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(54) **ASTHMA MONITORING DEVICE**

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(52) **U.S. Cl.**

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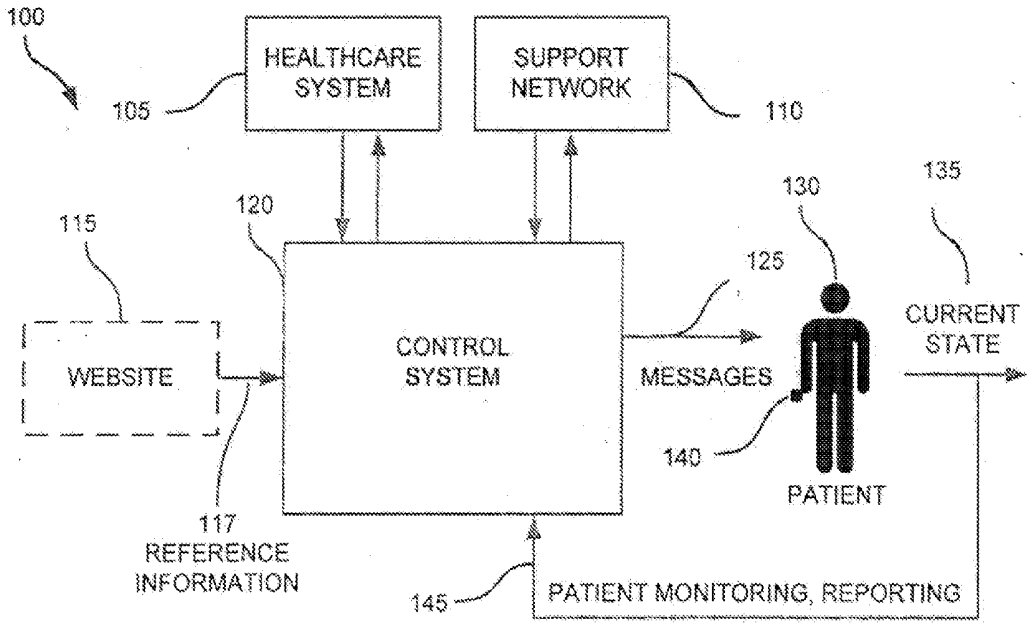
(57) **ABSTRACT**

A monitoring device to be used in conjunction with a patient's airway. Some embodiments of the monitoring device include at least one sensor assembly configured to detect inhaled and exhaled airflow and an optional communications subassembly configured to transmit measurements to at least one external computing device. Other embodiments include at least one sensor assembly configured to detect a measurement indicating airflow from the patient's lungs and at least one processor configured to detect whether the airflow is associated with medication administration or measurement of breathing characteristics. Some embodiments include a circuit that allows patient information to be analyzed by an external computing device and/or the monitoring device to determine whether the patient's breathing has declined indicating a medical problem. Optionally, the monitoring device may include a display for displaying whether the airflow measurement indicates a good outcome, a potential concern, or a serious condition.



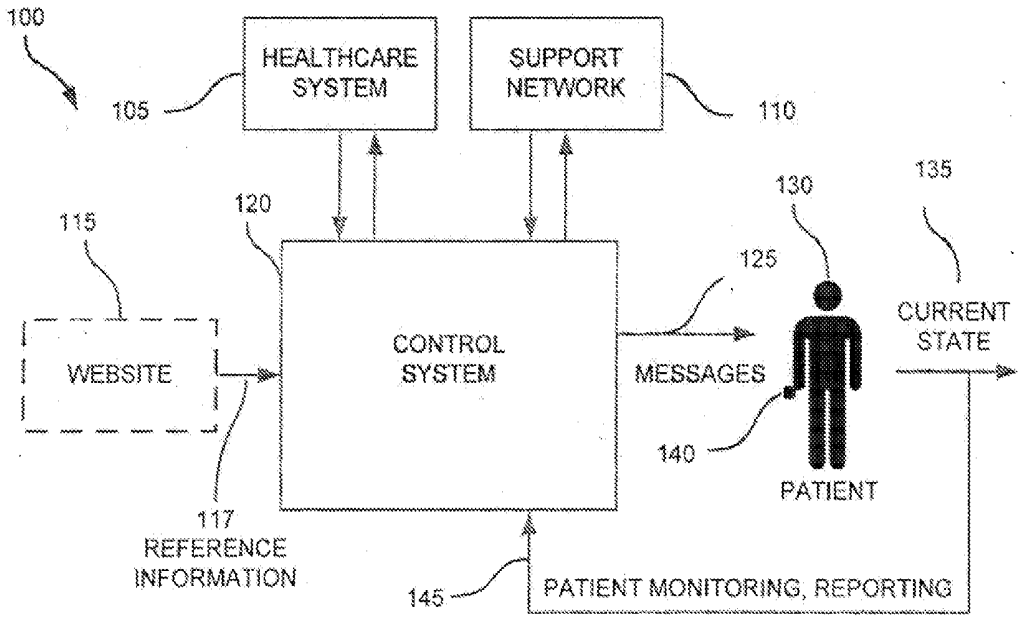


FIGURE 1

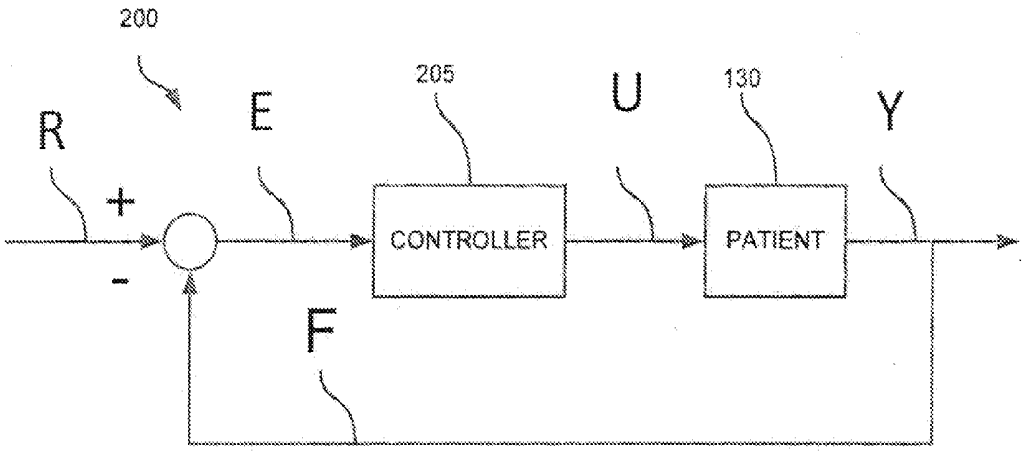


FIGURE 2

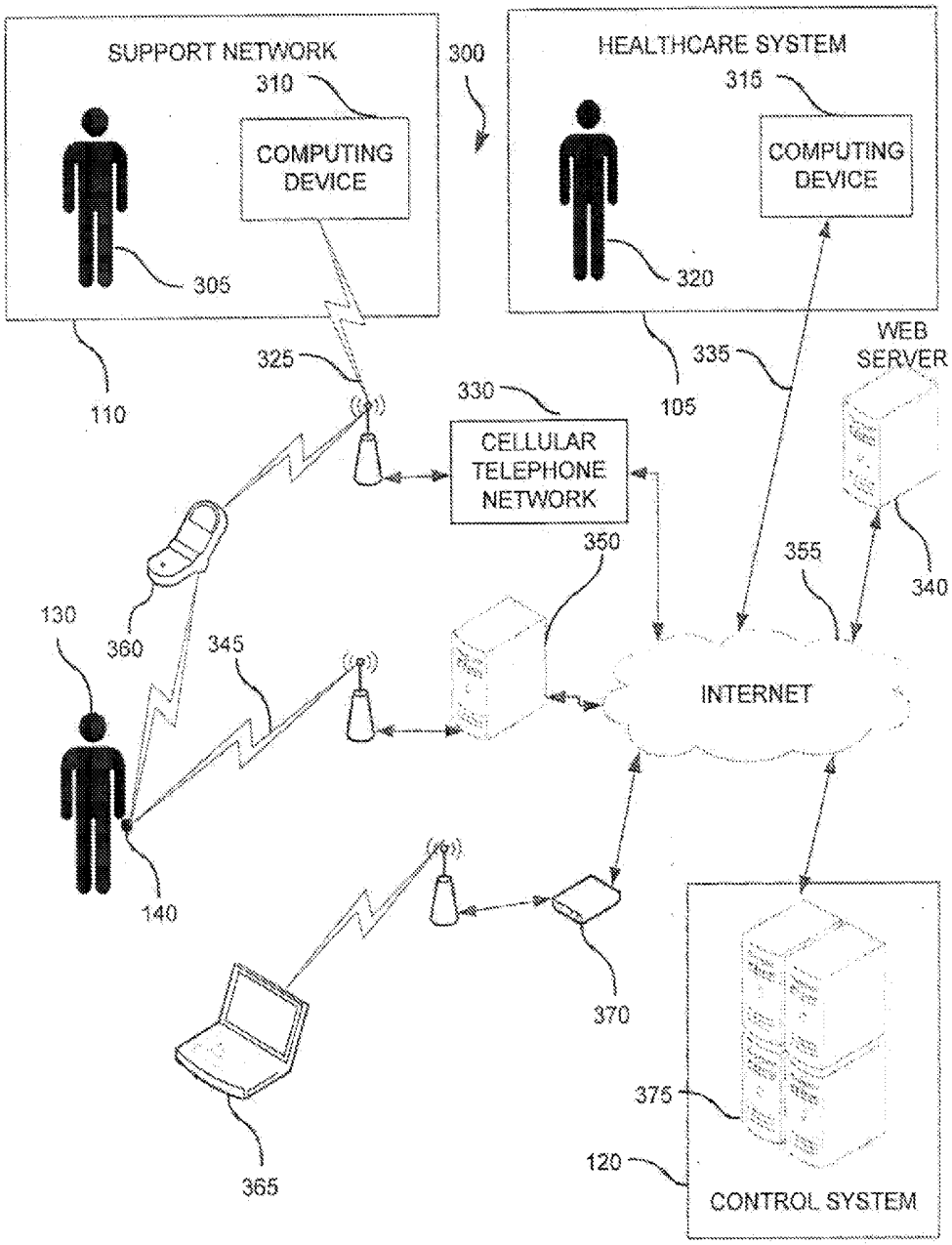

SUPPORT NETWORK
310
COMPUTING DEVICE
305
300
HEALTHCARE SYSTEM
315
COMPUTING DEVICE
320
110
325
105
335
WEB SERVER
330
CELLULAR TELEPHONE NETWORK
350
355
340
130
360
345
INTERNET
140
370
375
120
CONTROL SYSTEM
365

FIGURE 3

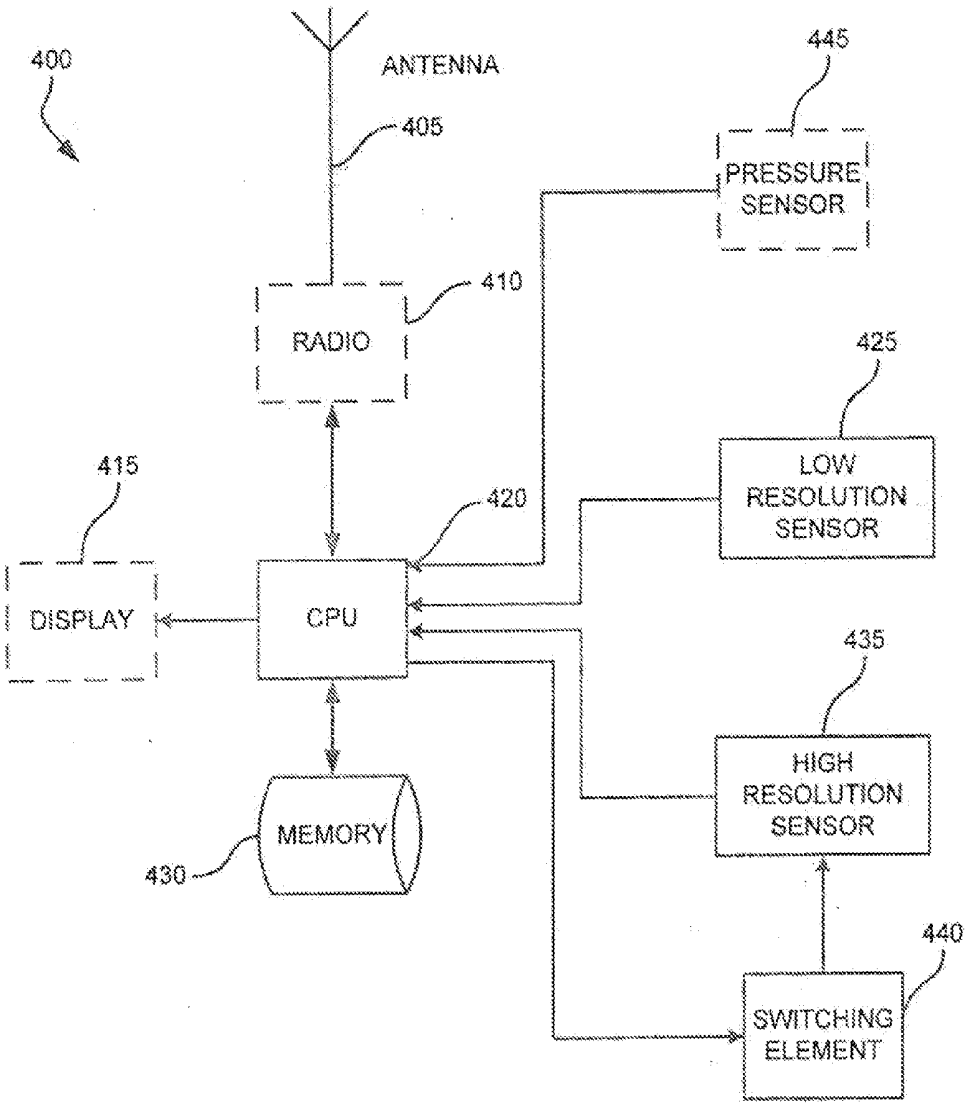

400
ANTENNA
405
445
PRESSURE SENSOR
410
RADIO
425
LOW RESOLUTION SENSOR
415
420
DISPLAY
CPU
435
HIGH RESOLUTION SENSOR
MEMORY
430
440
SWITCHING ELEMENT

FIGURE 4

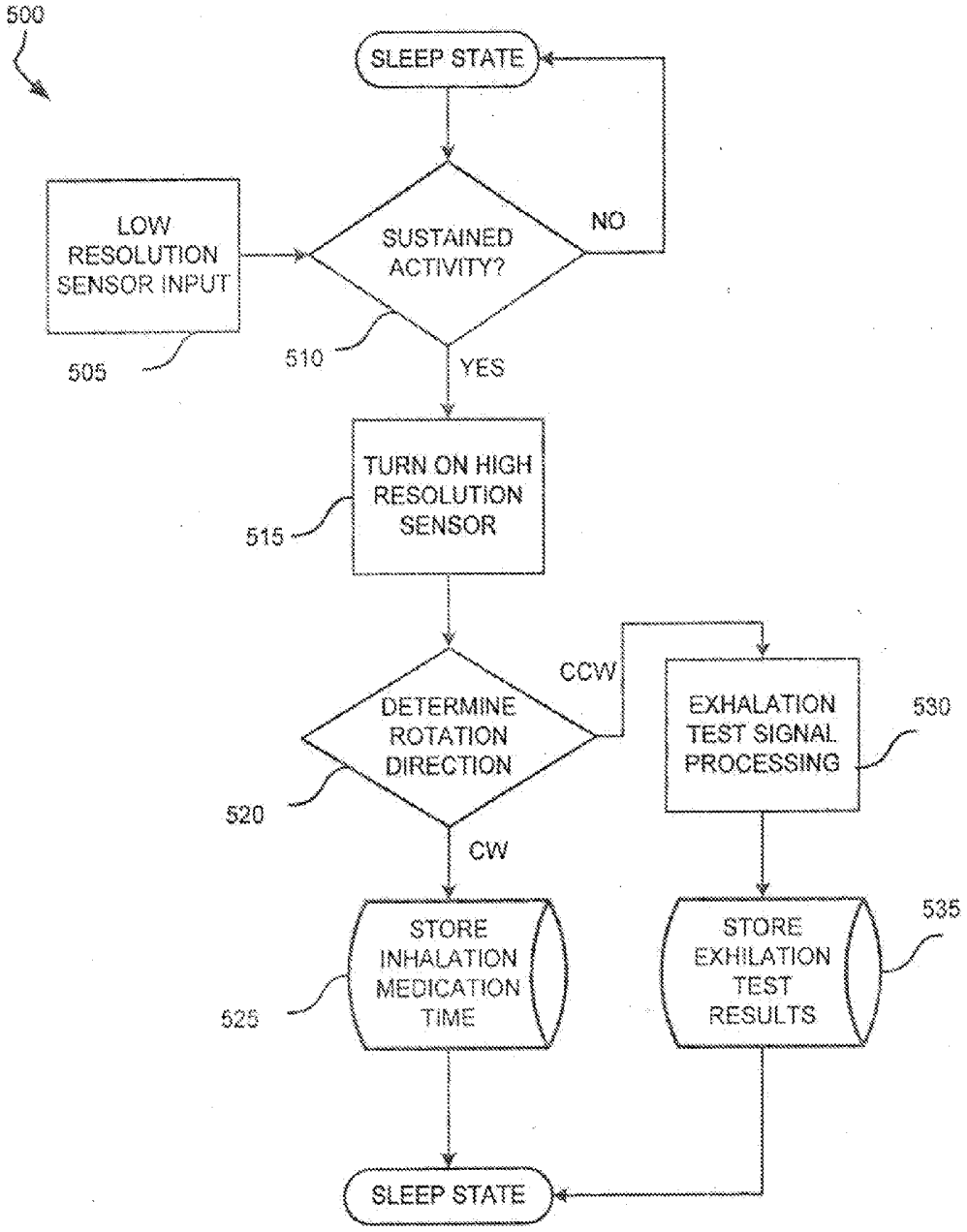

500
SLEEP STATE
LOW RESOLUTION SENSOR INPUT
505
SUSTAINED ACTIVITY?
510
NO
YES
TURN ON HIGH RESOLUTION SENSOR
515
DETERMINE ROTATION DIRECTION
520
CCW
CW
EXHALATION TEST SIGNAL PROCESSING
530
STORE INHALATION MEDICATION TIME
525
STORE EXHILATION TEST RESULTS
535
SLEEP STATE

FIGURE 5

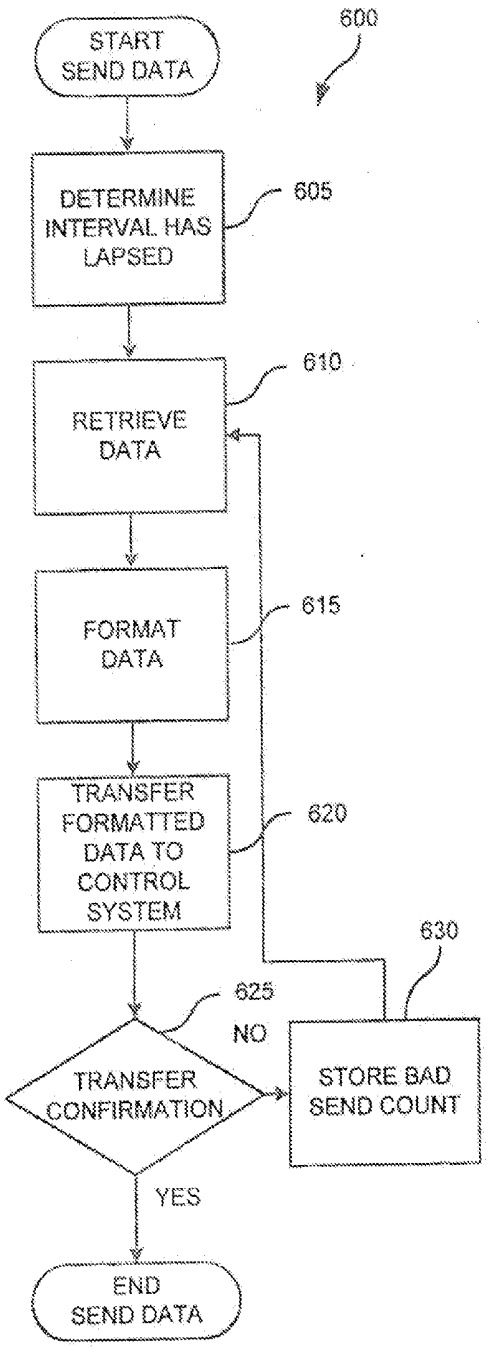


FIGURE 6A

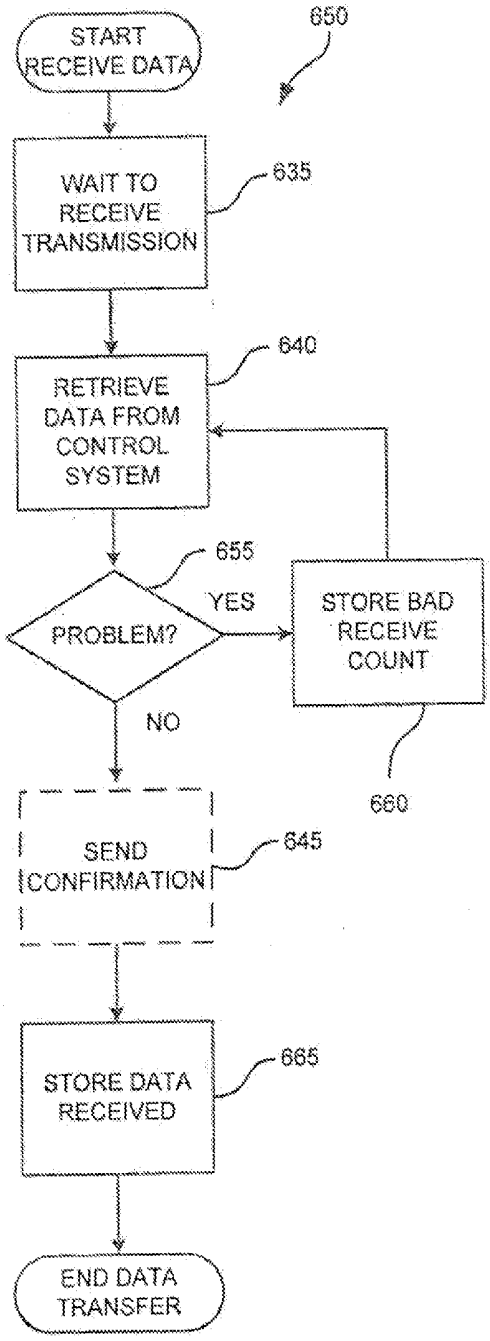


FIGURE 6B

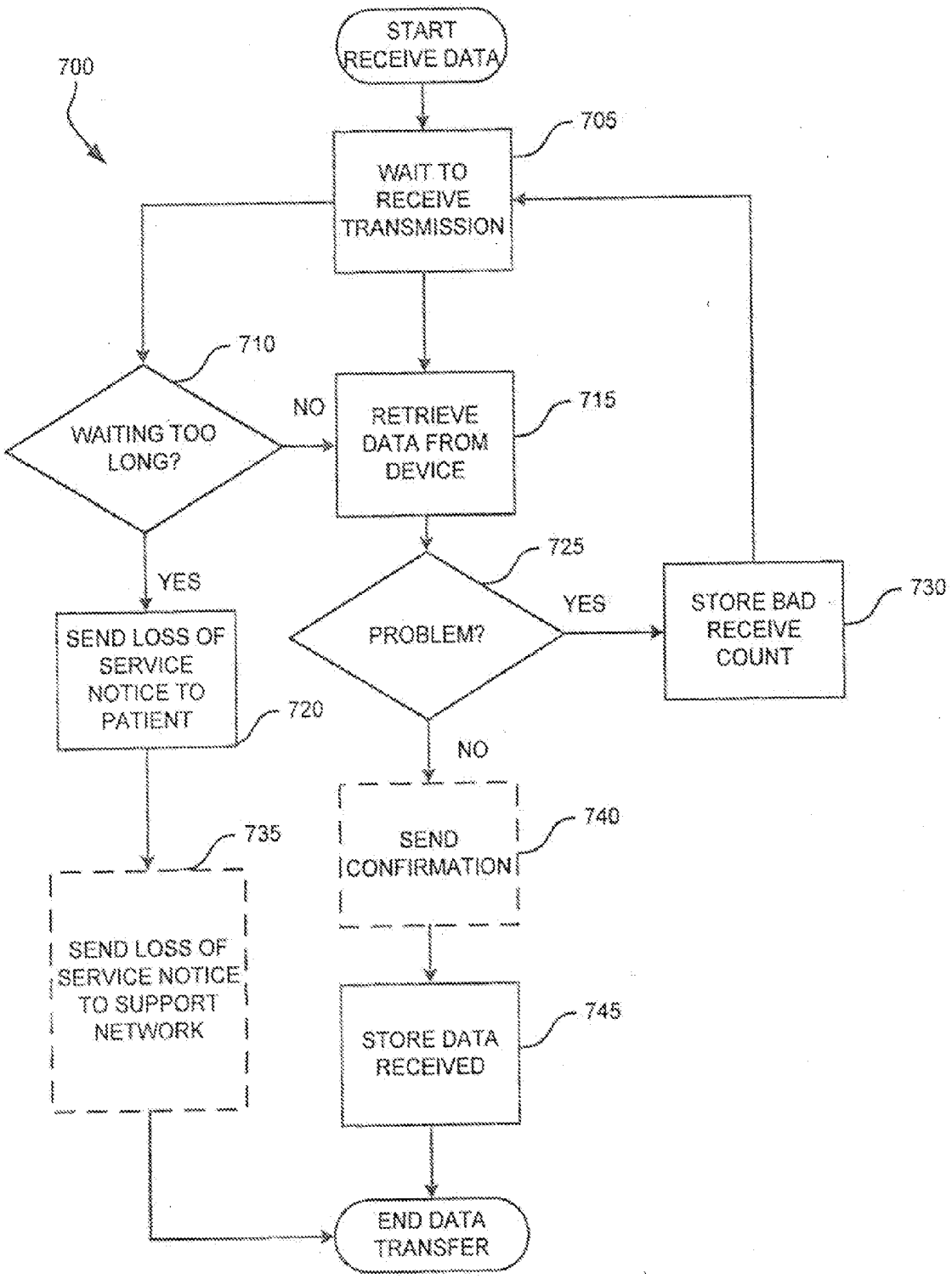

700
START RECEIVE DATA
705
WAIT TO RECEIVE TRANSMISSION
710
WAITING TOO LONG?
NO
715
RETRIEVE DATA FROM DEVICE
YES
725
PROBLEM?
YES
730
STORE BAD RECEIVE COUNT
SEND LOSS OF SERVICE NOTICE TO PATIENT
720
NO
740
SEND CONFIRMATION
735
SEND LOSS OF SERVICE NOTICE TO SUPPORT NETWORK
745
STORE DATA RECEIVED
END DATA TRANSFER

FIGURE 7

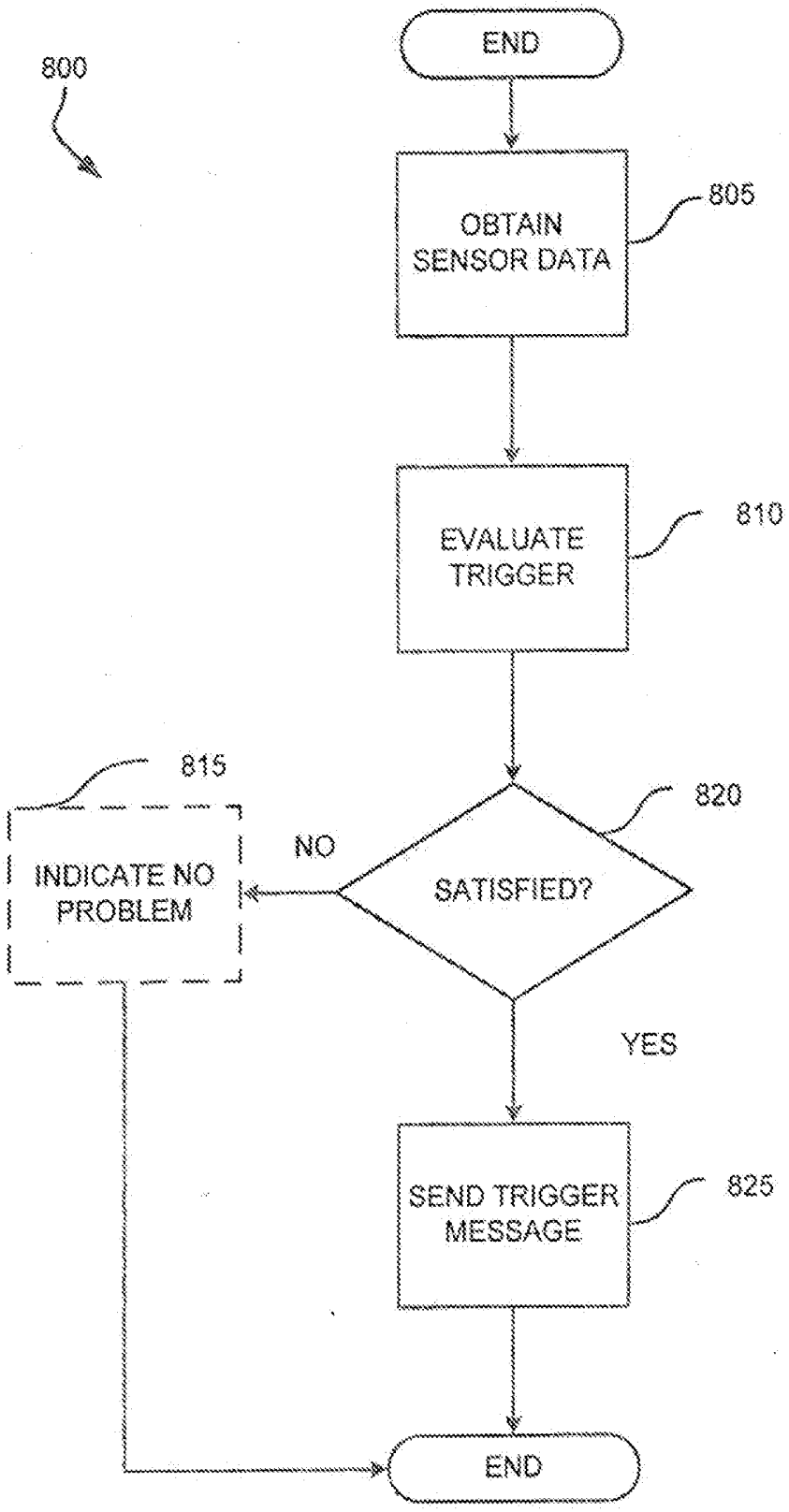

800
END
OBTAIN SENSOR DATA
805
EVALUATE TRIGGER
810
815
INDICATE NO PROBLEM
NO
820
SATISFIED?
YES
SEND TRIGGER MESSAGE
825
END

FIGURE 8

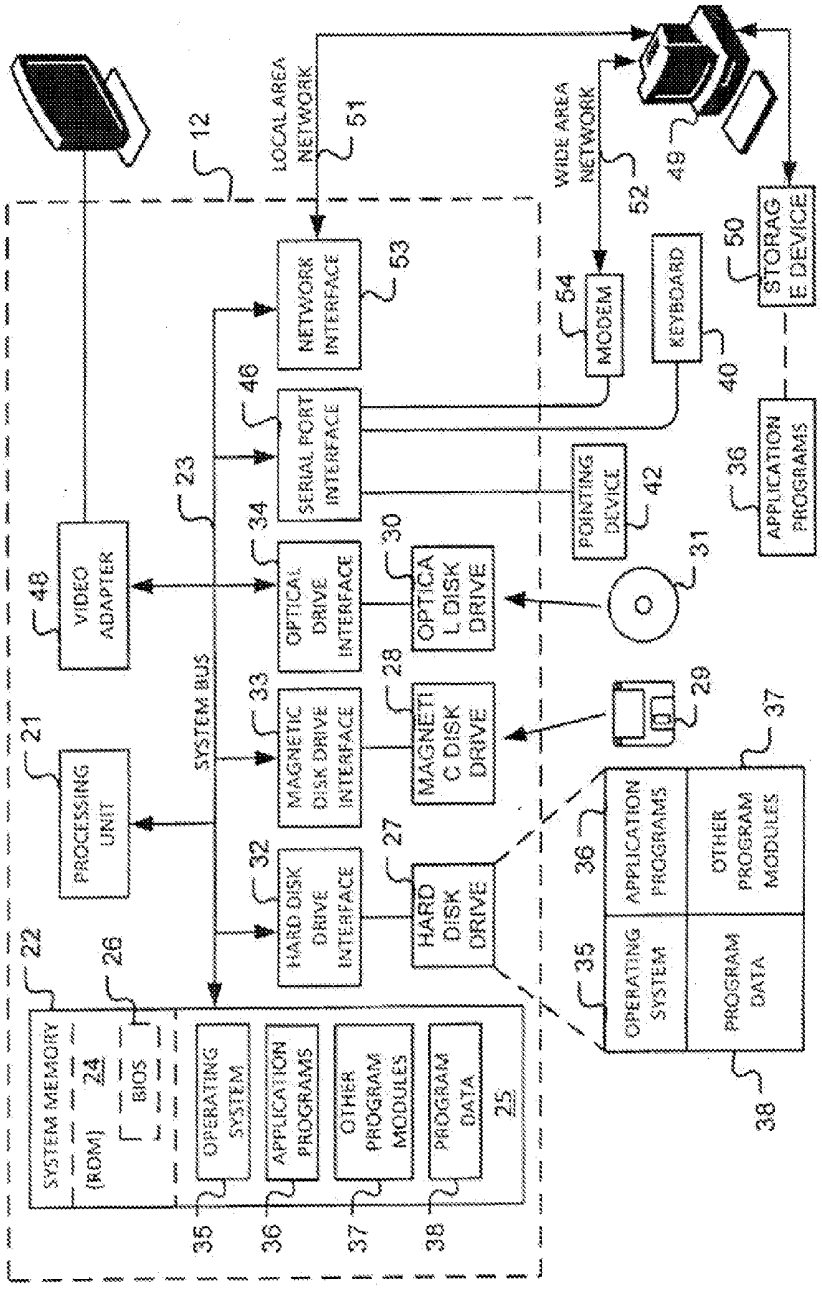

12
LOCAL AREA NETWORK
51
WIDE AREA NETWORK
52
49
NETWORK INTERFACE
53
54
MODEM
KEYBOARD
40
50
STORAGE DEVICE
SERIAL PORT INTERFACE
46
23
POINTING DEVICE
42
36
APPLICATION PROGRAMS
VIDEO ADAPTER
48
34
OPTICAL DRIVE INTERFACE
30
OPTICAL DISK DRIVE
31
SYSTEM BUS
21
PROCESSING UNIT
33
MAGNETIC DISK DRIVE INTERFACE
28
MAGNETIC DISK DRIVE
29
37
32
HARD DISK DRIVE INTERFACE
27
HARD DISK DRIVE
36
APPLICATION PROGRAMS
OTHER PROGRAM MODULES
35
OPERATING SYSTEM
PROGRAM DATA
38
22
SYSTEM MEMORY
24
[ROM]
26
BIOS
OPERATING SYSTEM
APPLICATION PROGRAMS
OTHER PROGRAM MODULES
PROGRAM DATA
25
35
36
37
38

FIGURE 9

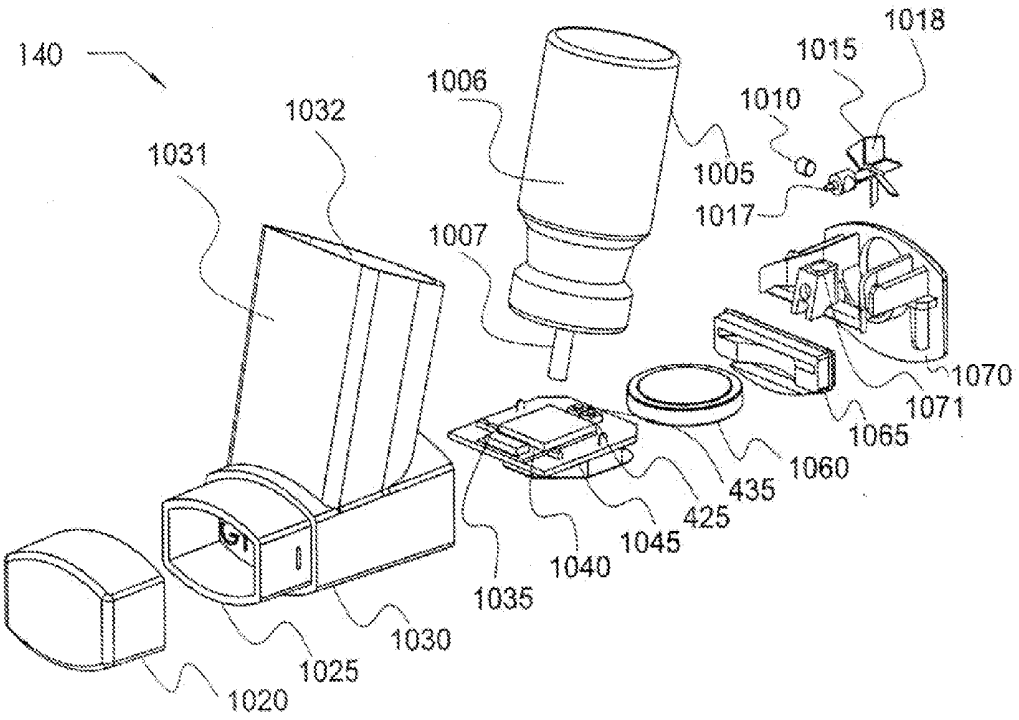

140
1031
1032
1006
1007
1005
1010
1015
1018
1017
1070
1071
1065
1060
435
425
1045
1040
1035
1030
1025
1020

FIGURE 10

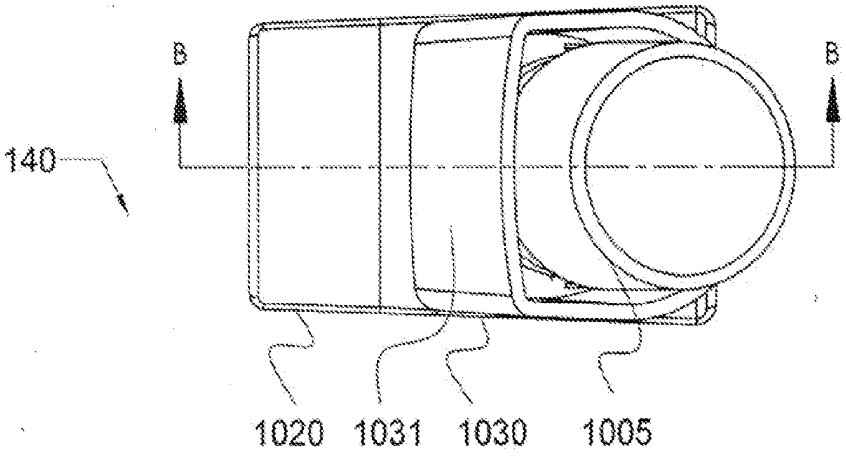
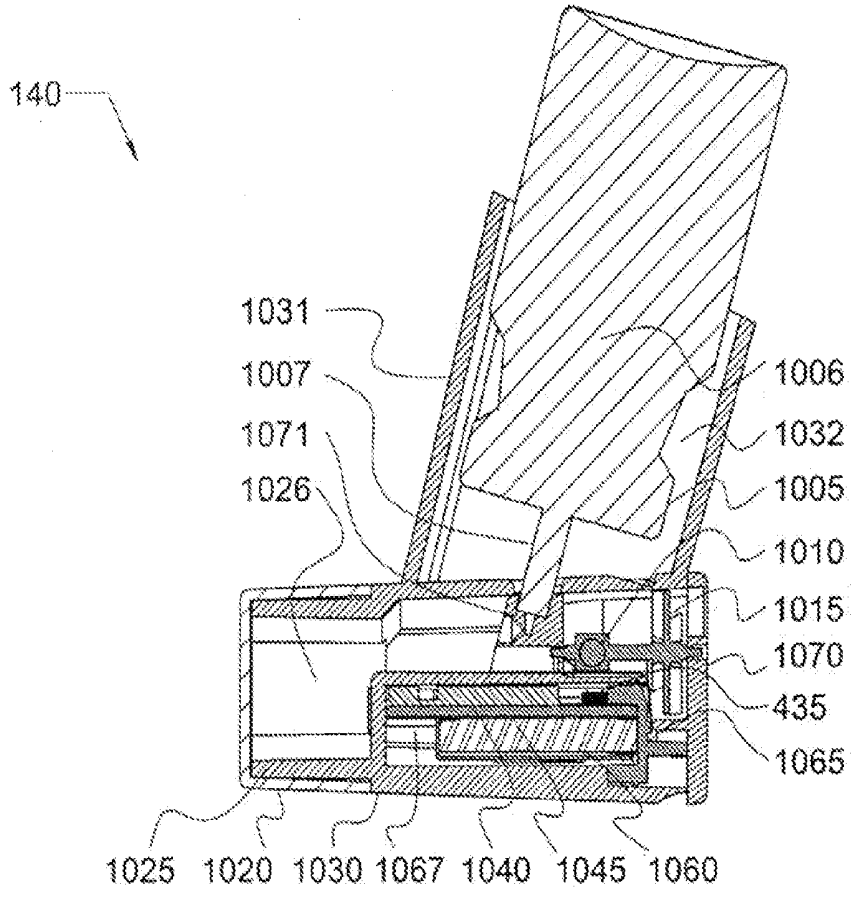


FIGURE 11



SECTION B-B

FIGURE 12

ASTHMA MONITORING DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention is directed generally to devices and methods of monitoring patient health, and more particularly, to methods and systems of managing asthma and other airway disorders.

[0003] 2. Description of the Related Art

[0004] Monitoring patient parameters is quite common in medical care environments, such as hospitals, doctors' offices, and the like. Further, patient monitoring outside of a clinical setting is increasing because of the rising cost of traditional healthcare. There is a need for devices configured to monitor a patient's health. Devices configured to inform professional healthcare providers when appropriate are particularly desirable.

[0005] Asthma is a disease characterized by airway constriction often caused by a genetic predisposition and sensitivity to environmental factors. These environmental factors or triggers, as they are sometimes called, are often idiosyncratic to a particular patient. Environmental triggers of asthma can cause chronic or acute symptoms that can range from annoying to life threatening. These symptoms typically range from coughing, wheezing, and shortness of breath to drastically decreased air exchange as measured by a spirometer or peak expiratory flow meter.

[0006] Both indoor and outdoor environments can include substances that trigger asthma. Some common indoor environmental triggers are biologic allergens, tobacco smoke, irritant chemical and fumes as well as products of combustion. Outdoor environmental triggers that are most common include O_2, SO_2, NO_2, lead, and particulate matter (e.g., particles smaller than about 10 microns).

[0007] It is important for patients to learn about their particular environmental triggers and to adapt to avoid them or minimize their effects. It is also important to determine a treatment plan with a healthcare provider to diminish or avoid the symptoms of asthma. This treatment plan needs to be personalized and maintained. The treatment plan may need to be adjusted over time because of changes in environmental conditions, a patient's response(s) to stress, and other health related issues.

[0008] During an acute asthma attack, narrowing of the patient's airway can cause severe discomfort or worse. These events are dangerous and are to be avoided if possible. But it can be difficult to manage this condition successfully. Asthma attacks can leave family and friends in the position of providing first responder care to the patient whether they know anything about the disease or not.

[0009] There are several types of medications that are used to alleviate asthma symptoms. They are generally put in two classes. The first class of medications includes drugs administered on a relatively regular basis that have a long lasting effect. The second class of medications includes drugs that are used in an acute condition and are often referred to as rescue inhalers.

[0010] Both types of medications are typically administered to the patient orally by means of a metered dose inhaler applicator and breathed into the patient's airway directly. These inhaler applicators provide measured dosages for a recommended number of applications or doses. Some sophisticated inhaler applicators provide a mechanical counter that counts the number of doses administered by the inhaler to indicate when the recommended number of doses have been administered by the inhaler applicator. The patient is able to view the counter and use it to determine whether the specified number of doses of a drug have been administered by the inhaler applicator indicating it is time to obtain more of the drug.

[0011] It is recognized that precursor symptoms often precede asthma attacks. One such precursor symptom that is widely accepted as a useful measure of health is peak expiratory airflow. Peak expiratory airflow can be used to identify problems before they become apparent to the patient. With careful monitoring of peak expiratory airflow, it may be possible to help the patient recognize impending problems and avert an emergency or lessen its severity.

[0012] If a patient's airways are constricted, it takes longer for the patient to empty the patient's lungs. The amount of time required for the patient to empty his/her lungs may be determined by having the patient blow through a device that measures maximum exhalation rate. Both mechanical and electronic devices currently exist in the marketplace that measure maximum exhalation rate. Healthcare practitioners commonly recommend the use of such devices to patients for the purposes of understanding and managing their condition.

[0013] Unfortunately, it is inconvenient to carry and/or use such devices for airflow measurement. It is also not easy to track and trend medication usage for review by the healthcare provider. Further, it is difficult to determine how many applications of a medication have been dispensed by an inhaler applicator. And, it is difficult to know whether a child or elderly person is administering his/her medication according to a treatment plan. Therefore, a need exists for methods and systems that track a patient's physiological parameters (e.g., peak expiratory airflow) and medication administration to help manage asthma in chronic and/or acute conditions.

[0014] The present application provides these and other advantages as will be apparent from the following detailed description and accompanying figures.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0015] FIG. **1** is a diagram of a system configured to manage asthma.

[0016] FIG. **2** is a diagram of a control loop implemented by the system of FIG. **1**.

[0017] FIG. **3** is a diagram of an embodiment of the system of FIG. **1**.

[0018] FIG. **4** is a diagram of an exemplary circuit that may be used to construct a medication dispensing device to collect inhaler medication data and airflow data.

[0019] FIG. **5** is a flow diagram of a method for determining direction of airflow.

[0020] FIG. **6**A is a flow diagram of a method of transmitting patient data collected to the control system.

[0021] FIG. **6**B is a flow diagram of a method performed by the medication dispensing device when receiving messages and or data from the control system.

[0022] FIG. **7** is a flow diagram of a method performed by the control system when receiving the patient data from the medication dispensing device.

[0023] FIG. **8** is a flow diagram of a method of analyzing the patient data performed by the control system.

[0024] FIG. **9** is a diagram of a hardware environment and an operating environment in which one or more of the computing devices of the system of FIG. **1** may be implemented.

[0025] FIG. **10** is an exploded perspective view of an embodiment of the medication dispensing device.

[0026] FIG. **11** is a top view of the medication dispensing device shown in FIG. **10**.

[0027] FIG. **12** is a cross-sectional view of the medication dispensing device taken along sectioned line B--B of FIG. **11**.

DETAILED DESCRIPTION OF THE INVENTION

Overview

[0028] The present invention is directed generally to devices and methods of monitoring patient health, and more particularly, to methods and systems of managing asthma and other airway disorders including, for example, chronic obstructive pulmonary disease (COPD) or other diseases or conditions relating to the respiratory system. For illustrative and explanatory purposes, the description below describes embodiments of the present invention with regard to treating asthma conditions, but it will be appreciated by a person of ordinary skill in the art that the present invention is applicable to other airway disorders as well.

[0029] Referring to FIG. **1**, the present application describes a system **100** that includes a device **140** used by a patient **130** that is connected (e.g., wirelessly) to a control system **120**. The control system **120** may be connected (e.g., wirelessly) to a healthcare system **105**, a support network **110**, and the like. The healthcare system **105** includes healthcare professionals, physicians, hospitals, pharmacies, and the like. The support network **110** includes the patient's friends, family, as well as others involved in the patient's care. The patient **130**, support network **110**, and/or the healthcare system **105** may provide reference information **117** to the control system **120**. The reference information **117** may be used to setup or configure the control system **120**. By way of a non-limiting example, the reference information **117** may include patient information (e.g., age, height, weight, etc.), patient diagnosis, past asthma attack triggers, weather, pollen count, ozone levels, air pollution, message routing information, and trigger values. The reference information **117** may also include instructions (e.g., patient instructions) associated with the trigger values. Such instructions may include a predetermined prescribed treatment plan (e.g., instructions to increase a dosage or use a particular type of inhaler medication), instructions to perform airflow tests over a given time period, requests for patient symptom information, instructions to contact a healthcare professional, and the like. The reference information **117** may have been provided to a website **115** generated by an optional web server **340** (illustrated in FIG. **3**) and forwarded to the control system **120** by the web server **340**.

[0030] The control system **120** may issue messages **125** to the patient **130** (e.g., via the patient's cell phone, or the like) that could cause a modification in the patient's state **135** (e.g., a reduction in asthma symptoms, a reduction in the likelihood of an asthma attack, and the like). When triggered by trigger values, the messages **125** may include one or more instructions associated with the trigger values.

[0031] The device **140** is configured to be used by the patient **130** for the administration of inhaler medications and for the measurement of airflow. When used in this manner, the device **140** occasionally collects data that may be processed by the control system **120** to obtain medication administration information and peak expiratory airflow information. The data collected by the device **140** is sent to the control system **120** in a device message **145**. In particular implementations, the device **140** is configured to determine both an amount of medication administered and the patient's peak expiratory airflow and to send this information to the control system **120** in a device message **145**. In other implementations, the device **140** is configured to determine that medication has been administered by the device **140** and the patient's peak expiratory airflow and to send this information to the control system **120** in a device message **145**. The control system **120** analyzes the data received from the device **140** in the device message **145** to determine the medication administration information and peak expiratory airflow information.

[0032] Over time, multiple airflow measurements may be collected and tracked for the purposes of detecting a trend in medication administration, airflow, or patient airway restriction. The previously obtained airflow measurements and medication administration events may be stored in the reference information **117**.

[0033] The healthcare provider or system **105** may access the control system **120** to review the airflow measurement(s) to detect potential problems and/or recommend treatments or changes in treatment. Further, when the control system **120** detects a trend or sudden change of the airflow capacity, the control system **120** may send messages to the healthcare system **105**, the support network **110**, the patient **130**, and the like. Preconfigured system trigger values may be used to detect a trend or sudden change of the airflow capacity. Further, one or more instructions may be associated with each of the system trigger values. When triggered by a preconfigured system trigger value, messages sent to the healthcare system **105**, the support network **110**, the patient **130**, and the like may include the one or more instructions associated with the system trigger value.

[0034] By way of a non-limiting example, a juvenile might take a peak expiratory flow measurement that is lower than a preconfigured trigger value, such as 60% of the maximum recorded peak expiratory flow measurement. This measurement would be transmitted a server of the system for analysis and would be compared to patient history and preconfigured trigger values. A low measurement compared to a trigger value might launch several preconfigured actions. The first might be to send a message to the juvenile's phone (e.g., the patient **130**) instructing the juvenile to administer a medication, limit activity, or limit exposure to an irritant. A second preconfigured message might be to the parent's cellular phone or computing device (e.g., the support network **110**) informing them of a problem that has occurred that requires their attention. Additionally, a preconfigured message for the healthcare professional (e.g., the healthcare system **105**) might be sent such that when the doctor reviews the asthma treatment plan and patient history, clear deviations are readily apparent.

[0035] Likewise, the absence of event tracking information might inform a user or caregiver of a missed scheduled medication administration or measurement event, or even a prolonged loss of contact that may indicate a device failure. In some embodiments, this would trigger a message to the appropriate individual(s) in charge of a patient's care.

[0036] Messages sent to the healthcare system **105**, the support network **110**, and/or the patient **130** may include SMS cellular telephone messages, recorded voice messages (e.g., including educational information), alerts, alarms, and the like.

[0037] Thus, the system **100** provides a means of assessing changes in the medicine administration and the peak expiratory airflow of a patient and more particularly the onset of asthma symptoms and attacks. The assessment may be conducted remotely by the control system **120** and/or the healthcare system **105**. Members of a support network **110** such as parents and/or the healthcare system **105** need not be present to collect or evaluate the airflow measurement. Instead, airflow measurements may be collected automatically by the device **140** and optionally, transferred (e.g., wirelessly) to the system **100**. Medicine administration and airflow measurements may be collected on an ongoing basis over any desired length of time.

[0038] The system **100** may be conceptualized as a continually readjusting system that seeks a stable desired condition (e.g., an absence of asthma symptoms). The system **100** may implement a control loop **200** illustrated in FIG. **2**. In the control loop **200**, reference information "R" is provided and compared with feedback information "F." With respect to the system **100**, the reference information "R" may be the reference information **117** provided to the control system **120**, and the feedback information "F" may be the device messages **145** transmitted by the device **140**.

[0039] The difference between the reference information "R" and the feedback information "F" is an error "E." The error "E" is input into a controller **205**. In system **100**, the error "E" is calculated by the control system **120**. The controller **205** in turn issues commands "U" (e.g., the messages **125**) that are used to affect the state of the patient **130**. In the system **100**, the control system **120** may issue the messages **125** to the patient **130**, the support network **110**, and/or the healthcare system **105**. This is reflected in a current state "Y." In FIG. **1**, the patient's current state is labeled with reference numeral **135**. The current state "Y" provides the feedback information "F" that is compared to the reference information "R." In other words, the patient's state **135** provides the device messages **145** (with data used to obtain the airflow measurement) that are compared to the reference information **117** (e.g., previously obtained airflow measurements). Based on the results of this comparison, one or more messages **125** may be sent to the patient **130**, the support network **110**, and/or the healthcare system **105** to modify the patient's state **135** by modifying his or her behavior.

System **300**

[0040] FIG. **3** illustrates a system **300**, which is an exemplary implementation of the system **100** (see FIG. **1**). Turning to FIG. **3**, the control system **120** includes a database server **375**. The reference information **117** (see FIG. **1**) is stored in the database server **375**. The reference information **117** may be received by the database server **375** during an initial setup process as well as on an ongoing basis. The system **300** may include the optional web server **340** configured to generate the website **115** (see FIG. **1**) to which the reference information **117** may be provided and transferred to the database server **375** (e.g., over the Internet **355** or other network) of the control system **120**. The database server **375** may also store pertinent data about the patient **130** (such as patient history, patient record, and the like), trigger event levels (discussed below), and addresses to which messages (e.g., notifications, alerts, and the like) are to be sent.

[0041] Feedback information (e.g., the device message **145** illustrated in FIG. **1**) most often originates from the patient **130** and/or the device **140**. This feedback information can travel several alternate paths depending upon the implementation details. For example, the feedback information may be input into a computing device (e.g., a patient desktop computer **350**, a patient cellular telephone **360**, a patient portable computer **365**, and the like) connected to the database server **375** (or the web server **340**) via the Internet **355**. The device **140** may communicate with the computing devices via a wired or wireless communication link (e.g., a communication link **345**). Over a wireless communication link, the device **140** may communicate with the computing devices using SMS messages, WIFI protocols, Bluetooth protocols, and the like. The computing devices may transfer the feedback information to the database server **375** of the control system **120**. The device **140** may communicate the device messages **145** to the computing devices for subsequent transmission thereby to the database server **375**.

[0042] In the embodiment illustrated, the patient desktop computer **350** is connected to the Internet **355** via a conventional wired connection. In the embodiment illustrated, the patient cellular telephone **360** and the patient portable computer **365** are connected to the Internet **355** by an Internet gateway device **370** (e.g., a modem). The patient cellular telephone **360** and the patient portable computer **365** may also communicate with the Internet gateway device **370** using WIFI protocols, Bluetooth protocols, and the like.

[0043] By way of a non-limiting example, the feedback information may be transmitted by the device **140** via a radio link (e.g., the radio link **345**) to the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, and the like. By way of another non-limiting example, the feedback information may be transmitted by the device **140** directly to the Internet gateway device **370**.

[0044] The feedback information is received by the database server **375**. In the embodiment illustrated, the database server **375** implements the control system **120** (see FIG. **1**) that compares the current state **135** of the patient **130** and the reference information **117** (which may include previously received feedback information).

[0045] One or more messages **125** (see FIG. **1**) to be reviewed by the patient **130** may be transmitted by the database server **375** to the device **140**, the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, and the like. By way of a non-limiting example, such messages may be displayed on the website **115** (see FIG. **1**) generated by the web server **340**. In such embodiments, the database server **375** is configured to instruct the web server **340** to display messages on the website **115**. The patient desktop computer **350**, the patient cellular telephone **360**, and/or the patient portable computer **365** may connect to the web server **340** over the Internet **355** and display the website **115** using a conventional web browser application.

[0046] The support network **110** may include one or more computing devices (e.g., a support network computing device **310**) connected to the database server **375** via the Internet **355**. One or more messages to be reviewed by a support person **305** (e.g., a parent of a patient) may be transmitted by the database server **375** to the computing device **310**. By way of a non-limiting example, such messages may be displayed on the website **115** (see FIG. **1**) generated by the web server **340**. In the embodiment illustrated, the computing device **310** is connected to the Internet **355** via a wireless communication link **325** with a cellular telephone network **330**. The computing device **310** may connect to the web server **340** over the Internet **355** and may display the website **115** using a con-

ventional web browser application. Some patients may rely on help from the support network **110** while others may have no such support.

[0047] The healthcare system **105** may include one or more computing devices (e.g., a healthcare provider or caregiver computing device **315**) connected to the database server **375** via the Internet **355**. One or more messages to be reviewed by a caregiver **320** may be transmitted by the database server **375** to the computing device **315**. By way of a non-limiting example, such messages may be displayed on the website **115** (see FIG. **1**) generated by the web server **340**. In the embodiment illustrated, the computing device **315** is connected to the Internet **355** via a wired communication link **335**. The computing device **315** may connect to the web server **340** over the Internet **355** and may display the website **115** using a conventional web browser application.

[0048] A diagram of hardware and an operating environment in conjunction with which implementations of the database server **375**, the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, the support computing device **310**, the caregiver computing device **315**, and the web server **340** may be practiced is provided in FIG. **9** and described below.

Circuit **400**

[0049] FIG. **4** is a block diagram illustrating example electrical components of the device **140**. The electrical components of the device **140** include a circuit **400**, which includes a low resolution sensor **425**, a high resolution sensor **435**, a switching element **440**, a memory **430**, an antenna **405**, a radio **410**, a display **415**, a processor **420** (e.g., a CPU), and an optional pressure sensor **445**.

[0050] The low and high resolution sensors **425** and **435** are each operative to detect magnetic fields. In the embodiment illustrated, the low and high resolution sensors **425** and **435** use a Hall Effect to sense a magnetic field and are configured to output a digital signal in the presence of a perpendicular magnetic field of suitable intensity. Further, the low and high resolution sensors **425** and **435** include digital circuitry that cycles power and retains state information. The low resolution sensor **425** may cycle less frequently to reduce power consumption at the expense of resolution.

[0051] In some embodiments, the low resolution sensor **425** remains powered continuously and the processor **420** is typically in a sleep state, continuously powered to retain data stored in the memory **430**. Magnetic activity of suitable strength will initiate a signal from the low resolution sensor **425** to the processor **420**. The processor **420** will then communicate to the switching element **440**, which will provide power to the high resolution sensor **435**. The operation of the circuit **400** is discussed below.

Methods

[0052] As will be explained in detail below, whether the patient is inhaling or exhaling into the device **140** may be determined based on a direction of rotation of a magnetic element (e.g., a magnet **1010** illustrated in FIG. **10**) coupled to a rotatable body (e.g., a rotatable body **1015** illustrated in FIG. **10**). The rotatable body is configured to rotate the magnetic element in both a clockwise "CW" direction and a counter clockwise direction "CCW." The low and high resolution sensors **425** and **435** shown in FIG. **4** are configured to sense the magnetic field of the magnetic element.

[0053] FIG. **5** is a flow diagram of a method **500** of determining whether the patient is inhaling into the device **140** (taking medication) or exhaling into the device **140** (measuring airflow). Before the method **500** begins, the processor **420** is in a sleep state. In a first block **505**, the state of the low resolution sensor **425** is changed by the rotation of the magnetic element. The state of the low resolution sensor **425** changes when the sensor detects a perpendicular magnetic field of suitable intensity. Thus, when the magnetic element (e.g., a magnet **1010** illustrated in FIG. **10**) is being rotated by the rotatable body (e.g., a rotatable body **1015** illustrated in FIG. **10**) relative to the low resolution sensor **425**, the sensor changes state. Changes in state of the low resolution sensor **425** are transmitted to the processor **420**. The processor **420** evaluates the state change in decision block **510** to determine whether the change is sustained activity or hysteresis. A change in the magnetic field sense state of the low resolution sensor **425** changes a voltage level on an interrupt line connected to the processor **420**. This voltage change brings the processor **420** out of a low power state. The processor **420** then looks for additional changes in the voltage of the low resolution sensor **425**. If no additional state changes occur in a predetermined period, the processor **420** returns to a low power state.

[0054] If activity is not sustained, the decision in the decision block **510** is "NO," and the processor **420** returns to a sleep state. On the other hand, if activity is sustained, the decision in the decision block **510** is "YES," and in block **515**, the switching element **440** activates the high resolution sensor **435**.

[0055] In decision block **520**, the processor **420** determines whether the magnet is rotating clockwise "CW" or counter clockwise "CCW." By knowing the physical geometry of the device **140** and comparing the timing of signals from the low and high resolution sensors **425** and **435**, the processor **420** may determine signal timing precedence from the sensors **425** and **435** and infer the direction of rotation of the magnetic element.

[0056] If in decision block **520**, the processor **420** determines the magnetic element is rotating clockwise "CW," the processor **420** advances to block **525**. In the embodiment illustrated, air moving through the device **140** toward the patient **130** causes the magnetic element to rotate in a clockwise "CW" direction. In such embodiments, when the magnetic element is rotating in a clockwise "CW," the patient **130** is inhaling. This inhalation is assumed to be a medication dispensing event and in block **525**, the time the inhalation occurred is stored in the memory **430** (see FIG. **4**). The processor **420** then returns to a sleep or wait state.

[0057] If, in decision block **520** the processor **420** determines the magnetic element is rotating counter clockwise "CCW," the processor **420** advances to block **530**. In the embodiment illustrated, air is moving though the device away from the patient **130** causes the magnetic element to rotate in a counter clockwise "CCW" direction. In such embodiments, when the magnetic element is rotating in a counter clockwise "CCW," the patient is exhaling (i.e., testing expiratory flow rate). Timing measurements are taken of the rotation event to determine characteristics of the exhalation, such as airflow rate.

[0058] By capturing the speed and direction of the rotating body **1015** many times a second as it rotates, the rate of airflow at different times during the exhalation and subsequent inhalation events may be measured, stored, integrated,

analyzed, or transmitted. A comparison of these airflow measurements over time can be useful to a healthcare provider in understanding the disease state. Tests can be initiated that measure both inhalation as well as exhalation characteristics when the events are continuous. Many possible spirometry measurements are possible. Some of these measurements might include forced expiratory flow, forced expiratory volume in a time period (e.g., 1 second), forced expiratory volume ratios, forced vital capacity, tidal volume, and the like.

[0059] In a non-limiting example, peak expiratory flow rate is calculated in block **530**. In block **535**, the results of the direct measurements or calculations are stored in the memory (see FIG. **4**). Then, the processor **420** turns off the high resolution sensor **435** and returns to a sleep state. Optionally, the processor **420** may transmit the data via the radio **410** and the antenna **402** to the control system **120**. Then, the method **500** terminates.

[0060] FIG. **6**A is a flow diagram of a method **600** of transferring data from the device **140** to the control system **120**. When the method **600** begins, the processor **420** is in the wait state. In block **605**, the processor **420** determines a predetermined transmission interval has lapsed since a transmission was last sent by the device **140** to an external device (e.g., the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, the Internet gateway device **370**, and the like). As discussed above, the external device is configured to transfer the data sent to it by the device **140** to the control system **120**. In other embodiments, the device **140** may send data to the control system **120** without using an intermediate device. In block **610**, the processor **420** retrieves the rotational data, airflow rate data, time encoding data, medication type, dosages, expiration dates, and/or other data stored in the memory **430** (see FIG. **4**) during blocks **525** and **535** of method **500** (see FIG. **5**). In block **615**, the information retrieved is formatted for transmission (e.g., placed in transmission packets) and subsequently transferred to the external device or control system **120** in block **620**.

[0061] In decision block **625**, the processor **420** determines whether a transfer confirmation has been received from the external device. The decision in decision block **625** is "YES" when the device **140** has received a transfer confirmation from the external device in response to the transmission sent in block **620**. Otherwise, the decision in decision block **625** is "NO" when the device has not received a transfer confirmation from the external device in response to the transmission sent in block **630**. Optionally, even if a transfer confirmation is received, the decision in decision block **625** may nevertheless be "NO," if the processor **420** determines that a problem occurred when the calculated values were transmitted in block **620**. When the decision in decision block **625** is "YES," the method **600** terminates. When the decision in decision block **625** is "NO," in block **630**, the processor **420** stores bad send data in the memory **430** for analysis. Then, after a delay, the processor **420** returns to block **610**.

[0062] FIG. **6**B is a flow diagram of a method **650** performed by the processor **420**. The method **650** is performed when the device **140** receives data from the control system **120** (e.g., through an external device). The device **140** may receive data from the control system **120** such as dosage count information following the successful transfer of data (e.g., the airflow values) to the control system **120**. In first block **635**, the processor **420** waits to receive a transmission from the control system **120**. In block **640**, the device **140** receives data, such as a setting value, or the like, from the control system **120**. In block **655**, the processor **420** determines whether a problem occurred when the data was received from the control system **120**. For example, if too much time has elapsed since data was last received from the control system **120**, the processor **420** may determine a problem occurred. The decision in decision block **655** is "YES" when the processor **420** determines a problem has occurred. On the other hand, the decision in decision block **655** is "NO" when the processor **420** determines a problem has not occurred.

[0063] When the decision in decision block **655** is "YES," in block **660** the processor **420** stores data related to the problem (e.g., increments a bad receive count value). Then, the processor **420** returns to block **640** to wait for additional transmissions from the control system **120**. By way of a non-limiting example, the control system **120** may retransmit data to the device **140** if the control system **120** determines the data was not received by the device. When the decision in decision block **655** is "NO," in optional block **645** the processor **420** may send a receipt confirmation to the control system **120** confirming the data was received. Then, in block **665**, the device **140** stores the data received and the method **650** terminates.

[0064] FIG. **7** is a flow diagram of a method **700** of receiving the calculated flow rate values at the control system **120** shown in FIG. **1**. By way of a non-limiting example, the method **700** will be described as being performed by the database server **375** (see FIG. **3**). In first block **705**, the database server **375** waits to receive a transmission from the device **140** (e.g., via one of the external devices). In decision block **710**, the database server **375** determines whether it has been waiting too long (e.g., longer than a predetermined amount of time) indicating there may be a problem with the device **140** or, in embodiments of the device **140** configured to communicate wirelessly, that the device **140** was positioned outside a radio coverage area. The decision in decision block **710** is "YES" when the database server **375** has been waiting too long for a transmission from the device **140**. On the other hand, the decision in decision block **725** is "NO" when the database server **375** has not been waiting too long for a transmission from the device **140**.

[0065] When the decision in decision block **710** is "YES," the database server **375** has been waiting too long for a transmission from the device **140** and, in block **720**, sends a notification indicating a problem has occurred to the device **140**, the patient desktop computer **350**, the patient cellular telephone **360**, and/or the patient portable computer **365** to be reviewed by the patient **130**. In optional block **735**, the database server **375** may send a notification to the support network **110** and/or the healthcare system **105** indicating a problem has occurred.

[0066] When the decision in decision block **710** is "NO," the database server **375** continue to wait and in block **715**, receives the transmission including data or calculated values data obtained from the device **140**. In decision block **725**, the database server **375** determines whether a problem occurred when the data or calculated values received from the device **140**. For example, the calculated value for the high resolution sensor **435** may be compared to a valid range stored in the database server **375**. If the calculated value for the high resolution sensor **435** is outside the valid range, the database server **375** may determine a problem occurred. The decision in decision block **725** is "YES" when the database server **375** determines a problem has occurred. On the other hand, the

decision in decision block **725** is "NO" when the database server **375** determines a problem has not occurred.

[0067] When the decision in decision block **725** is "YES," in block **730** the database server **375** stores data related to the problem (e.g., increments a bad receive count value). Then, the database server **375** returns to block **705** to wait for additional transmissions from the device **140**. By way of a non-limiting example, the device **140** may retransmit data to the control system **120** if the device **140** determines the formatted data was not received by the control system.

[0068] When the decision in decision block **725** is "NO," in optional block **740** the database server **375** may send a receipt confirmation to the device **140** confirming the data and calculated values were received. In block **745**, the database server **375** stores the data and calculated values received. Then, the method **700** terminates. The data and calculated values may be stored in a patient record associated with the device **140**. By way of a non-limiting example, the transmission received by the control system **120** may include a device identifier associated with the device **140** that may be used to identify the patient record associated with the device.

[0069] FIG. **8** is a flow diagram of a method **800** of processing triggers specified for sensors other than the low and high resolution sensors **425** and **435**. The method **800** may be performed by the device **140**, the control system **120**, and/or a combination thereof. For ease of illustration, the method **800** will be described as being performed by the database server **375** but could also be considered to be on the patient's cellular phone **360** or other device. As mentioned above, the patient **130**, the support person **305** (e.g., parent) and/or the caregiver **320** may use the website **115** to specify trigger conditions (e.g., threshold values) that trigger messages to the patient **130**, the support person **305**, and/or the caregiver **320**. The method **800** may also be used with data input by the patient **130**, support person **305** or the caregiver **320**. The method **800** may be used with the calculated values obtained from the sensors **425** and **435** combined with the data from one or more other sensors or data available on the patient cell phone **360** or other computing device in the control system **120**. Further, data on the internet **355** such as, but not limited to, temperature, weather conditions, humidity, wind, rain, ozone level, air pollution, pollen count, air quality index, and the like may be integrated into the evaluate trigger block **810** localized by the location of a user (e.g., as indicated by his or her cellular phone location).

[0070] In the first block **805**, the database server **375** obtains the relevant sensor data. In block **810**, the database server **375** analyzes the sensor data relative to one or more triggers to determine whether any of the triggers have been satisfied such that a trigger message is to be sent to the patient **130** (e.g., the message **125** illustrated in FIG. **2**), the support person **305**, and/or the caregiver **320**. For example, a trigger may have been entered into the website **115** indicating that if the patient's medication administration rises above a specified level, a trigger message is to be sent to the patient **130**, the support person **305**, and/or the caregiver **320** reporting unusual activity. By way of another example, increased airway obstruction might trigger a predetermined prescribed treatment plan that could include increasing a dosage of maintenance or rescue inhaler medication. By way of yet another example, sensor measurements (e.g., measurements indicating increased difficulty in breathing via peak expiratory airflow indication) may trigger additional stress testing, automated patient symptom questions, a nurse to call or messages to setup an appointment with a healthcare provider. In block **820**, the database server **375** may try to identify a trend indicative of a problem.

[0071] In decision block **820**, the database server **375** determines whether one or more triggers are satisfied, indicating a problem. The decision in decision block **820** is "YES" when the database server **375** determines one or more triggers are satisfied. In this case, in block **825** a trigger message is sent to the device **140**, the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, and the like. On the other hand, the decision in decision block **820** is "NO" when the database server **375** determines none of the triggers is satisfied. When the decision in decision block **820** is "NO," in optional block **815** the database server **375** may send a notification indicating no problem has been detected to the device **140**, the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, and the like. The notification may be viewable on the website **115** (see FIG. **1**). Optionally, the database server **375** may send a notification indicating no problem has been detected to the computing device **310** to be viewed by the support person **305** and/or to the computing device **315** to be viewed by the caregiver **320**. Any such notifications may be viewable on the website **115** (see FIG. **1**). Then, the method **800** terminates.

Device **140**

[0072] As described above, FIG. **4** illustrates the circuit **400** that may be used to construct the device **140**. Referring now to FIGS. **10-12**, various components that may be used to construct the device **140** are described.

[0073] Turning to FIG. **12**, in the embodiment illustrated, the circuit **400** (see FIG. **4**) is mounted on a substrate **1045** (e.g., a printed circuit board) housed inside a two-part electronics enclosure—a main enclosure **1030** and a frame **1070**. A removable battery **1060** may provide power to the circuit **400**, but it is understood that other power means such as photovoltaic, capacitance, energy harvesting, combination thereof, and the like may be used instead of or in addition to the removable battery **1060**. In the embodiment illustrated, the processor **420**, memory **430**, optional radio **410**, and antenna **405** are integrated in a module **1040** that is mounted on the substrate **1045**. The module **1040** communicates with the optional display **415**, which in this embodiment includes light emitting diodes ("LEDs") **1035** that display green, yellow, or red depending upon the airflow measurements obtained. By way of a non-limiting example, the LEDs **1035** may include a green LED that when illuminated produces green light, a yellow LED that when illuminated produces yellow light, and a red LED that when illuminated produces red light.

[0074] The colors green, yellow, and red are commonly understood asthma descriptions of peak exhalation airflow significance. Green is interpreted as a good outcome, yellow is interpreted as a potential concern, and red is interpreted as a serious condition.

[0075] In some embodiments, the processor **420** compares a current peak expiratory airflow measurement to a previously obtained peak expiratory airflow measurement (e.g., the highest peak expiratory airflow measurement stored in the memory **430**). The previous peak expiratory airflow measurement is used as a comparison measurement. If the current peak expiratory airflow measure is greater than 80% of the comparison measurement, the green LED is illuminated,

indicating no problems. When the current peak expiratory airflow measure is higher than the highest peak expiratory airflow measure stored in the memory **430**, the processor **420** replaces the highest peak expiratory airflow measure with the current peak expiratory airflow measure. If the current peak expiratory airflow measurement is between 50% and 80% of the comparison measurement, the yellow LED is illuminated, indicating that there may be a problem with the patient's expiratory flow rate. If the current peak expiratory airflow measurement is lower than 50% of the comparison measurement, the red LED is illuminated.

[0076] All of the LEDs may additionally be blinked to inform the patient **130** of additional conditions such as the end of a specified dosage. The red, yellow, and green LEDs may be spaced sufficiently far apart from one another to avoid miscommunication for color blind individuals. Further, different illumination patterns may be used for different LEDs. For example, the green LED may be continuously illuminated, the yellow LED may blink slowly when illuminated, and the red LED may blink faster than the yellow LED when illuminated. This will further reduce misreads and express the urgency of a red indication.

[0077] Although, this color coding is described with respect to some embodiments of the optional display **415** of the device **140**, this color coding may also be provided by the display of the user cellular phone **360**, the display of the desktop computer **350**, the display of the portable computer **365**, the display of the support network computing device **310**, and/or the display of the healthcare system computing device **315**. Further, the display **415** of the device **140** may include other display elements instead of or in addition to the LEDs **1035**, such as a liquid crystal display (LCD), or the like.

[0078] The low resolution sensor **425** and the high resolution sensor **435** may be mounted on the substrate **1045**. The low and high resolution sensors **425** and **435** are positioned to interact with the magnet **1010** that is mounted on a shaft **1017** of the rotatable body **1015**. When the rotatable body **1015** is rotated, the shaft **1017** and the magnet **1010** rotate therewith as a unit. The magnet **1010** is magnetized diametrically such that north and south pole fields alternately sweep across the low and high resolution sensors **425** and **435** during rotation of the rotatable body **1015**. The rotatable body **1015** has vanes **1018** to transfer energy from the airflow to move the rotatable body **1015** in a clockwise or counter clockwise rotation depending on the direction (toward or away from the patient **130**) of the airflow and speed of the airflow, through the device **140**. This rotation speed is compared with a look-up table of rotation timer values to determine airflow characteristics, including peak expiratory flow rate (see block **530** of the method **500** of FIG. **5**). The look-up table may be stored in the memory **430** and used by the processor **420** to determine the airflow characteristics.

[0079] The rotatable body **1015**, shaft **1017**, and magnet **1010** form an assembly that is mounted in and supported by the frame **1070**. This assembly is rotatable relative to the frame **1070** but is constrained from lateral or longitudinal movement relative thereto. The frame **1070** includes a nozzle **1071** through which medication may be dispensed to the patient **130** from a metered dose applicator **1005**. The metered dose applicator **1005** stores the medication that is dispensed by the device **140**. In some embodiments, the metered dose applicator **1005** is removable and is replaced when a predetermined number of does of the medication stored thereby have been used.

[0080] As discussed above, the device **140** may also be used by a patient as a conventional inhaler. The metered dose applicator **1005** includes an aerosol canister body **1006** containing a medication-containing aerosol (or simply "medication") for the treatment of asthma. The aerosol canister body **1006** includes a valve stem **1007** extending downward therefrom. When the valve stem **1007** is pressed toward the canister body **1006**, a metered amount of the medication-containing aerosol is released from the valve stem. As shown in FIGS. **11** and **12**, the metered dose applicator **1005** may be positioned within a chamber **1032** formed by an upwardly extending sidewall **1031** of the main enclosure body **1030**. In this installed position, the valve stem **1007** is positioned within the nozzle **1071**. In some embodiments, the metered dose applicator **1005** and portions of the main enclosure body **1030** may be configured using conventional inhaler components.

[0081] During use as an inhaler, a patient may position his/her mouth over a patient mouthpiece portion **1025** of the main enclosure body **1030**. The patient may then manually depress the canister body **1006** while inhaling, which causes the valve stem **1007** to be pushed into the canister body. The medication-containing aerosol is released from the valve stem **1007** into the nozzle **1071**, where it then travels through a channel **1026** in the main enclosure body **1030** to be ejected out of the patient mouthpiece portion **1025** of the enclosure body so it may be inhaled by the patient. As discussed above with reference to the method **500** of FIG. **5**, when the patient is inhaling, the device **140** senses this and the inhalation is assumed to be a medication dispensing event that may be stored and/or transmitted as described above.

[0082] During use as an airflow meter, a patient may position his/her mouth over the patient mouthpiece portion **1025** and exhale into the mouthpiece, causing air to flow into the channel **1026** whereby the rotatable body **1015** is rotated at a speed dependent on the rate of airflow. As discussed above with reference to the method **500** of FIG. **5**, the device **140** senses when the patient is exhaling, and proceeds to measure airflow characteristics (e.g., peak expiratory flow rate), which may then be stored and/or transmitted as described above.

[0083] The frame **1070** also retains a seal plug **1065** in the main enclosure body **1030**. This provides a waterproof seal to an electronics enclosure **1067**. The seal plug **1065** also allows the device to be washed. A cover **1020** may be positioned over the patient mouthpiece **1025** when the device **140** is not in use. The shape and size of the completed enclosure is intended to mate with standard spacer tubes that are currently on the market and commonly used by children who are less able to time the device **140** spray with their own inhalation.

[0084] In an alternate embodiment, the device **140** may include two pressure sensors, instead of the low and high resolution sensors **425** and **435**. In such an embodiment, one of the pressure sensors is positioned in a cavity that opens into the airway of the patient **130** and the other pressure sensor communicates with a venturi meter that joins the cavity with the outside air. Such a device can be configured to sense and differentiate inhalation and exhalation airflow and airflow rates.

[0085] There are several variations of this device **140** that may be constructed depending on the requirements of the patient **130**. For a patient with a modest disease condition, the radio **410** may not be required. In this regard, simply indicating with the display **415** (e.g., via the green, yellow, and red LEDs) the results of the comparison of the current peak

exhalation airflow measurement and the comparison measurement may be satisfactory. On the other hand, a patient **130** with a more severe disease condition may prefer the control system **120** features described above. The optional pressure sensor **445** (see FIG. **4**) may be used to improve precision in cases of changing altitude or weather, which may alter the measurements by the low and high resolution sensors **425** and **435** due to changes in air pressure.

[0086] By integrating an airflow meter with a medication dispensing device, several significant advantages over current art are achieved. Although it is a common recommendation to perform regular peak exhalation flow measurements, it can be difficult in practice. It is inconvenient to carry an additional object. And it is recommended to use the flow meter even when the patient is feeling well. By integrating the medication administration device and the airflow meter into a single device, the patient **130** is more likely to have the flow measurement device and more likely to use it because the patient may already have it in hand. This device **140** places the flow meter in the mouth of the patient **130**, who only needs to exhale to obtain an airflow measurement. This also facilitates incentive spirometry activities. Further, the device **140** may be configured to be in a sleep state when not in use. This allows the device **140** to recognize airflow events without requiring the patient to perform any turn on or turn off actions making the device even more convenient to use.

[0087] Recommendations for peak exhalation airflow measurement sometimes suggest that the patient **130** take several tests and choose the largest number for logging purposes. The processor **420** may be configured to evaluate a series of exhalation airflow measurements taken in close succession, automatically identify the largest measurement in the series, and transmit the identified measurement (via the radio **410**) to the control system **120** for storage in the patient record on the database server **375**.

[0088] The device **140** and/or the database server **375** may also track the number of dosages used from a metered dose inhaler. In such embodiments, the metered dose applicator **1005** may be discarded when it exceeds its manufacturer's specified dosage capacity. In some embodiments, two or more devices **140** may be attached to different metered dose inhalers that contain different medications. In this way, it is possible for the control system **120** to track more than one medication for a particular patient.

[0089] By using a camera of the patient cellular phone with an appropriate bar code reader program, the medication can be scanned, and the drug type, dosage, counter zeroing, and other similar data storage and application tasks may be performed.

[0090] The camera of the patient cellular phone **360** may, optionally, also be actuated to gather additional environmental information when a rescue inhaler has been used. This picture may be forwarded to the database server **375** and may be analyzed for commonalities of environmental triggers.

[0091] The radio **410** of the device **140** provides a data link to the cellular phone **360** and the control system **120**. In some embodiments, to link the radio **410** to the cellular phone **360**, it may be necessary to pair the two devices. This is particularly the case with Bluetooth and may be accomplished with this device **140**, for example, by blowing through the device **140** while it and the patient's cellular phone **360** are in Bluetooth pairing mode. Similarly, the device **140** may be subjected to several cycles of inhalation and exhalation in quick succession to instruct the processor **420** to clear the retained memory **430** of data regarding peak exhalation flow measurements and dosage specifications. This technique may be referred to as "breath signaling." In addition to these types of controls, the device **140** may also include one or more inputs (e.g., buttons, keys, etc.) that are operative to allow the user to control the circuit **400** and/or to control the communication of data with the control system **120**.

Computing Device

[0092] FIG. **9** is a diagram of hardware and an operating environment in conjunction with which implementations of the database server **375**, the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, the support computing device **310**, the caregiver computing device **315**, and the web server **340** may be practiced. The description of FIG. **9** is intended to provide a brief, general description of suitable computer hardware and a suitable computing environment in which implementations may be practiced. Although not required, implementations are described in the general context of computer-executable instructions, such as program modules, being executed by a computer, such as a personal computer. Generally, program modules include routines, programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types.

[0093] Moreover, those skilled in the art will appreciate that implementations may be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. Implementations may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

[0094] The exemplary hardware and operating environment of FIG. **9** includes a general-purpose computing device in the form of a computing device **12**. The database server **375**, the patient desktop computer **350**, the patient cellular telephone **360**, the patient portable computer **365**, the support computing device **310**, the caregiver computing device **315**, the web server **340** may each be implemented using one or more computing devices like the computing device **12**.

[0095] The computing device **12** includes a system memory **22**, the processing unit **21**, and a system bus **23** that operatively couples various system components, including the system memory **22**, to the processing unit **21**. There may be only one or there may be more than one processing unit **21**, such that the processor of computing device **12** includes a single central-processing unit ("CPU"), or a plurality of processing units, commonly referred to as a parallel processing environment. When multiple processing units are used, the processing units may be heterogeneous. By way of a nonlimiting example, such a heterogeneous processing environment may include a conventional CPU, a conventional graphics processing unit ("GPU"), a floating-point unit ("FPU"), combinations thereof, and the like. The computing device **12** may be a conventional computer, a distributed computer, or any other type of computer.

[0096] The system bus **23** may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. The memory **430** (illustrated FIG. **4**) may be

substantially similar to the system memory **22**. The system memory **22** may also be referred to as simply the memory, and includes read only memory (ROM) **24** and random access memory (RAM) **25**. A basic input/output system (BIOS) **26**, containing the basic routines that help to transfer information between elements within the computing device **12**, such as during start-up, is stored in ROM **24**. The computing device **12** further includes a hard **5** disk drive **27** for reading from and writing to a hard disk, not shown, a magnetic disk drive **28** for reading from or writing to a removable magnetic disk **29**, and an optical disk drive **30** for reading from or writing to a removable optical disk **31** such as a CD ROM, DVD, or other optical media.

[0097] The hard disk drive **27**, magnetic disk drive **28**, and optical disk drive **30** are connected to the system bus **23** by a hard disk drive interface **32**, a magnetic disk drive interface **33**, and an optical disk drive interface **34**, respectively. The drives and their associated computer-readable media provide nonvolatile storage of computer-readable instructions, data structures, program modules, and other data for the computing device **12**. It should be appreciated by those skilled in the art that any type of computer-readable media which can store data that is accessible by a computer, such as magnetic cassettes, flash memory cards, solid state memory devices ("SSD"), USB drives, digital video disks, Bernoulli cartridges, random access memories (RAMs), read only memories (ROMs), and the like, may be used in the exemplary operating environment. As is apparent to those of ordinary skill in the art, the hard disk drive **27** and other forms of computer-readable media (e.g., the removable magnetic disk **29**, the removable optical disk **31**, flash memory cards, SSD, USB drives, and the like) accessible by the processing unit **21** may be considered components of the system memory **22**.

[0098] A number of program modules may be stored on the hard disk drive **27**, magnetic disk **29**, optical disk **31**, ROM **24**, or RAM **25**, including an operating system **35**, one or more application programs **36**, other program modules **37**, and program data **38**. A user may enter commands and information into the computing device **12** through input devices such as a keyboard **40** and pointing device **42**. Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, touch sensitive devices (e.g., a stylus or touch pad), video camera, depth camera, or the like. These and other input devices are often connected to the processing unit **21** through a serial port interface **46** that is coupled to the system bus **23**, but may be connected by other interfaces, such as a parallel port, game port, a universal serial 5 bus (USB), or a wireless interface (e.g., a Bluetooth interface). A monitor **47** or other type of display device is also connected to the system bus **23** via an interface, such as a video adapter **48**. In addition to the monitor, computers typically include other peripheral output devices (not shown), such as speakers, printers, and haptic devices that provide tactile and/or other types physical feedback (e.g., a force feed back game controller).

[0099] The input devices described above are operable to receive user input and selections. Together the input and display devices may be described as providing a user interface. The input devices may be used to receive information from the patient **130**, the support person **305**, the caregiver **320**, and the like. The user interface may be used to display messages (e.g., notifications and alerts) to the patient **130**, the support person **305**, the caregiver **320**, and the like.

[0100] The computing device **12** may operate in a networked environment using logical connections to one or more remote computers, such as remote computer **49**. These logical connections are achieved by a communication device coupled to or a part of the computing device **12** (as the local computer) Implementations are not limited to a particular type of communications device.

[0101] The remote computer **49** may be another computer, a server, a router, a network PC, a client, a memory storage device, a peer device or other common network node, and typically includes many or all of the elements described above relative to the computing device **12**. The remote computer **49** may be connected to a memory storage device **50**. The logical connections depicted in FIG. **10** include a local-area network (LAN) **51** and a wide-area network (WAN) **52**. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets and the Internet.

[0102] Those of ordinary skill in the art will appreciate that a LAN may be connected to a WAN via a modem using a carrier signal over a telephone network, cable network, cellular network, or power lines. Such a modem may be connected to the computing device **12** by a network interface (e.g., a serial or other type of port). Further, many laptop computers may connect to a network via a cellular data modem.

[0103] When used in a LAN-networking environment, the computing device **12** is connected to the local area network **51** through a network interface or adapter **53**, which is one type of communications device. When used in a WAN networking environment, the computing device **12** typically includes a modem **54**, a type of communications device, or any other type of communications device for establishing communications over the wide area network **52**, such as the Internet.

[0104] The modem **54**, which may be internal or external, is connected to the system bus **23** via the serial port interface **46**. In a networked environment, program modules depicted relative to the personal computing device **12**, or portions thereof, may be stored in the remote computer **49** and/or the remote memory storage device **50**. It is appreciated that the network connections shown are exemplary and other means of and communications devices for establishing a communications link between the computers may be used.

[0105] The computing device **12** and related components have been presented herein by way of particular example and also by abstraction in order to facilitate a high-level view of the concepts disclosed. The actual technical design and implementation may vary based on particular implementation while maintaining the overall nature of the concepts disclosed.

[0106] The memory of the database server **375** stores computer executable instructions that when executed by one or more processors cause the one or more processors to perform all or portions of the methods **700**, **750**, and/or **800**.

[0107] The memory **430** of the device **10** stores processor executable instructions that when executed by the processor **420** cause the processor to perform all or portions of the methods **500**, **600**, **650**, **750**, and/or **800**.

[0108] Any of the instructions described above, including the instructions stored by the memory of the database server **375** and in the memory **430** of the device **140**, may be stored on one or more non-transitory computer-readable media.

[0109] The patient **130** may choose to ignore, interpret, or follow the messages or instructions received from the control

system **120**. But, this networking of asthma medication administration and patient airflow testing provide numerous advantages over the current art. Adherence to a medication treatment plan is likely to improve if it is measured and adapted. Often the simple act of monitoring human behavior can change it. Also, particularly in the case of a child whose understanding and resolve can be limited, providing real-time data to the support network **310** that includes a parent may improve compliance. Compliance may be monitored by the recognition of insufficient usage of a maintenance medication or the overuse of a rescue inhaler. The system can function as a medication reminder for those patients with a consistent dosage treatment plan who miss an application or overuse a medicine.

[0110] It is often difficult for a patient to remember the exact amount of medicine taken and when it was taken when answering a doctor's questions. By automatically providing trended data to the healthcare provider, he or she can review the effectiveness of the treatment plan and make more careful adjustments. In many cases, the patient data review and adjustment of treatment plan may be accomplished without a visit to a practitioner, which may save medical cost and improve healthcare. More generally, the control system **120** shown in FIGS. **1** and **2** and embodied in a device network shown in FIG. **3** allows the doctor improved monitoring and superior control of their patient's disease.

[0111] In addition to medication administration and airflow analysis, in the case of an asthma attack, additional information can be collected. As discussed above, some environmental information is available on the Internet. Weather information such as temperature, humidity, wind born small particles, ozone levels, air pollution, pollen count and the like are available. This information can be localized by use of the patient's cellular phone **360**, by either cell tower signal location **330** or global positioning system. This additional data may be used to modify a patient's treatment plan and/or to identify causes of changes in a patient's asthma symptoms. A bronchodilator or rescue inhaler administration could cause the control system **120** to capture this localized environmental data available on the web and store it with the patient's electronic record on the server **375**. Additionally, the patient **130** may receive a request for additional information from the server **375** to log additional characteristics of the event or events. In some embodiments, a bronchodilator or rescue inhaler administration and/or a severely low peak expiratory flow measurement may cause the device **140** to send a message to the patient cellular phone **360** or other device to automatically display the treatment plan protocol for attack events.

[0112] With this detailed history of the exact patient record, it is possible to determine an approximate level of risk of an asthma attack. This patient record or history data may include medication administration, airway flow, attack history, attack location history, environmental conditions, patient responses and the like. The patient **130** may optionally be tracked and his situation evaluated continuously for conditions that might have historically contributed to an attack. This level of risk could be communicated to the patient's cellular phone **360** or other devices (e.g., a support network computing device or a healthcare provider computing device) using messages on a continually updated basis. As a non-limiting example, a person with a particular susceptibility to pollen and windborne particulates may have that data automatically evaluated and downloaded to their cellular phone **360** depending on their location and weather conditions. For example, a changeable icon on a patient's home screen of their cellular phone might change to represent their personal real-time risk factors.

[0113] In the case where an asthma attack occurs, the control system **120** may also be able to help. Often a protocol of medicine administration and periods for reapplication or test is specified. A rescue inhaler administration may optionally initiate a program on the cellular phone **360** that reminds the patient **130** of the prescribed treatment plan, sets timers, and questions the patient **130** for details of their condition.

[0114] That data then may be immediately transferred to the server database **375** for evaluation. The control system **120** may then take preprogrammed actions that may include contacting the support network **310** or the healthcare system **315** with current health conditions and the location of the cellular phone **360**. In this way, as an example, a parent may be automatically notified of a child's asthma attack in close to real-time with GPS location by preprogrammed control system **120** configuration.

[0115] The control system **120**, as mentioned earlier, can know the amount of medication consumed by the patient **130** and compare it to the treatment plan. But the control system **120** can also use this information to facilitate reordering of medication. It is possible for the patient **130** or their support network **310** to define the amount of safety stock required and to reorder medication automatically or via prompts when it is required through a control system connection to an Internet-enabled pharmacy.

[0116] In addition to the supervisory function of the control system **120**, it can also function as a means of providing information and education to the patient. In an optional implementation, the database server **375** may send messages to the patient's cell phone **360** or the support network person **305** to educate and generally inform them about asthma. In addition to messages, links may also be made available to a patient's detailed drug information, counter indications, and the like. As can be appreciated, there is much that the patient **130** can do to improve their condition through a better understanding of how to cope with their disease.

[0117] The foregoing described embodiments depict different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected," or "operably coupled," to each other to achieve the desired functionality.

[0118] While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from this invention and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of this invention. Furthermore, it is to be understood that the invention is solely defined by the appended claims. It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims

(e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present.

[0119] For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations).

[0120] Accordingly, the invention is not limited except as by the appended claims.

1.-11. (canceled)

12. A system for use with an external device and an asthma monitoring device of a patient, at least one of the external device and the asthma monitoring device comprising a display device, the external device and the asthma monitoring device each being connected to the system by at least one network, the asthma monitoring device being operable to collect at least one airflow measurement of the patient and transmit the at least one airflow measurement to the system via the at least one network, the asthma monitoring device being further operable to collect medication application data and transmit the medication application data to the system via the at least one network, the system comprising:

one or more processors;

one or more storage devices connected to the one or more processors, each of the one or more storage devices storing at least one of data and instructions, the data comprising a predetermined treatment plan for treating an asthma condition of the patient, the instructions being executable by the one or more processors and when executed thereby implement a method comprising:

receiving state information from the asthma monitoring device comprising at least one of medication application data and airflow measurement data;

comparing the state information with reference information comprising at least one of the predetermined treatment plan and historical data for the patient;

determining whether the state information deviates from the reference information based on the comparison;

if the one or more processors determine the state information has deviated from the reference information in one or more predetermined ways, the method further comprising:

sending a first message over the at least one network to at least one of the external device and the asthma monitoring device for display thereby on the display device, the first message comprising information directed to the patient concerning the patient's asthma condition.

13. The system of claim **12**, wherein the method implemented by the processor executing the instructions further comprises delivering information relating to the patient's asthma condition to at least one of a support network computing device and a healthcare provider computing device.

14. The system of claim **12**, wherein the method implemented by the processor executing the instructions further comprises providing airflow measurement data to at least one of a support network computing device and a healthcare provider computing device.

15. The system of claim **12**, wherein the reference information comprises the predetermined treatment plan and the state information comprises current and historical patient data, and wherein the method implemented by the processor executing the instructions further comprises sending messages to external devices of the patient and the patient's support network or healthcare provider pertaining to the patient's adherence to the predetermined treatment plan.

16. The system of claim **12**, wherein the system is operative for use with a rescue inhaler of the patient that is connected to the system by the at least one network, the rescue inhaler being operable to collect usage data and to transmit the usage data to the system via the at least one network, wherein the usage of the rescue inhaler triggers the system to log data received from the external device and the Internet pertaining to at least one of: current location of the external device, time of day, date, temperature, humidity, wind speed, rain, pollen count, ozone level, air pollution, and an image taken by the external device.

17. The system of claim **16**, wherein the method implemented by the processor executing the instructions further comprises comparing the data logged by the system with current conditions at the location of the patient and sending messages to external devices of the patient and the patient's support network or healthcare provider based on the results of the comparison.

18. The system of claim **17**, wherein the results of the comparison are made available as a changeable icon on the display of one or more of the external devices.

19. The system of claim **12**, wherein the method implemented by the processor executing the instructions further comprises sending messages to a support network computing device when it is determined that the patient's airflow measurements are below a predetermined level.

20. The system of claim **12**, wherein the method implemented by the processor executing the instructions further comprises:

receiving usage information for a particular medication from the asthma monitoring device;

comparing the received usage information to a specified usage capacity for the medication;

determining when the medication is at or near its specified usage capacity based on the comparison; and

initiating an order for a replacement medication that is to be provided to the patient.

21.-29. (canceled)

30. A system for use with an external device and an asthma monitoring device of a patient, at least one of the external device and the asthma monitoring device comprising a dis-

play device, the external device and the asthma monitoring device each being connected to the system by at least one network, the asthma monitoring device being operable to collect at least one airflow measurement of the patient and transmit the at least one airflow measurement to the system via the at least one network, the asthma monitoring device being further operable to collect medication application data and transmit the medication application data to the system via the at least one network, the system comprising:

one or more processors;

one or more storage devices connected to the one or more processors, each of the one or more storage devices storing at least one of data and instructions, the data comprising data relating to an asthma condition of the patient, the instructions being executable by the one or more processors and when executed thereby implement a method for recognizing changes in the patient's asthma condition and providing realtime feedback to the patient or an entity associated with the patient to reduce the severity of the patient's current asthma condition, the method comprising:

receiving airflow measurement data from the asthma monitoring device over the at least one network;

comparing the airflow measurement data with one or more preconfigured trigger values; and

if the one or more processors determine the airflow measurement data has exceeded one or more of the trigger values in one or more predetermined ways, the method further comprising:

sending a first message over the at least one network to at least one of the external device and the asthma monitoring device for display thereby on the display device, the first message comprising information directed to the patient or to the entity associated with the patient concerning the patient's asthma condition.

31. (canceled)

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专利名称(译)	哮喘监测装置		
公开(公告)号	US20150150484A1	公开(公告)日	2015-06-04
申请号	US14/615328	申请日	2015-02-05
[标]申请(专利权)人(译)	BIOGUIDANCE		
申请(专利权)人(译)	BIOGUIDANCE LLC		
当前申请(专利权)人(译)	BIOGUIDANCE LLC		
[标]发明人	WEKELL WILLIAM OREN		
发明人	WEKELL, WILLIAM OREN		
IPC分类号	A61B5/087 G06F19/00 G06Q30/06 A61B5/00		
CPC分类号	A61B5/087 A61B5/0022 G06Q30/0635 A61B5/742 G06F19/3475 A61B5/7282 A61B5/09 A61B5/6887 A61B5/746 A61M15/008 A61M15/009 A61M2016/0021 A61M2016/0027 A61M2016/0036 A61M2205/3553 A61M2205/3592 A61M2205/502 A61M2205/8206 G16H20/40 G16H40/67		
外部链接	Espacenet USPTO		

摘要(译)

一种与患者呼吸道一起使用的监测装置。监测设备的一些实施例包括至少一个传感器组件和可选的通信子组件，传感器组件配置成检测吸入和呼出的气流，可选的通信子组件配置成将测量值传输到至少一个外部计算设备。其他实施例包括至少一个传感器组件和至少一个处理器，所述传感器组件配置成检测指示来自患者肺部的气流的测量值，所述至少一个处理器配置成检测气流是否与药物施用或呼吸特性的测量相关联。一些实施例包括允许外部计算设备和/或监控设备分析患者信息以确定患者的呼吸是否已经下降指示医疗问题的电路。可选地，监控设备可以包括显示器，用于显示气流测量值是指示良好结果，潜在顾虑还是严重情况。