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(54) **ZONE-BASED HVAC SYSTEM**

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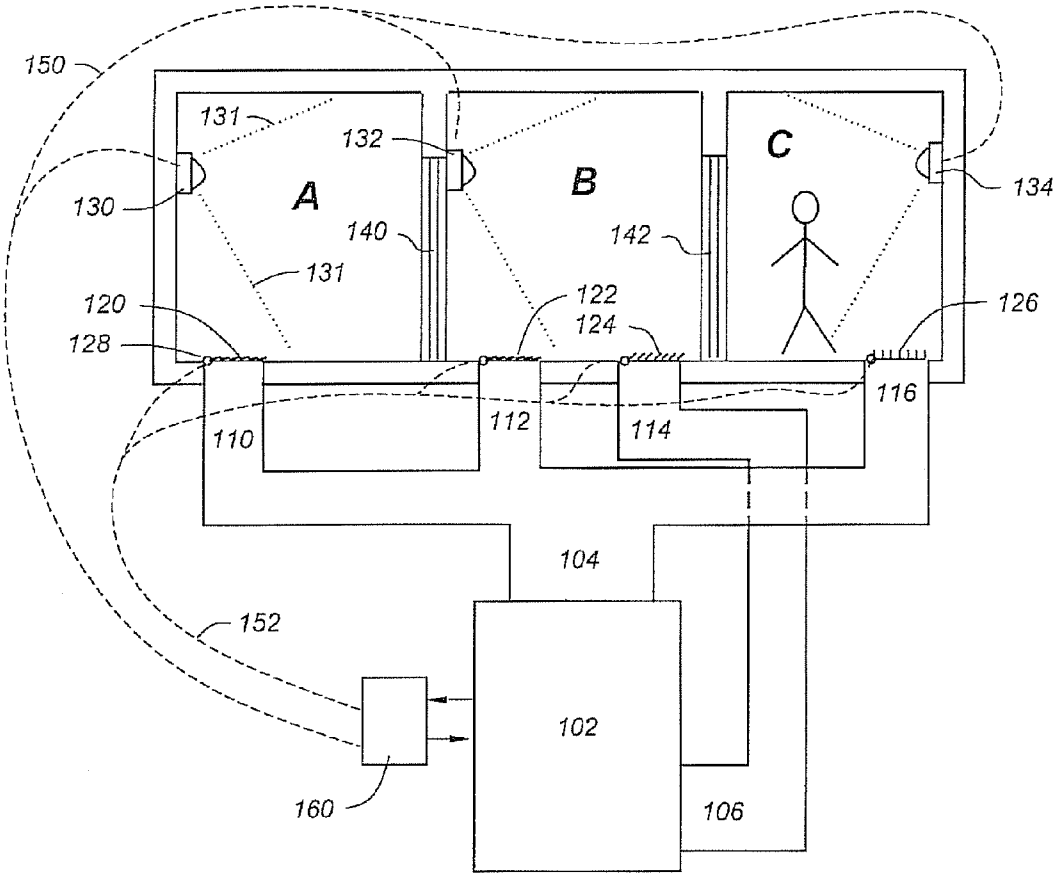
(57) **ABSTRACT**

A zone-based heating, ventilating, and air conditioning (HVAC) system uses occupant sensors and controllable vents to favor environmental conditions in occupied areas. A plurality of comfort delivery devices are provided, each being associated with at least one of the zones, each comfort delivery device being responsible for delivering a change in climate to its respective zone through the HVAC unit. A sending unit is disposed in each zone, the sending unit including a first sensor for determining whether the zone is occupied by one or more persons, a second sensor for determining an environmental condition in the zone, and a communications device for outputting a signal relating to the occupancy and environmental condition. A control unit includes an input for receiving the signal from each sending unit and selectively activating and deactivating the comfort delivery devices to prioritize the climate control provided by the HVAC unit to zones that are occupied. The control unit further may incorporate information from other sources, both internal and external, and learned behavior from previous measurements. Unoccupied areas may be utilized as sources of pre-conditioned air, previously stored for efficiency or economy reasons.



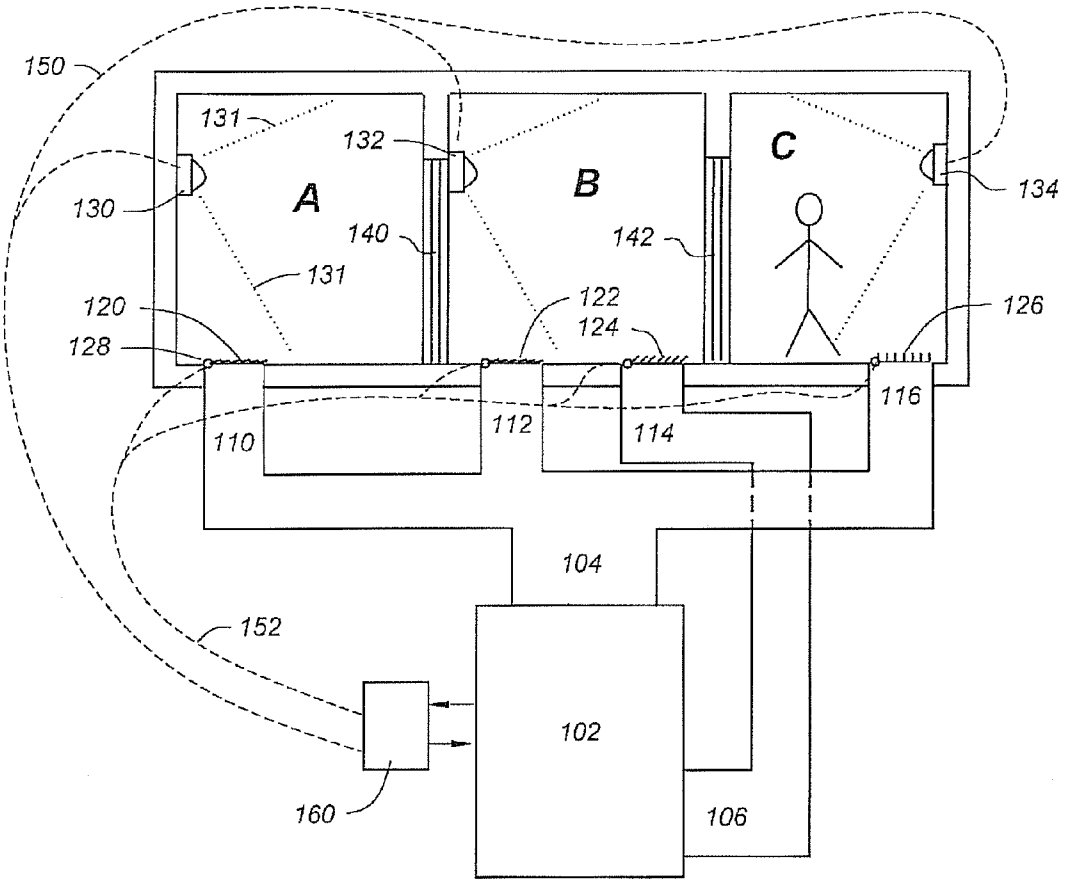

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Fig - 1

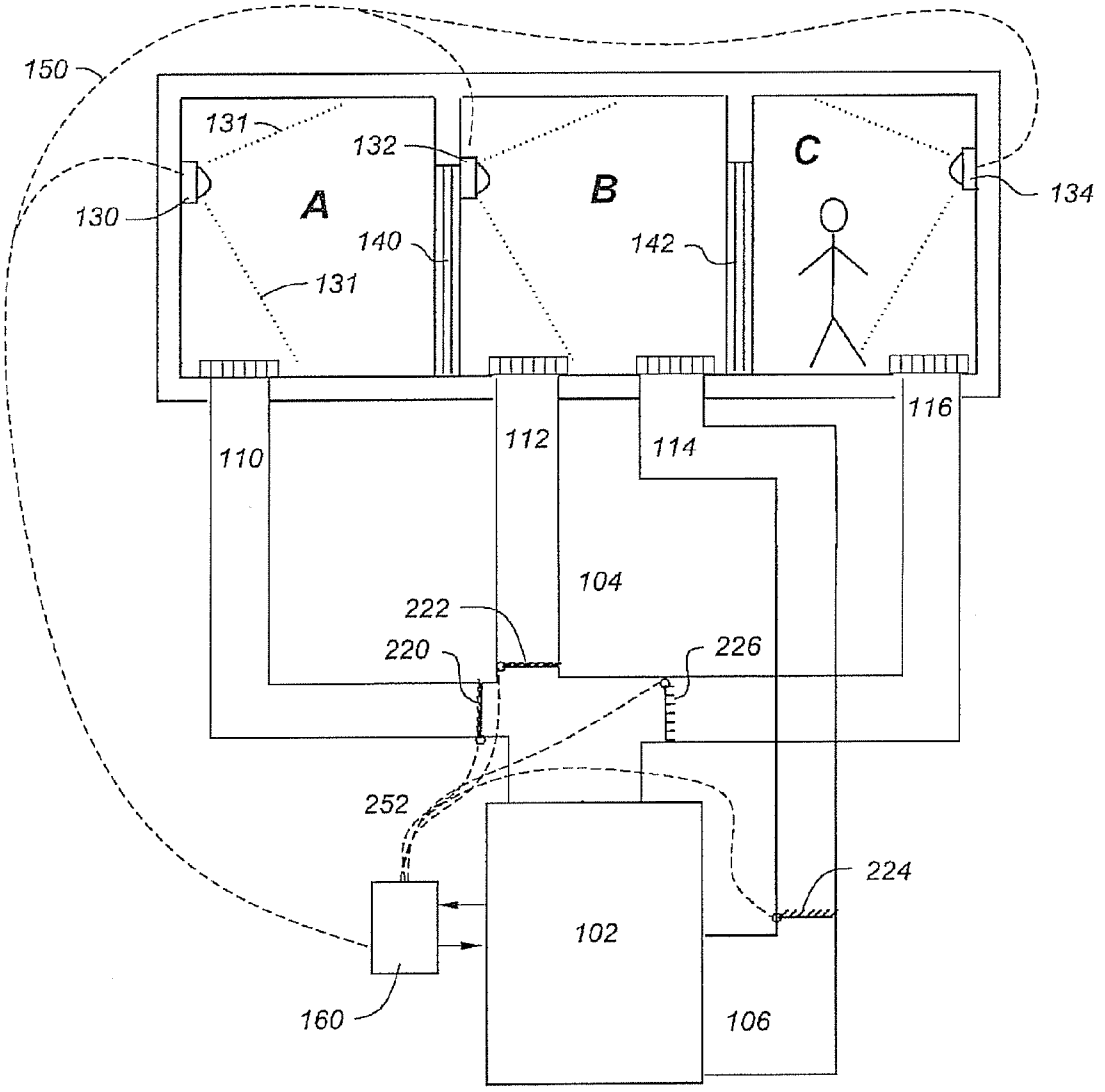
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Fig - 2

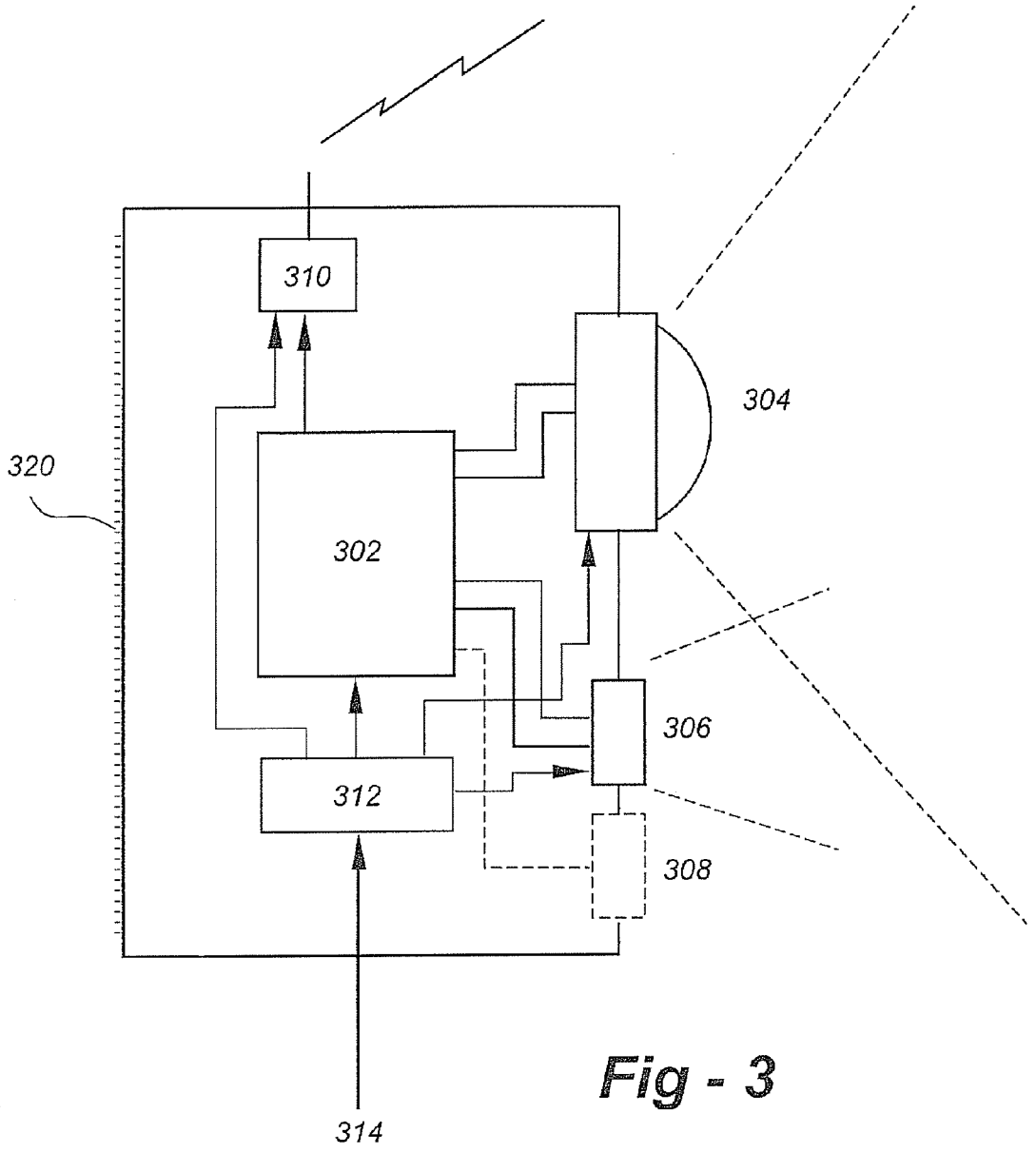

Fig - 3

ZONE-BASED HVAC SYSTEM

REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from U.S. Provisional Patent Application Ser. No. 61/323,921, filed Apr. 14, 2010, the entire content of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] This invention relates generally to heating and cooling and, in particular to a zone-based heating, ventilating, and air conditioning (HVAC) system that uses occupant sensors and controllable vents to favor environmental conditions in occupied areas.

BACKGROUND OF THE INVENTION

[0003] Energy costs continue rise. Over the years, ideas have been proposed to control heat loss in buildings and limits to the use of air conditioning are being proposed.

[0004] As one example of many, U.S. Pat. No. 4,407,447, entitled "Energy Control System," has a plurality of occupancy sensors, with each sensor adapted to detect the presence of a human being in a room. The occupancy sensors are all connected to a computer with the computer controlling a plurality of dampers that regulate the air flow in the air ducts into the various rooms. Upon the detection of the presence of a human being in a room by the occupancy sensor, the computer sends a signal to the air damper controlling the air flow into that room to open the air flow through that air duct.

[0005] While systems of the type just identified may prove beneficial in some situations, they could do more in terms of energy management. In the '447 patent, for example, there is no provision for any control of return-air. Nor is there any provision for shifting air [or energy] between rooms, or for using the heat capacity of unoccupied rooms for energy "storage."

SUMMARY OF THE INVENTION

[0006] This invention resides in a system for controlling a heating, ventilating, and air conditioning (HVAC) unit servicing a plurality of comfort zones. A plurality of comfort delivery devices are provided, each being associated with at least one of the zones, each comfort delivery device being responsible for delivering a change in climate to its respective zone through the HVAC unit. A sending unit is disposed in each zone, the sending unit including a first sensor for determining whether the zone is occupied by one or more persons, a second sensor for determining an environmental condition in the zone, and a communications device for outputting a signal relating to the occupancy and environmental condition. A control unit includes an input for receiving the signal from each sending unit and selectively activating and deactivating the comfort delivery devices to prioritize the climate control provided by the HVAC unit to zones that are occupied.

[0007] The HVAC unit may be a furnace or an air conditioner, with the change in climate being temperature. The HVAC unit may cause a change in humidity. The comfort delivery devices may be controllable louvers or vents. In the preferred embodiment the first sensors are infrared sensors and the second sensors are temperature sensors. The communications devices may be wireless transmitters. Each sending unit may be coded, enabling the control unit to determine the zone or zones within which the sending units are disposed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a simplified, schematic diagram illustrating the basic operation of one embodiment of the invention; and

[0009] FIG. **2** depicts an alternative embodiment of the invention wherein controlled vents are disposed at or near a furnace; and

[0010] FIG. **3** is a simplified block diagram of a typical OSTTU according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0011] This invention reduces energy consumption and enables potential equipment downsizing by providing a heating/cooling system that operates on a zone basis (i.e., room-by-room).

[0012] Broadly, the invention uses occupant sensors and controllable vents to favor environmental conditions in area (s) occupied by people, disfavoring other areas if/until people actually visit or frequent such places.

[0013] Advantageously, the system reclaims warmed or cooled air that has been applied to now-vacated zones, and redirect the warmed or cooled air to zones that are currently occupied.

[0014] The system may also utilize unoccupied zones to "store" heated or cooled air to be drawn upon at a later time, with the intention of advantageously utilizing this "reserve capacity" to mitigate the effects of other energy-saving features, such as electrical power distribution systems that automatically interrupt the power for air conditioners at peak periods of usage, or using lower overnight temperatures to store cool air in unoccupied zones so that it can be utilized during the hotter daylight hours.

[0015] Depending on the specific circumstances and financial considerations, heat-exchangers or other apparatus may be employed to optimize the efficiency of transfer of energy between zones. In addition, equivalent facilities may be implemented to redirect air from one zone to another, based on temperature, humidity, air purity, or other environmental considerations.

[0016] The system makes intelligent decisions based upon various input factors, such as the allowable degree of variation in temperatures, or "learned behaviors," such as patterns of movements throughout the zones at particular times of day or certain days of the week. For example, the system may "learn" that the occupant of a home likes to prepare a "midnight snack" in the kitchen 30 minutes before retiring for the night, and could adjust the temperatures of various zones based on an anticipated schedule, or remaining family members in other zones. External inputs can also be integrated into the decision-making process, as, for example, factoring in the setting of an alarm clock or other wake-up device to automatically raise the temperature of a bathroom in anticipation of a morning shower.

[0017] Another option would be to apply different rules/considerations based on a pre-defined "profile" for a particular person. For example, a particular person may prefer to keep the room they are occupying at a higher or lower temperature than other potential occupants; in cases such as these, the system may identify particular occupants by their size, heat signature, or other methods of analysis and, based

on their profile, define the environmental parameters to be applied to the rooms they are occupying at a particular time. When multiple occupants having dissimilar profiles are in the same room, the system would derive compromise settings based on pre-defined rules for factoring in the profiles of each occupant.

[0018] In addition, some homes employ multiple heating systems (either because of long duct runs, or for redundancy), and the systems described herein are capable of interfacing multiple HVAC units to manage their functionality as a single integrated system. The resulting benefit could include alternating the use of the units to prevent one unit from becoming overloaded, or using all units simultaneously to speed the response to system-related demands.

[0019] FIG. **1** is a simplified, schematic diagram illustrating the basic operation of one embodiment of the invention. The drawing shows three rooms, A, B, C, with the understanding that the invention is not limited in terms of the number of areas considered. Items labeled **140** and **142** are doors between the rooms.

[0020] Item **102** represents a furnace, combined furnace/AC unit, boiler, humidifier, dehumidifier, or any other unit associated with heating, cooling or other faun of residential, commercial or industrial environmental control. Assuming unit **102** is a furnace, the furnace includes a hot air plenum **104** feeding registers **110**, **112**, **116**, with a cold-air return coupled to plenum **106**. Again, more or fewer hot/cold vents may be accommodated

[0021] Each vent **110**, **112**, **114**, **116** may include controlled louvers **120**, **122**, **124**, **126**. For example, louvers **120** are controlled by motor **128**. Each room A, B, C, in this case also includes an Occupant Sensor/Thermostat Transmitter Unit (OSTTU) **130**, **132**, **134** described in further detail below. Each OSTTU is characterized by a field of view (i.e., **131**) used to detect persons entering, leaving, or remaining within a respective room. In the preferred embodiment, the OSTTUs include infrared sensors for this purpose. In practice, these sensing means can be combined with motion sensors or other detectors, and the sensitivities of these sensors can be adjusted, so as to moderate the impact of some events (such as entering a zone just for a few minutes before leaving again), or ignoring other events (such as a pet roaming the zones).

[0022] The controlled louvers and OSTTUs are in communication with a control unit **160** which, in turn, communicates and controls unit **102**, whether a furnace or otherwise. In the preferred embodiment, the OSTTUs are battery operated devices which communicate wirelessly (i.e., RF or infrared) via broken lines **150** to the control unit **160**. This is preferred since an installer may wish to locate the OSTTUs in various wall-mounted locations, including locations having no continuous power supply available. In some embodiments, however, the OSTTUs may be incorporated into wall outlets, light fixtures, or the like and derive power through them without the need for batteries, or alternatively through power derived from batteries recharged by locally mounted solar-cells or recharged by other means.

[0023] The louver controllers may also be battery operated and wirelessly controlled. However, there are some disadvantages to being battery operated, so they are more preferably hard-wired via broken lines **152** to control unit **160** to ensure reliable operation. Particularly as an after-market product, low-voltage wiring may be oriented through existing duct-work to louvers **120**, **122**, **124**, **126**, thereby forgoing the need for wiring nearby AC outlets, for example.

[0024] By way of a simple example, in operation OSTTU "sees" that a person is occupying room C. According, a signal is sent to control unit **160**, causing louver **116** to open. Depending upon the way in which the system is programmed, as discussed in greater detail below, louvers **120**, **122** may be closed since the rooms are void of occupants. Again depending upon the way in which the system is programmed, cold-air return **124** may be partially open to circulate at least a portion of the air from room C.

[0025] OSTTUs preferably include thermostats, which may be of the programmable set-back type. Alternatively, a subset of the OSTTUs may include thermostats, with the others simply including thermometers, depending upon the operational environment. If provided with thermostats, the OSTTUs may be set at the same temperature or at different temperatures.

[0026] Continuing the simplified example of FIG. **1**, assume that all of the OSTTUs **130**, **132**, **134** include thermostats, that all are set to 65° F., and that the person just entered room C from room B. If OSTTU **134** detects that room C is cold—say, 60° F.—the furnace **102** may be turned ON (if not already ON), and louver **116** will be opened (again, if not already opened), until OSTTU **134** detects that the room has been heated to 65° F., at which time louver **126** may be closed and/or furnace **102** turned OFF. Cold-air return **114** may also be opened and closed as desired to attain the desired environmental condition(s).

[0027] The reason why louver **126** may be closed and/or furnace **102** turned OFF when a desired condition is met depends upon various factors, including conditions in other rooms, time of day, movement of occupants, and so forth. For instance, if the person just entered room C from room B, and room B is at a desired temperature, louver **116** may be opened and louver **122** may be closed, as shown, with the furnace remaining ON, to favor heating room C over previously heated room B. Generally speaking, in a heating embodiment, the invention is used to open and close louvers, and turn the furnace ON/OFF, so that occupied rooms are comfortable while non-occupied rooms are allowed to cool down. For example, if thermostats are set to 65° F., occupied rooms may be heated to that temperature, while non-occupied rooms are allowed to cool to, say, 60° F. or lower (depending upon programming).

[0028] In the preferred embodiments, the system is programmed to make intelligent decisions regarding overall operation beyond room occupancy, including number of occupants, occupant movement between rooms, length of stay in a room, time of day, and so forth.

[0029] For example, if movement is detected to a previously unheated room, heating that room may be delayed to determine if the person(s) intend to stay in that room. The infrared sensors may be used to detect activation of lights, televisions, and so forth for additional evidence of intent. Similarly, if movement is detected from a previously heated room, allowing that room to cool may be delayed, to determine if the person(s) intend to return to that room. Again, the infrared sensors may be used to detect de-activation of the lights, televisions, and so forth for additional evidence of intent.

[0030] If it is evident that one or more persons are continually moving between the same two rooms, both may be favored in terms of heating. If the person in room C just

entered the room from work at 7 PM, and the entire dwelling is cold due to temperature set-back programming, louver **116** may be open with one or more other louvers being or remaining open to continue heating the rest of the house (though probably not to 65° F. for the reasons discussed above). Those of skill in the art will appreciate that a complex state diagram readily may be derived in accordance with the invention to account for occupant movement, time of day/year, heating versus cooling, etc.

[0031] FIG. **2** depicts an alternative embodiment of the invention wherein the controlled vents **220**, **222**, **224**, **226** are disposed at or near the furnace **102**. Whether for retrofit applications or new construction, this embodiment allows all wiring and controls to be located away from comfort zones such as in a basement, thereby simplifying installation. The trade-off is that the ductwork within which the controlled vents are placed may feed multiple registers although this may actually be advantageous in some situations.

[0032] FIG. **3** is a simplified block diagram of a typical OSTTU according to the invention. The device includes a microprocessor **302** providing overall control. The processor **302** receives occupant presence signals from IR sensor **304** and temperature signals from sensor **306**. Other sensor(s) represented by unit **308** may include a humidity sensor, etc. As discussed above, other occupant sensors may be used such as video cameras, including IR video cameras. Pattern recognition may be provided enabling the system to determine the number, and movement of, occupants, and prevent pets from exerting unintended influence on decision-making by the system.

[0033] Continuing the reference to FIG. **3**, a power supply **312** powers the various components. Block **312** is preferably a battery, which may be rechargeable, with line **314** representing an auxiliary power source such as line voltage or input from a solar cell. Item **310** is a wireless transmitter relaying conditions to control unit **160**, which may utilize an RF signal, WiFi or any other suitable communication. Each OSTTU is coded with an ID number so that the signals received by the control unit **160** may be properly interpreted in terms of the different zones being accommodated. A wall-mounting adhesive film may be provided at **320**.

[0034] In some of the embodiments, it may be desirable to draw air from a zone or room after it becomes unoccupied (or even in some cases while still occupied, but with a different group of occupants. Depending on the configuration of the ductwork, it may be advantageous or even necessary to implement additional vents or fans (not shown) to facilitate the movement of air through particular sections of ducts or zones. Control of these fans is managed by the system and coordinated with the opening and closing of the various vent openings, in order to supply or extract air from any particular zone as desired.

[0035] While the invention has been described in terms of a forced-air system in a residential setting, other environments, including commercial and industrial may be readily accommodated. Forced-air implementations are perhaps the most responsive in terms of temperature or humidity adjustment; however, other systems, including hot water (boiler), heated flooring, heat pumps and other equipment are not precluded. In addition, other facilities (such as humidifiers, de-humidifiers, heat exchangers, and air-filtration units) may be integrated into and managed by the overall system, as needed or desired. Further, other sources of information may be integrated into the control system decision-making processes, such as external sensors to detect outside temperature and humidity changes, or external communication links to connect to the Internet for receiving and interpreting programming information from the users, or weather forecasts for advance planning of environmental settings. Depending on these and other sources, the control system may be programmed to store heat or "store" cold in unused rooms, so that these sources of pre-conditioned air will be available for later use, thereby improving the efficiency and response time of the system.

We claim:

1. A system for controlling an HVAC unit servicing a plurality of comfort zones, comprising:

a plurality of comfort delivery devices, each associated with at least one of the zones, each comfort delivery device being responsible for delivering a change in climate to its respective zone through the HVAC unit;

a sending unit disposed in each zone, the sending unit including a first sensor for determining whether the zone is occupied by one or more persons, a second sensor for determining an environmental condition in the zone, and a communications device for outputting a signal relating to the occupancy and environmental condition; and

a control unit including an input for receiving the signal from each sending unit and selectively activating and deactivating the comfort delivery devices to prioritize the climate control provided by the HVAC unit to zones that are occupied.

2. The system of claim **1**, wherein the HVAC unit is a furnace and the change in climate is temperature.

3. The system of claim **1**, wherein the HVAC unit is an air conditioner and the change in climate is temperature.

4. The system of claim **1**, wherein the HVAC unit causes a change in humidity.

5. The system of claim **1**, wherein the comfort delivery devices are controllable louvers or vents.

6. The system of claim **1**, wherein the first sensors are infrared sensors.

7. The system of claim **1**, wherein the second sensors are temperature sensors.

8. The system of claim **1**, wherein the communications devices are wireless transmitters.

9. The system of claim **1**, wherein each sending unit is coded, enabling the control unit to determine the zone or zones within which the sending units are disposed.

* * * * *