forecast that motion will be detected by Switch #**8**). The control box then sends messages to light switches involved in the forecast (e.g., Switch #**8**). Switch #**8** then automatically turns on the

light before motion is detected. The automatic lighting can be prevented if ambient lighting is above a threshold. In this way, a person's path can be illuminated as they walk throughout the house even if light switches are on opposite sides of the room from entryways.

Specific details are given in the above description to provide a thorough understanding of the embodiments. However, it is understood that the embodiments may be practiced without these specific details. For example, circuits may be shown in block diagrams in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

Implementation of the techniques, blocks, steps and means described above may be done in various ways. For example, these techniques, blocks, steps and means may be implemented in hardware, software, or a combination thereof. For a hardware implementation, the processing units may be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described above, and/or a combination thereof.

Also, it is noted that the embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed, but could have additional steps not included in the figure. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or the main function.

Furthermore, embodiments may be implemented by hardware, software, scripting languages, firmware, middleware, microcode, hardware description languages, and/or any combination thereof. When implemented in software, firmware, middleware, scripting language, and/or microcode, the program code or code segments to perform the necessary tasks may be stored in a machine readable medium such as a storage medium. A code segment or machine-executable instruction may represent a procedure, a function, a subprogram, a program, a routine, a subroutine, a module, a software package, a script, a class, or any combination of instructions, data structures, and/or program statements. A code segment may be coupled to another code segment or a hardware circuit by passing and/or receiving information, data, arguments, parameters, and/or memory contents. Information, arguments, parameters, data, etc. may be passed, forwarded, or transmitted via any suitable means including memory sharing, message passing, token passing, network transmission, etc.

While the principles of the disclosure have been described above in connection with specific apparatuses and methods, it is to be clearly understood that this description is made only by way of example and not as limitation on the scope of the disclosure.

What is claimed is:

1. A event-forecasting system comprising:

a measurement database that stores a plurality of sensor measurements, each sensor measurement having been provided by a thermostat device, wherein a primary purpose of each thermostat device is to control a temperature condition within a structure in addition to collecting measurements from a non-temperature related sensor that collected the sensor measurement, wherein said non-temperature related sensor is selected from the group consisting of: seismic activity sensors hazard related environmental sensors, microphones optical sensors and radiation sensors;

a measurement set identifier that selects a set of sensor measurements from the plurality of sensor measurements provided by the thermostat devices in the measurement database, wherein the thermostat devices associated with the set of sensor measurements are in close geographical proximity relative to their geographical proximity to other devices;

an inter-device correlator that accesses the selected set of sensor measurements provided by the thermostat devices and that collectively analyzes the sensor measurements;

an event detector that determines whether an event has occurred based on the results of the collective analysis, wherein the determination that an event has occurred requires that a criterion involving at least two of the sensor measurements provided by the thermostat devices be satisfied;

an event forecaster that forecasts a future event property, wherein the future event property is forecasted based on a same or different collective analysis of the sensor measurements provided by the thermostat devices; and

an alert engine that identifies one or more entities to be alerted of the future event property, that generates at least one alert identifying the future event property, and that transmits the at least one alert to the identified one or more entities.

2. The event-forecasting system of claim **1**, further comprising a device-location database that stores, for each thermostat device of a plurality of thermostat devices, a location associated with the thermostat device,

wherein the measurement set identifier accesses the device-location database when selecting the set of sensor measurements provided by the thermostat devices.

3. The event-forecasting system of claim **1**, wherein the event forecaster forecasts the future event property upon a determination that the event has occurred.

4. The event-forecasting system of claim **1**, wherein the sensor measurements provided by the thermostat devices in the measurement set are associated with a similar measurement time.

5. The event-forecasting system of claim **1**, wherein thermostat devices associated with the sensor measurements in the measurement set are further associated with a plurality of users.

6. The event-forecasting system of claim **1**, wherein the event includes a weather-related or natural-disaster event.

7. A method for forecasting events, the method comprising:

storing a plurality of sensor measurements in a measurement database, each sensor measurement having been provided by a thermostat device, wherein a primary purpose of at least one respective thermostat device is to control a temperature condition within a structure in addition to collecting measurements from a non-temperature related sensor that collected the sensor measurement, wherein said non-temperature related sensor is selected from the group consisting of: seismic activity sensors, hazard related environmental sensors microphones, optical sensors, and radiation sensors;

selecting a set of sensor measurements from the plurality of sensor measurements provided by the thermostat devices in the measurement database, wherein the thermostat devices associated with the set of sensor measurements are in close geographical proximity relative to their geographical proximity to other devices;

collectively analyzing the sensor measurements provided by the thermostat devices to determine whether a large-scale event was occurring, wherein the determination that a large-scale event was occurring requires consistency between at least two of the sensor measurements provided by the thermostat devices;

forecasting a future event property, wherein the future event property is forecasted based on a same or different collective analysis of the sensor measurements provided by the thermostat devices;

identifying one or more entities to be alerted of the future event property;

generating at least one alert identifying the future event property; and

transmitting the at least one alert to the identified one or more entities.

8. The method for forecasting events as recited in claim **7**, wherein the one or more entities include a thermostat device not associated with the set of thermostat devices and associated with geographic location extending beyond a geographic area associated with the thermostat devices associated with the set of sensor measurements.

9. The method for forecasting events as recited in claim **7**, wherein transmitting the at least one alert comprises sending a signal to a phone of a user associated with a thermostat device likely to be affected by the event in the future.

10. The method for forecasting events as recited in claim **7**, wherein the event comprises an earthquake.

11. The method for forecasting events as recited in claim **7**, wherein collectively analyzing the sensor measurements provided by the thermostat devices comprises generating or refining a time-sensitive model.

12. The method for forecasting events as recited in claim **7**, wherein collectively analyzing the sensor measurements provided by the thermostat devices comprises counting a number of sensor measurements in the set of sensor measurements.

13. The method for forecasting events as recited in claim **7**, wherein the same or different collective analysis of the sensor measurements provided by the thermostat devices comprises predicting a trajectory of the event.

14. A crowdsourced event detection network, comprising:

a population of thermostat devices, each said thermostat device comprising a housing and at least one non-temperature related sensor coupled to the housing, the at least one non-temperature related sensor being configured to sense at least one environmental characteristic or condition that is generally unrelated to controlling a temperature condition within a structure, each said thermostat device further comprising a data transmission component configured to transmit first information representative of said least one sensed environmental characteristic or condition for reception by an aggregating processor, wherein said non-temperature related sensor is selected from the group consisting of: seismic activity sensors, hazard related environmental sensors, microphones, optical sensors, and radiation sensors;

wherein the aggregating processor is configured and programmed to receive the first information from each of a plurality of the thermostat devices, to forecast a future event based on a collective analysis thereof, to identify one or more entities to be alerted of the forecasted future event, and to transmit second information representative of the forecasted future event to the identified one or more entities.

15. The crowdsourced event detection network of claim **14**, wherein another thermostat device comprises the aggregating processor.

16. The crowdsourced event detection network of claim **14**, further comprising a central server that comprises the aggregating processor.

17. The crowdsourced event detection network of claim **14**, wherein the at least one non-temperature related sensor in each of said population of thermostat devices includes an accelerometer, and wherein the central server is configured to forecast earthquake events based on a collective analysis of the received first information derived from motion sensed by said accelerometers.

18. The crowdsourced event detection network of claim **14**, wherein each said thermostat device further comprises: a data receiving and processing component configured to receive data communications from said aggregating processor and to identify therefrom said second information representative of the forecasted future event; and

an alerting mechanism configured to alert a nearby home occupant of the forecasted future event.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,620,841 B1
APPLICATION NO. : 13/601890
DATED : December 31, 2013
INVENTOR(S) : John B. Filson et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims:

Column 30, Line 7 - Please omit "sensors hazard" and replace with -- sensors, hazard --.
Column 30, Line 8 - Please omit "microphones optical" and replace with -- microphones, optical --.
Column 30, Line 9 - Please omit "sors and radiation" and replace with -- sors, and radiation --.
Column 30, Line 66 - Please omit "environmental sensors micro-" and replace with -- environmental sensors, micro- --.

Signed and Sealed this
Twenty-ninth Day of April, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office