

ADAPTIVE SENSOR SAMPLING OF A COLD CHAIN DISTRIBUTION SYSTEM**TECHNICAL FIELD**

[0001] The subject matter disclosed herein relates to environmental parameter monitoring, and to a system and a method for monitoring environmental parameters.

DESCRIPTION OF RELATED ART

[0002] Typically, cold chain distribution systems are used to transport and distribute perishable goods and environmentally sensitive goods (herein referred to as perishable goods) that may be susceptible to temperature, humidity, and other environmental factors. Perishable goods may include but are not limited to fruits, vegetables, grains, beans, nuts, eggs, dairy, seed, flowers, meat, poultry, fish, ice, blood and pharmaceuticals. Advantageously, cold chain systems allow perishable and environmentally sensitive goods (herein referred to as perishable goods) to be effectively transported and distributed without damage or other undesirable effects.

[0003] Environmental parameter sensors are often used in cold chain distribution systems to monitor the conditions and integrity of the cold chain and consequently the goods transported. Current environmental parameter sensing systems may sample and transmit data periodically at a high frequency to provide real time monitoring of the perishable goods. High frequency real time monitoring strains the overall sensor system bandwidth and drains the sensor's battery. A system and method that can provide monitoring of environmental parameters in an energy efficient manner is desired.

BRIEF SUMMARY

[0004] According to an embodiment, an apparatus for cold chain monitoring of perishable goods, includes at least one environmental sensor to monitor at least one environmental parameter, at least one event detector to detect at least one of an environmental altering event and a user induced event, and a controller to receive and log a plurality of readings from the at least one environmental sensor at a selected sampling rate, wherein the sampling rate adjusts depending on at least one of the perishable goods, the environmental altering event, and the user induced event.

[0005] In addition to one or more of the features described above, or as an alternative, further embodiments could include wherein the at least one environmental sensor, further comprises a power source providing electrical power to the at least one environmental sensor.

[0006] In addition to one or more of the features described above, or as an alternative, further embodiments could include wherein at least one of the controller and the at least one environmental sensor commands the sampling rate to adjust.

[0007] In addition to one or more of the features described above, or as an alternative, further embodiments could include a communication module in operative communication with the controller and wireless operative communication with a remote controller, wherein the communication module is configured to transmit at least one data signal associated with the plurality of readings to the remote controller.

[0008] In addition to one or more of the features described above, or as an alternative, further embodiments could include wherein the communication module is configured to receive at least one remote command from the remote controller and transmit the at least one remote command to the controller.

[0009] In addition to one or more of the features described above, or as an alternative, further embodiments could include wherein the remote controller commands the sampling rate to adjust.

[0010] In addition to one or more of the features described above, or as an alternative, further embodiments could include wherein the apparatus is associated with a transportation operation.

[0011] In addition to one or more of the features described above, or as an alternative, further embodiments could include wherein the communication module is a cellular interface to communicate with a cellular network.

[0012] In addition to one or more of the features described above, or as an alternative, further embodiments could include wherein the perishable goods include at least one of food and pharmaceuticals.

[0013] According to an embodiment, a method for cold chain monitoring of perishable goods, includes monitoring, using at least one environmental sensor, at least one environmental parameter, receiving and logging, using a controller, a plurality of readings from the at least one environmental sensor at a selected sampling rate, monitoring, using at least one event detector, at least one of an environmental altering event and a user induced event, and adjusting the sampling rate depending on at least one of the perishable goods, the environmental altering event, and the user induced event.

[0014] In addition to one or more of the features described above, or as an alternative, further embodiments could include electrically powering, using a dedicated power source, the at least one environmental sensor.

[0015] In addition to one or more of the features described above, or as an alternative, further embodiments could include commanding the adjustment of the sampling rate via at least one of the controller and the at least one environmental sensor.

[0016] In addition to one or more of the features described above, or as an alternative, further embodiments could include wirelessly transmitting, using a communication module in operative communication with the controller, at least one data signal associated with the plurality of readings to a remote controller.

[0017] In addition to one or more of the features described above, or as an alternative, further embodiments could include receiving, using the communication module, at least one remote command from the remote controller; and transmitting the at least one remote command to the controller.

[0018] In addition to one or more of the features described above, or as an alternative, further embodiments could include commanding the adjustment of the sampling rate via the remote controller.

[0019] In addition to one or more of the features described above, or as an alternative, further embodiments could include transporting the perishable goods.

[0020] In addition to one or more of the features described above, or as an alternative, further embodiments could include the communication module is a cellular interface to communicate with a cellular network.

[0021] In addition to one or more of the features described above, or as an alternative, further embodiments could include the perishable goods include at least one of food and pharmaceuticals.

[0022] Other aspects, features, and techniques will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0023] The foregoing and other features, and advantages of the disclosure are apparent from the following detailed description taken in conjunction with the accompanying drawings in which like elements are numbered alike in the several FIGURES:

[0024] FIG. 1 illustrates a schematic view of an environmental parameter monitor in a cold chain distribution system, in accordance with an embodiment; and

[0025] FIG. 2 is a schematic view of an environmental parameter monitoring system, in accordance with an embodiment.

DETAILED DESCRIPTION

[0026] Referring now to the drawings, FIG. 1 illustrates a schematic view of an exemplary cold chain transportation system 10 suitable for use with an environmental parameter monitoring system 20. Typically, cold chain transportation systems 10 are used to transport and distribute perishable goods and environmentally sensitive goods (herein referred to as perishable goods). In the illustrated embodiment, a cold chain transportation system 10 includes an environmentally controlled container 14, an environmental control system 28 and perishable goods (not shown). The container 14 may be pulled by a tractor 12. It is understood that embodiments described herein may be applied to shipping containers that are shipped by rail, sea, or any other suitable container, without use of a tractor 12. The container 14 may define an interior compartment 18.

[0027] In an embodiment, the environmental control system 28 is associated with container 14 to provide desired environmental parameters, such as, for example temperature, pressure, humidity, carbon dioxide, ethylene, ozone, light exposure, and other conditions to the interior compartment 18. In further embodiments, the environmental control system 28 is a refrigeration system capable of providing a desired temperature and humidity range. In a yet further embodiment, perishable goods may include but are not limited to fruits, vegetables, grains, beans, nuts, eggs, dairy, seed, flowers, meat, poultry, fish, ice, blood, pharmaceuticals, or any other suitable cargo requiring cold chain transport.

[0028] Referring to FIG. 2, in the illustrated embodiment, the environmental parameter monitoring system 20 includes, at least one environmental sensor 22, at least one event detector 24, and a controller 30. In an embodiment, the sensor 22 is utilized to monitor environmental parameters and generate a sensor reading. The sensor 22 is configured to monitor at least one environmental parameter, such as for example temperature, pressure, humidity, carbon dioxide, ethylene, ozone, light exposure, vibrations, and other conditions in the interior compartment 18. Accordingly, suitable sensors 22 are utilized to monitor the desired parameters. Advantageously, sensors 22 may be selected for certain applications depending on the perishable cargo to be monitored and the corresponding environmental sensitivities. In an embodiment, temperatures are monitored. In certain embodiments, a user desires to maintain and monitor temperatures or other parameters within an acceptable range. As seen in FIG. 1 the sensor 22 may be placed in a variety of locations within the interior compartment 18, including directly on the perishable goods.

[0029] The at least one event detector 24 is configured to detect at least one of an environmental altering event and a user induced event. For instance, the event detector 24

may determine whether at least one of an environmental altering event and a user induced event has occurred such as, for example a temperature change, or a door opening in the container 14. In further embodiments, the event detector 24 may be internal or external to the sensor 22.

[0030] Further, the controller 30 is configured to log a plurality of readings from the at least one environmental sensor 22 at a selected sampling rate. In a further embodiment, the plurality of readings are further augmented with time, position stamps or other relevant information. In a further embodiment, the controller 30 may be an electronic controller including a microprocessor and an associated memory bank. The processor may be but is not limited to a single-processor or multi-processor system of any of a wide array of possible architectures, including field programmable gate array (FPGA), central processing unit (CPU), application specific integrated circuits (ASIC), digital signal processor (DSP) or graphics processing unit (GPU) hardware arranged homogeneously or heterogeneously. The memory may be but is not limited to a random access memory (RAM), read only memory (ROM), or other electronic, optical, magnetic or any other computer readable medium. The sampling rate adjusts depending on at least one of the perishable goods, the environmental altering event, and the user induced event. Different perishable goods may require different levels of monitoring, which would determine the sampling rate. The sampling rate is how often the sensor 22 transmits a reading to the controller 30. For instance, some perishable goods may be very susceptible to temperature changes and the temperature must be closely monitored and logged in the controller 30, which would thus require a higher sampling rate. In another example, some perishable goods may not be as sensitive and thus only a major change might prompt the sensor 22 to transmit a reading to the controller 30, such as a drastic temperature change in the container 14. At least one of an environmental altering event and a user induced event may also change the sampling rate due to the fact that the perishable good may now have to be more closely monitored to ensure that conditions stabilize in a timely manner. For instance, if a door opens to the refrigerated container 14, the sampling rate may have to be increased to ensure that the temperature of the perishable good quickly returns to the correct temperature.

[0031] In an illustrated embodiment, the at least one environmental sensor 22, further includes a power source 26 providing electrical power to the sensor 22. The power source 26 may be a battery or power generation device including, but not limited to, primary cell batteries, secondary cell batteries, gas powered generators, or solar cells. Since the sensor 22 will have a dedicated power source 26, power conservation is beneficial and thus reducing

the sampling rate to save power is helpful. Further, the sensor 22 may command the sampling rate to adjust. For instance, a selected sampling rate may be preloaded into the sensor 22 and the sensor 22 may, on its own, decide not to send a reading to the controller 30 unless at least one of an environmental altering event and a user induced event has occurred. For instance, if the temperature is remaining stable in the container 14, there would be no reason for the sensor 22 to transmit a reading and waste power. Thus, the sensor 22 may only transmit a reading to the controller if there is a change in an environmental parameter. In alternative embodiments, the controller 30 may determine how often the 22 transmits a reading, by pulling the readings from the sensor 22. Again the sampling rate may be adjusted based on at least one of the perishable good, the environmental altering event, and the user induced event.

[0032] In an illustrated embodiment, the environmental parameter monitoring system 20 may further include a communication module 32 in operative communication with the controller 30 and in wireless operative communication with a remote controller 70 via a network 60. The communication module 32 is configured to transmit at least one data signal associated with the plurality of readings to the remote controller 70. In further embodiments, the wireless communication may be, but is not limited to, radio, microwave, satellite networks, cellular networks, cloud computing network, wide area network, or another wireless communication method. In a further embodiment, the environmental parameter monitoring system 20 may include a short range interface, wherein the short range interface includes at least one of: a wired interface, an optical interface, and a short range wireless interface. In further embodiments, the remote controller 70 may be but is not limited to a dedicated remote controller device, cellular phone, tablet, laptop, smartwatch, a desktop computer or any other similar device.

[0033] In a further embodiment, the controller 30 may allow a secondary data download after the perishable cargo has reached a checkpoint or a destination. Data may be transferred to an external download device. The locally downloaded data may be authenticated, provide additional data for diagnostic purposes or provide data in accordance with receiver/shipper protocols. The controller 30 may transfer data by any suitable local method, including, but not limited to USB, serial transmission, optical transmission, local Wi-Fi, personal area networks, or any other suitable local interface.

[0034] In the illustrated embodiment, the communication module 32 is configured to receive at least one remote command from the remote controller 70 and transmit the at least

one remote command to the controller 30. In further embodiments, the remote controller 70 commands the sampling rate to adjust.

[0035] FIG. 2 shows the architecture of an environmental monitoring system 20 in conjunction with an environmental control system 28. The environmental monitoring system 20 will provide feedback to the environmental control system 28 to help maintain the proper environmental conditions. In an embodiment, the architecture of the environmental monitoring system 20 includes at least one environmental sensor 22, a controller 30, an environmental control system 28, and at least one event detector 24. The event detector 24 may be internal to or separate from the sensor 22. Between the controller 30 and the environmental control system 28, may be a zero-order hold (ZOH) 42 to condition the electrical signal from digital to analog for the environmental control system 28.

[0036] In an embodiment, reference parameters (x_{ref}) are loaded into the sensor 22 depending on the specific type of perishable good. The x_{ref} is the desired reference set-point for the sensor 22. The sensor 22 will monitor environmental parameters ($x(t_k)$) of the perishable goods and may read the reference parameter input (x_{ref}) and sense a change in the environmental parameter ($x(t_k)$) over a period of time. The sensor 22 will communicate the change in the reference parameter (x_{ref}) and environmental parameter ($x(t_k)$) to the event detector 24, which will determine whether at least one of an environmental altering event and a user induced event has occurred. If at least one of an environmental altering event and a user induced event has occurred, the event detector 24 will then transmit a command back to the sensor 22 to send a reading to the controller 30, which will then analyze the reading and transmit a command to the an environmental control system 28, that is conditioned by the ZOH 42. For example, if a trailer door to a refrigerated container 14 is opened or the user changes the reference set-point, the error $\{(x(t_k)) - (x_{ref})\}$ will increase and the event detector 24 will trigger data transmission to the controller 30. The environmental control system 28 will then adjust accordingly.

[0037] The controller 30 and/or the sensor(s) 22 may also increase or decrease the sampling rate of one or more sensors 22 based on the presence or absence of at least one of an environmental altering event and a user induced event. The presence of at least one of an environmental altering event and a user induced event may cause the controller 30 to instruct one or more sensors 22 to increase a sampling rate. For example, if temperature in the compartment 18 is varying rapidly (e.g., pulldown mode) then the sampling rate for sensors 22 may be increased. Alternatively, the absence of at least one of an environmental altering event and a user induced event may cause the controller 30 to instruct one or more sensors 22

to decrease a sampling rate. For example, if temperature in the compartment 18 is stable, then the sampling rate for sensors 22 may be decreased. Alternatively, the sensor 22 may be an electronic controller including a microprocessor and an associated memory bank, which would allow the sensor 22 to increase or decrease the sampling rate, on its own without the help of the controller 30.

[0038] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. While the description has been presented for purposes of illustration and description, it is not intended to be exhaustive or limited to embodiments in the form disclosed. Many modifications, variations, alterations, substitutions or equivalent arrangement not hereto described will be apparent to those of ordinary skill in the art without departing from the scope of the disclosure. Additionally, while the various embodiments have been described, it is to be understood that aspects may include only some of the described embodiments. Accordingly, the disclosure is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

CLAIMS

1. An apparatus for cold chain monitoring of perishable goods, comprising:
 - at least one environmental sensor to monitor at least one environmental parameter;
 - at least one event detector to detect at least one of an environmental altering event and a user induced event; and
 - a controller to receive and log a plurality of readings from the at least one environmental sensor at a selected sampling rate, wherein the sampling rate is selected based on the type of perishable goods;
 - wherein the sampling rate further adjusts depending on at least one of:
 - a) the type of perishable goods;
 - b) the environmental altering event; and
 - c) the user induced event.
2. The apparatus of claim 1, wherein the at least one environmental sensor, further comprises:
 - a power source providing electrical power to the at least one environmental sensor.
3. The apparatus of claim 1 or claim 2, wherein:
 - the at least one environmental sensor commands the sampling rate to adjust.
4. The apparatus of any one of the preceding claims, wherein:
 - the controller commands the sampling rate to adjust.
5. The apparatus of any one of the preceding claims, further comprising:
 - a communication module in operative communication with the controller and wireless operative communication with a remote controller, wherein the communication module is configured to transmit at least one data signal associated with the plurality of readings to the remote controller.
6. The apparatus of claim 5, wherein:
 - the communication module is configured to receive at least one remote command from the remote controller and transmit the at least one remote command to the controller.
7. The apparatus of claim 5 or claim 6, wherein:
 - the remote controller commands the sampling rate to adjust.
8. The apparatus of any one of claims 5-7, wherein:
 - the communication module is a cellular interface to communicate with a cellular network.
9. The apparatus of any one of the preceding claims, wherein:

- the apparatus is associated with a transportation operation.
10. The apparatus of any one of the preceding claims, wherein:
the type of perishable goods includes at least one of food and pharmaceuticals.
 11. A method for cold chain monitoring of perishable goods, comprising:
monitoring, using at least one environmental sensor, at least one environmental parameter;
selecting a sampling rate based on the type of perishable goods;
receiving and logging, using a controller, a plurality of readings from the at least one environmental sensor at the selected sampling rate;
monitoring, using at least one event detector, at least one of an environmental altering event and a user induced event;
and
further adjusting the sampling rate depending on at least one of:
 - a) the type of perishable goods;
 - b) the environmental altering event; and
 - c) the user induced event.
 12. The method of claim 11, further comprising
electrically powering, using a dedicated power source, the at least one environmental sensor.
 13. The method of claim 11 or claim 12, further comprising
commanding the adjustment of the sampling rate via the at least one environmental sensor.
 14. The method of any one of claims 11-13, further comprising
commanding the adjustment of the sampling rate via the controller.
 15. The method of any one of claims 11-14, further comprising:
wirelessly transmitting, using a communication module in operative communication with the controller, at least one data signal associated with the plurality of readings to a remote controller.
 16. The method of claim 15, further comprising:
receiving, using the communication module, at least one remote command from the remote controller; and
transmitting the at least one remote command to the controller.
 17. The method of claim 15 or claim 16, further comprising:

commanding the adjustment of the sampling rate via the remote controller.

18. The method of any of claims 15-17, wherein:
the communication module is a cellular interface to communicate with a cellular network.
19. The method of any one of claims 11-18, further comprising:
transporting the perishable goods.
20. The method of any one of claims 11-19, wherein:
the type of perishable goods includes at least one of food and pharmaceuticals.