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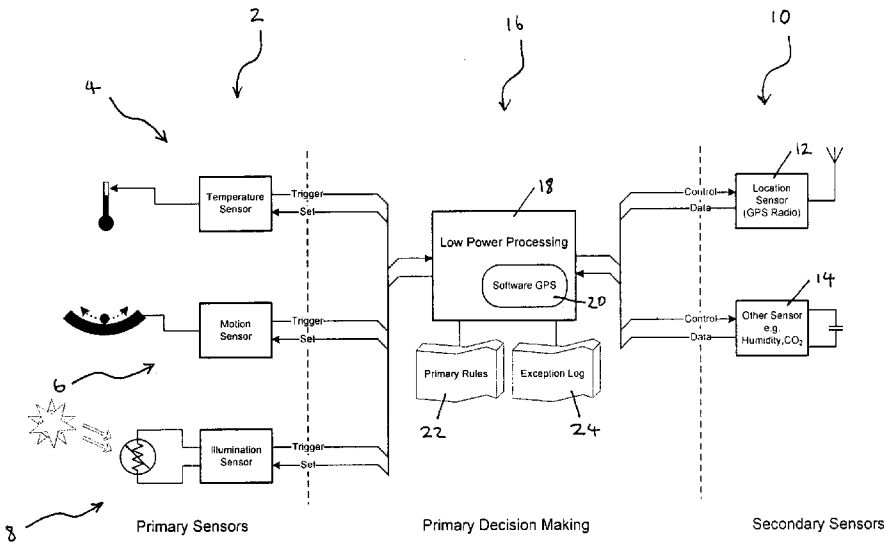
(54) **Title:** CONTEXT MONITORING FOR REMOTE SENSOR PLATFORMS



(57) **Abstract:** A remote sensor platform for asset tracking monitors the context of the local environment to conserve power. Primary sensors (2) monitor local environment stimuli such as temperature (4), pressure or illumination (8). A low-power processor (16) uses the primary sensors (2) to monitor the environment and thereby determine whether to activate a secondary high power sensor (10), such as a GPS unit (12) or humidity or gas sensor (14). The low power processor may be triggered by the primary sensors (2) and may use configurable rules (22) for decision making. It may log exceptions (24) and sensor data for further decision making. A high-power processor (28) sends sensor data via a reporting means (34) to a server (40) using secondary configurable rules (3) conditionally on the primary (2) and secondary (10) sensor inputs. The server (40) can update the rules (22,30).

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Context Monitoring for Remote Sensor Platforms

The present invention relates to the control of sensors, in particular the control of the activation of sensors.

In the field of remote sensor platforms, tracking devices may be used to secure a valuable object, for example a painting, against theft. Small tracking devices have the advantage that they can be concealed on or in objects, however the small size restricts the battery capacity.

A typical conventional tracking device incorporates a GPS (global positioning system) location sensor and a means for reporting position and/or exception data to a control centre. For the example of a painting, with the assumption that the GPS receiver works in the painting's normal environment such as a gallery, then a decision has to be made about how often the tracking device is to wake up and check its location. The problem is that if the tracking device wakes frequently into the relatively high power state in which it is determining its location using the GPS sensor, this will quickly run down its battery. A flat battery will limit or cease the tracking function of

the device. However if the tracking device is woken less frequently to save draining the battery then there is a delay in the reporting of the sensor and/or exception data. Thus there is a compromise between the lifetime of the tracking device's battery and the proper reporting of the sensor data, affecting for example the time it takes to realise that a theft has taken place.

WO9529410 in the name General Electric Company discloses a tracking unit using a motion sensor as a primary sensor to control the activation of a GPS navigation set as a secondary sensor. A problem with using a motion sensors as the primary sensor is that the activation of the secondary sensor requires movement of the tracking unit. Furthermore, the context of the local environment or changes in the context are ignored by a motion sensor.

It is the object of an aspect of the present invention to optimise the activation of a secondary sensor.

It is a further object of an aspect of the present invention to optimise the reporting of sensor data.

According to the first aspect of the present invention there is provided an apparatus comprising:

a primary sensor operable to sense a local environment stimulus;

a primary sensor input operable to receive a signal from the primary sensor;

a secondary sensor output operable to send an activation signal to a secondary sensor; and

a primary processing means operable to use the signal received from the primary sensor to monitor

the environment of the primary sensor and thereby determine whether to activate the secondary sensor and operable to cause the secondary sensor output to send an activation signal to the secondary sensor.

Preferably, the apparatus comprises a plurality of the primary sensors each operable to sense a different local environment stimulus and the primary processing means is operable to use signals received from the plurality of the primary sensors to monitor the environment of the plurality of primary sensors and thereby determine whether to activate the secondary sensor.

This allows low power primary sensors to monitor the environment and only activate higher power secondary sensors when needed, thus providing longer battery life.

Preferably, the local environment stimulus comprises temperature.

Preferably, the local environment stimulus comprises illumination.

Preferably, the local environment stimulus comprises one of: humidity, gas concentration, barometric pressure, mechanical pressure, gas concentration, electrical fields, magnetic fields electromagnetic field strength at a particular frequency, and electromagnetic field strength at a range of frequencies.

Preferably, the operation of the primary processing means is triggered by a signal received from the primary sensor.

This further prolongs battery life as only the primary sensor, or sensors, need to be powered up.

Optionally, the primary sensor is operable to be periodically powered down.

Operation is then that of sampling and the arrangement of the sampling of the primary parameters is arranged so that the effect of continuous monitoring is maintained.

Optionally, the periodic powering down of the primary sensor is under the control of the primary processing means.

Preferably, the primary processing means is configurably operable to determine whether to activate the secondary sensor.

Preferably, the primary processing means is remotely configurable.

Optionally, the configuration of the primary processing means is active for a predetermined period.

Optionally, the configuration of the primary processing means is selected from a set of predetermined configurations.

Preferably, the configurable operation of the primary processing means uses configurable primary rules.

This allows the primary rules to be changed so that they may develop over time for more optimised operation of the apparatus.

Preferably, the configurable primary rules are remotely configurable.

This also allows the primary rules to be changed to account for new environments as the object being tracked is moved around, thus optimising battery life and the reporting of sensor data.

Preferably, the apparatus further comprises a secondary sensor input operable to receive a signal from the secondary sensor and the primary processing means is operable to use the signal received from the secondary sensor to activate a secondary processing means.

Preferably, the primary processing means is operable to log sensor data corresponding to the received signals from one or more of the primary and secondary sensors.

This allows the storage of sensed conditions for reference in future decision making.

Preferably, the operation of the primary processing means uses the logged sensor data to determine whether to activate the secondary sensor.

This allows the primary processing means to use values of sensor data from the past to decide what to do now, thus optimising its decision making.

Preferably, the operation of the primary processing means uses the rate of change of the received signals from one or more of the primary and secondary sensors to determine whether to activate the secondary sensor.

Preferably, the apparatus further comprises a reporting means operable to transmit a sensor data signal based on the received signal from at least one of the primary and secondary sensors and the apparatus further comprises the secondary processing means operable to activate the reporting means conditionally upon the received signal from at least one of the primary and secondary sensors.

This allows further battery savings as the reporting means will generally have a higher power consumption than the sensors and primary processing means.

Preferably, the secondary processing means is configurably operable to activate the reporting means.

Preferably, the secondary processing means is remotely configurable.

Preferably, the operation of the secondary processing means uses configurable secondary rules.

This allows the secondary rules to be changed so that they may develop over time for more optimised operation of the apparatus.

Preferably, the configurable secondary rules are remotely configurable.

This also allows the secondary rules to be changed to account for new environments as the object being tracked is moved around, thus optimising battery life and the reporting of sensor data.

Preferably, the secondary processing means is operable to configure the primary rules.

This allows the primary rules to be changed so that they may develop over time for more optimised operation of the apparatus, thus optimising battery life and the reporting of sensor data.

Preferably, the primary processing means is further operable to activate the secondary processing means, conditionally upon an output of at least one of the primary and secondary sensors.

This optimises battery life by only activating the secondary processing means when required.

Preferably, the apparatus further comprises the secondary sensor that has a higher power consumption than the primary sensor.

Preferably, the secondary sensor is operable to sense the location of the apparatus.

This provides a sensor platform ideally suited to tracking applications, where the context of the local environment can be used to determine whether to activate the generally higher power location sensing secondary sensor.

Alternatively, the secondary sensor is operable to sense a secondary local environment stimulus.

Preferably, the secondary local environment stimulus comprises humidity.

Preferably, the secondary local environment stimulus comprises gas concentration.

Preferably, the secondary local environment stimulus comprises one of: temperature, illumination, barometric pressure, mechanical pressure, gas concentration, electrical fields, magnetic fields electromagnetic field strength at a particular frequency, and electromagnetic field strength at a range of frequencies..

According to the second aspect of the present invention there is provided a server operable to communicate with a plurality of the apparatus according to the first or second aspect, so as to receive the transmitted sensor data signal, and to configure at least one of the primary and secondary rules.

The rules which govern the behaviour of a tracking device monitor the current expected context of the object being tracked. However, context will not be static, they will change as the circumstances and use of the object changes. This server allows the rules to be changed remotely according to the changing expected context.

The present invention will now be described by way of example only with reference to the figures in which:

Figure 1 illustrates, in schematic form, a remote sensor platform according to the preferred embodiment of the present invention;

Figure 2 illustrates, in schematic form, the sensor platform with a secondary decision making and sensor data reporting components; and

Figure 3 illustrates, in schematic form, a sensor device management server.

The preferred embodiment of the present invention provides an apparatus in a sensor platform having low and high powered components that is configured to improve both battery life and responsiveness of the sensor platform. The sensor platform of this embodiment is suitable for tracking objects such as valuables or paintings.

With reference to figure 1, the primary sensors 2 are used to monitor the environment of an object being tracked (not shown) with the apparatus. The primary sensors include a temperature sensor 4, a motion sensor 6 and an illumination sensor 8. A pressure sensor, such a barometric (air) pressure sensor (not shown) can be used as a primary sensor, or for example humidity or gas concentration can be measured. The relatively high powered secondary sensors 10 include a GPS radio location sensor 12 and another sensor 14 e.g. for sensing humidity or CO_2. The primary processing means 16 has a low power processing module 18 that includes GPS software 20. The processing means is a microcontroller, but may be a

computer or a software object within a computer or stored on carrier such as computer memory. The low power processing module of the primary processing means refers to primary rules 22 and generates an exception log 24. The primary sensors are those which would be active in a normal or idle state of the tracker. The electronic control circuitry associated with these sensors may be very simple and consume very little power, meaning that the tracker can remain in the idle state for periods of several years. The primary sensors are configured to produce a trigger if a stimulus that they are measuring goes outside of preset boundaries. For example, this could be a level of illumination indicating a move into daylight, a rapid change of temperature indicating a move into a different room, a series of sudden jerky movements or an unusual change in air pressure. A trigger from any one of the primary sensors causes the tracker to change from its idle state into a slightly higher power mode, in which the primary processing means 16 is activated.

The primary processing means has inputs operable to receive trigger signals from the primary sensors. It uses these signals to determine whether to activate a secondary sensor using the primary rules. Based on this decision, it may activate the secondary sensor by sending an activation signal via an output to the secondary sensor. In response to the primary sensor input signals in some cases the primary processing means will do nothing at all, in other cases a check of the secondary sensors will be required, perhaps including the GPS location sensor to verify that the object being tracked is still where it is supposed to be. Additional secondary sensors may need to be checked, for example a humidity

check if an old art work was being secured. Any other local environmental stimulus can be sensed by a secondary sensor to monitor the context of the local environment, such as temperature, pressure, illumination, gas (e.g. CO_2) concentration. If the primary and/or secondary sensors indicate a problem, again according to the primary rules, then the tracker may progress into the next non idle state. The circumstances which caused the move into the first non-idle state are logged as exceptions for later reporting and reference. The primary rules may also be reconfigured, for future use. Additional control over the period for which a context is active or the selection of an active context from a plurality of predefined contexts may be provided. This may require the selection of a set of rules.

The primary processing means may log sensor data from the primary and/or secondary sensors to store sensed conditions for reference in future decision making in order to determine whether to activate the secondary sensor.

The primary processing means can use the rate of change of the received signals from one or more of the primary and secondary sensors to determine whether to activate the secondary sensor.

Other primary and secondary sensors could be used to monitor the context of the local environment. For example, chemical sensors (for example Volatile Organic Chemicals (VOCs) such as those given off by paints).

Pressure in the mechanical sense of a weight on a surface rather than barometric could be another type of primary or secondary sensor.

Other potential parameters to sensed by the primary and secondary sensors may include: electrical fields, magnetic fields (for example by magnetometers used to derive magnetic compass heading, similar effect to motion sensing since movement will inevitably include some rotation with respect to magnetic North etc.) and electromagnetic fields. For example, in the latter case the electromagnetic field strength on a particular frequency or range of frequencies could be used to detect a context change.

Any of these could be primary or secondary sensors and the combination and use would depend upon the application.

With reference to figure 2, the primary sensors 2 and secondary sensors 10 are shown in communication with the primary processing means 16. A secondary processing means 26 has a relatively high power processing module 28 that refers to secondary rules 30 and generates an exception log 32. A GSM (Global System for Mobile communications) / GPRS (General Packet Radio Service) modem 34 reports sensor data via the aerial 36 wirelessly to the internet 38. Other reporting means may also be used, using for example Zigbee, WLAN (Wireless Local Area Network), UWB (Ultra-Wide Band), Bluetooth, 3G, 4G, EDGE, etc. for transmitting the sensor data.

The secondary processing means 26 is operable to activate the GSM/GPRS modem, conditionally upon an output of at least one of the primary and secondary sensors. In this embodiment, the data is prepared by the low power primary processing means 16. The secondary processing means operates using the configurable secondary rules 30, and is also operable to configure the primary rules in the primary processing means 16. The primary processing means 16 is operable to activate the secondary processing means 26, conditionally upon a trigger output of at least one of the primary 2 and secondary 10 sensors.

When the secondary processing means 26 is active, the tracker consults its secondary rules 30 about what to do, given the data from the lower level functions which caused it to wake up. For example, it may do nothing at all and turn off all but the primary sensors, it may up-date the primary rules and turn off all but the primary sensors after logging the exception, it may monitor the situation using some or all of the available sensors, or it may activate the GSM/GPRS modem and report selected sensor data via the internet to a server.

With reference to Figure 3 a server 40 is connected to the internet 38 communicates with one or more of the tracker devices. The server receives the sensor data transmitted from the GSM/GPRS modem and configures at least one of the primary and secondary rules. This configuration may be conditional on the received transmitted signal. It does this configuration with reference to its own set of tertiary rules 42. The server 40 generates further reports and management information, which is distributed via the internet 38 to

users' terminals 44. In the embodiment being used to track a painting, for example, the parameters describing the context of the painting on display on a gallery will be very different to those experienced when it is in transit between exhibitions or in storage. Changing between contexts and changing the primary and secondary rules to match, may be governed by the users of the tracking system, or automatically using the tertiary rules and conditionally on the received transmitted signal. Users will know if a painting is in transit and they will also know where it is going and what the environment will be in the new location. Therefore, for example, if the tracker is working properly and the painting is moved it will wake up and report the change. At this point, the server, according to its own tertiary rules, may accept the reports and up-date the primary and secondary rules to conform to what it knows is happening. It may request, for example, half-hourly location reports whilst in transit with an increase in frequency to once per minute if the additional sensors detect undue temperature changes or lighting changes that may indicate a problem with the transport.

In standard tracking or telematics there is little opportunity for the server to influence the behaviour of the remote device. It is an advantage of the present invention that the server plays an important role and is part of the overall capability of the remote tracker. The inclusion of the server in this way means that the tracking device can be thought of as partly the remote sensor platform and partly the software running on the device management server 40.

The present invention advantageously provides the opportunity to embed the tracking device inside an item with no, or a sparse, external power source. In this case the device can be designed to use its power over a long period, perhaps greater than the expected life of the item into which it is embedded. This provides for context monitoring of items by devices completely enclosed in the fabric of an item and inaccessible without at least partially destroying the item. Examples could be trackers within the wall or floor of a caravan or built into the casing of high value medical equipment.

The present invention, with its arrangement of rules, processing means and sensors reduces the overall power consumption of the remote device and increases the relevance of information reported. The layers of activity and intelligence ensure that the minimum amount of power is being consumed at any time. The next stage of the device is only woken up when absolutely needed. Redundant information is also minimised. Rather than many reports from a tracker, which amounts to "I am still here and everything is fine", users may receive information only when that information is important. This feature is increasingly valuable as the number and varieties of tracking devices expands. It would make a great difference to a person responsible for hundreds of tracked assets, if he only received reports from those assets which required attention and not hundreds of essentially information-free reports from all assets all the time. In the latter situation, it is more the absence of information which is significant, i.e. a missed report, and not the presence of information as provided by the present invention.

The decision making and configuration of rules uses primary, secondary and tertiary rules. However, other forms of logic or decision making may be used to achieve the same effect.

The device management server may be integrated into larger software applications used by businesses to control their operations. In that case, a complete automated asset management tool may be made available to a wide variety of business, organisations and, through service provision, to individuals.

Further modifications and improvements may be added without departing from the scope of the invention described by the claims.

Claims

1. An apparatus comprising:
a primary sensor operable to sense a local environment stimulus;
a primary sensor input operable to receive a signal from the primary sensor;
a secondary sensor output operable to send an activation signal to a secondary sensor; and
a primary processing means operable to use the signal received from the primary sensor to monitor the environment of the primary sensor and thereby determine whether to activate the secondary sensor and operable to cause the secondary sensor output to send an activation signal to the secondary sensor.

2. The apparatus of claim 1 wherein the apparatus comprises a plurality of the primary sensors each operable to sense a different local environment stimulus and the primary processing means is operable to use signals received from the plurality of the primary sensors to monitor the environment of the plurality of primary sensors and thereby determine whether to activate the secondary sensor.

3. The apparatus of claim 1 or claim 2 wherein the local environment stimulus comprises temperature.

4. The apparatus of any previous claim wherein the local environment stimulus comprises illumination.

5. The apparatus of any previous claim wherein the local environment stimulus comprises one of:

humidity, gas concentration, barometric pressure, mechanical pressure, gas concentration, electrical fields, magnetic fields electromagnetic field strength at a particular frequency, and electromagnetic field strength at a range of frequencies.

6. The apparatus of any previous claim wherein the operation of the primary processing means is triggered by a signal received from the primary sensor.

7. The apparatus of any previous claim wherein the primary sensor is operable to be periodically powered down.

8. The apparatus of claim 7 wherein the periodic powering down of the primary sensor is under the control of the primary processing means.

9. The apparatus of any previous claim wherein the primary processing means is configurably operable to determine whether to activate the secondary sensor.

10. The apparatus of claim 9 wherein the primary processing means is remotely configurable.

11. The apparatus of claim 9 or claim 10 wherein the configuration of the primary processing means is active for a predetermined period.

12. The apparatus of any of claims 9 to 11 wherein the configuration of the primary processing means is selected from a set of predetermined configurations.

13. The apparatus of any of claims 9 to 12 wherein the configurable operation of the primary processing means uses configurable primary rules.

14. The apparatus of claim 13 wherein the configurable primary rules are remotely configurable.

15. The apparatus of any previous claim further comprising a secondary sensor input operable to receive a signal from the secondary sensor and the primary processing means is operable to use the signal received from the secondary sensor to activate a secondary processing means.

16. The apparatus of any previous claim wherein the primary processing means is operable to log sensor data corresponding to the received signals from one or more of the primary and secondary sensors.

17. The apparatus of claim 16 wherein the operation of the primary processing means uses the logged sensor data to determine whether to activate the secondary sensor.

18. The apparatus of any previous claim wherein the operation of the primary processing means uses the rate of change of the received signals from one or more of the primary and secondary sensors to determine whether to activate the secondary sensor.

19. The apparatus of any of claims 15 to 18 further comprising a reporting means operable to transmit a sensor data signal based on the received signal from at least one of the primary and secondary sensors and the apparatus further comprises the secondary processing means operable to activate the reporting means conditionally upon the received signal from at least one of the primary and secondary sensors.

20. The apparatus of claim 19 wherein the secondary processing means is configurably operable to activate the reporting means.

21. The apparatus of claim 20 wherein the secondary processing means is remotely configurable.

22. The apparatus of any of claims 19 to 21 wherein the operation of the secondary processing means uses configurable secondary rules.

23. The apparatus of claim 22 wherein the configurable secondary rules are remotely configurable.

24. The apparatus of any of claims 19 to 23 wherein the secondary processing means is operable to configure the primary rules.

25. The apparatus of any of claims 19 to 24 wherein the primary processing means is further operable to activate the secondary processing means, conditionally upon an output of at least one of the primary and secondary sensors.

26. The apparatus of any of previous claims further comprising the secondary sensor that has a higher power consumption than the primary sensor.

27. The apparatus of claim 26 wherein the secondary sensor is operable to sense the location of the apparatus.

28. The apparatus of claim 26 or 27 wherein the secondary sensor is operable to sense a secondary local environment stimulus.

29. The apparatus of claim 28 wherein the secondary local environment stimulus comprises humidity.

30. The apparatus of claim 28 or 29 wherein the secondary local environment stimulus comprises gas concentration.

31. The apparatus of any of claims 28 to 30 wherein the secondary local environment stimulus comprises one of: temperature, illumination, barometric pressure, mechanical pressure, gas concentration, electrical fields, magnetic fields electromagnetic field strength at a particular frequency, and electromagnetic field strength at a range of frequencies.

32. A server operable to communicate with a plurality of the apparatus according to any of claims 19 to 31, so as to receive the transmitted sensor data signal,

and to configure at least one of the primary and secondary rules.

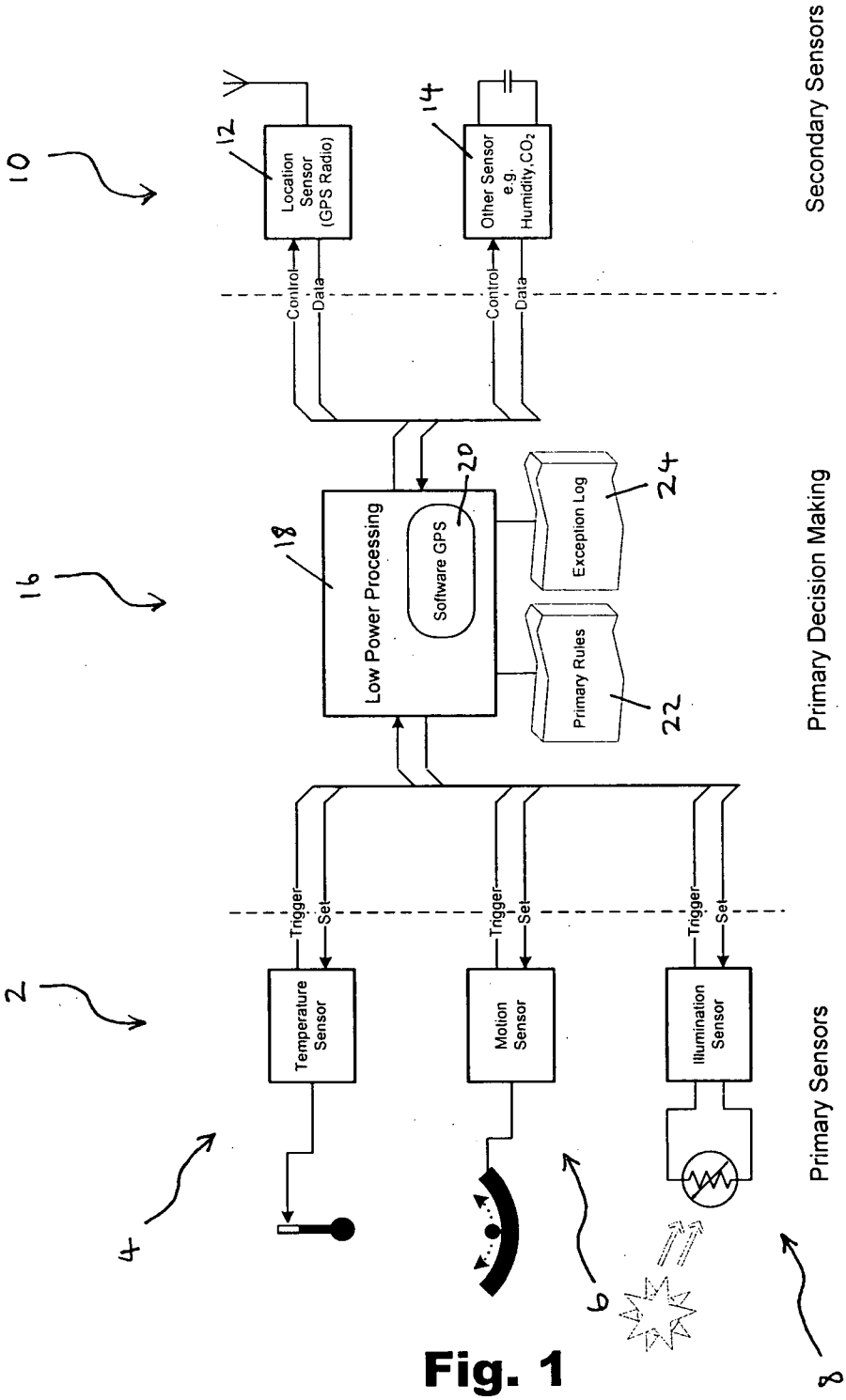
Secondary Sensors
Primary Decision Making
Primary Sensors
10
12
Location Sensor (GPS Radio)
14
Other Sensor e.g. Humidity, CO_2
Control
Data
Control
Data
16
18
Low Power Processing
20
Software GPS
Exception Log
24
Primary Rules
22
Trigger
Set
Trigger
Set
Trigger
Set
2
Temperature Sensor
Motion Sensor
Illumination Sensor
4
6
8

Fig. 1

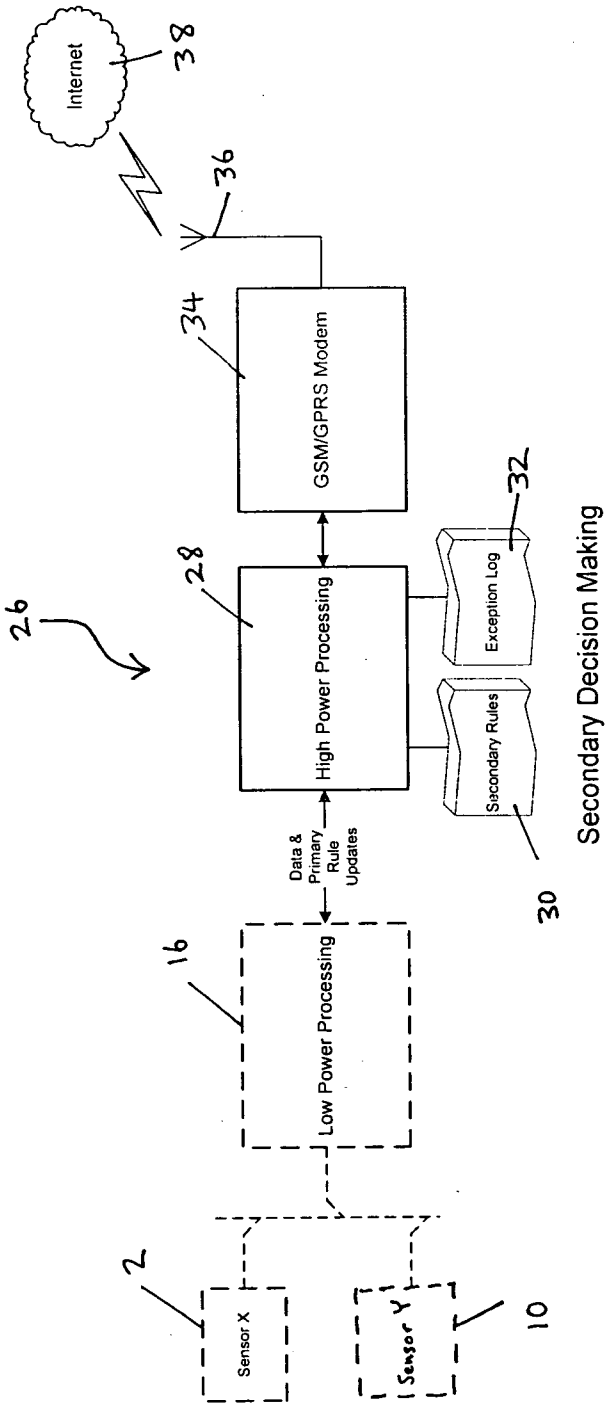
Internet
38
36
34
GSM/GPRS Modem
32
28
26
High Power Processing
Exception Log
Secondary Rules
Secondary Decision Making
30
Data & Primary Rule Updates
16
Low Power Processing
2
Sensor X
Sensor Y
10

Fig. 2

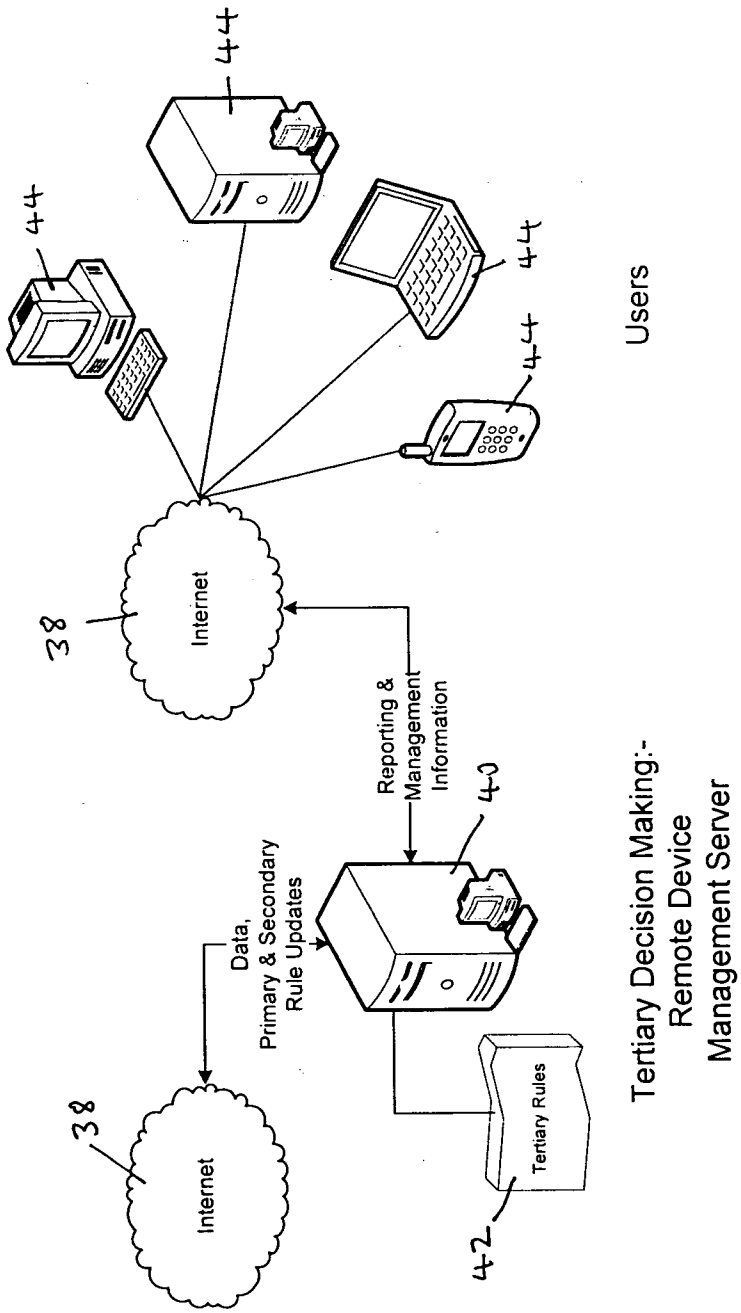
44
44
44
44
Users
38
Internet
Reporting &
Management
Information
40
Data,
Primary & Secondary
Rule Updates
Tertiary Decision Making:-
Remote Device
Management Server
38
Internet
Tertiary Rules
42

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/003136

A. CLASSIFICATION OF SUBJECT MATTER
INV. G08B29/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G08B H04M B60R G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/176127 A1 (BALLANTYNE WAYNE WIGGINS [US] ET AL) 9 September 2004 (2004-09-09)	1-9, 11-14, 18,26-32
Y	paragraphs [0003], [0004] paragraph [0015] paragraph [0017] paragraph [0020] paragraphs [0024] - [0027] paragraphs [0032], [0033]	10, 15-17, 19-25
Y	US 2003/151501 A1 (TECKCHANDANI ASHOK [US] ET AL) 14 August 2003 (2003-08-14) paragraphs [0038], [0041], [0042] paragraph [0048]	10, 15-17, 19-25

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 December 2007	02/01/2008

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/003136

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 538 579 A (ABB RESEARCH LTD [CH]) 8 June 2005 (2005-06-08) paragraphs [0019], [0021], [0022] paragraph [0029]	1,4,6-9, 11,15
X	WO 95/29410 A (GEN ELECTRIC [US]) 2 November 1995 (1995-11-02) cited in the application	1,2,6,7
A	page 10, line 1 - line 8	3-5,8-32
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