MONITORING OF CUSTOMER ACTIVITY IN A RETAIL SPACE USING LAMPS WITH NETWORKED THERMAL IMAGERS

TECHNICAL CONTRIBUTION

The present disclosure relates to monitoring of customer activity in a retail space. More particularly, the present disclosure relates to monitoring customer activity using lamp units integrated with networked thermal imagers.

BACKGROUND

Effective management of the layout of a retail space and the product placement within the retail space is both an art and a science, requiring creativity, psychological insight, testing, and continuous monitoring. Common means for monitoring customer activity include networked sensors and/or video cameras mounted within the retail space. Frequently used sensors include motion sensors and infrared sensors. Use of infrared sensor data in detecting stationary presence of humans is disclosed, for instance, in the European Patent Application Publication No. EP3069076A1 entitled “Human Presence Detection Techniques” published on 21 September 2016. Bluetooth brand beacons configured to interact with customer smart phones can also be used to monitor customer activity.

Video camera footage can be analysed manually by retail store staff or analysed automatically by computer-implemented systems. U.S. Patent Application Publication No. US2016/0253740A1, entitled “System and Methods for Generating and Using a Heat Map of a Retail Location to Reduce Overcrowding” published 01 September 2016, for instance, discloses use of video cameras and/or motion sensors to generate heat maps of customer activity. A grouping of heat spots in the heat map can indicate a high level of customer interest in a specific product or a traffic choke point in the retail space layout. The absence of a heat spot in an area of the retail space can, alternatively, indicate a blockage in the retail space layout or a lack of interest from customers in a group of product items displayed in that area of the retail space. Such feedback is useful in

modifying the retail space layout and/or the product placement strategy. Video footage, however, requires significant image processing and memory during its computer-implemented analysis.

A challenge arises also with the use of video cameras and sensors in regard to their optimal placement within the retail space. Full coverage of a retail space can be prohibitively expensive and/or so obtrusive as to impact customer behavior. Further, video cameras and sensors require a continuous power source for daily function. And a high degree of resolution in the heat map may be needed to distinguish the customer interest between different product item groupings located in adjacent fixtures.

Therefore what is needed in the art is a low price yet accurate system and method for monitoring customer activity within a retail space. Such a system and method would benefit from a proper vantage point from which to view customer activity at high resolution. Such a system and method would benefit also if inobtrusive, so as to not impact behavior of the customers during their perusal of product items in the retail space. Preferably such a system and method would also enable robust heat mapping of customer activity for specific time windows and for specific product items without an excessive demand for data processing and memory during its computer-implemented analysis.

SUMMARY

Most generally, the invention monitors customer activity in a retail space using a plurality of lamp units mounted in the retail space. Each lamp unit includes a lamp housing with a z-axis, a light source mounted within the lamp housing, a board with a microprocessor and a network module configured to connect to a server, and a thermal imager including an infrared sensor grid in electrical connection with the board. The infrared sensor grid of the thermal imager is directed downward along the z-axis of the lamp housing and configured to capture a plurality of thermal images of the customer activity in the retail space, each thermal image comprising a plurality of temperature readings captured by the infrared sensor grid. The server comprises a thermal history database, a map library, and a thermal mapping module. Thermal images are stored in

the thermal history database. The thermal mapping module is configured to create a heat map for each floor plan through an analysis of the thermal records.

A first embodiment of the invention is a system for monitoring customer activity in a retail space, comprising: (a) a plurality of lamp units mounted in the retail space, each lamp unit including a power connecter, a lamp housing with a z-axis and a proximate face, a light source mounted within the lamp housing, a board with a microprocessor and a network module, and a thermal imager including an infrared sensor grid in electrical connection with the board; and (b) a server comprising a thermal history database, a map library, and a thermal mapping module.

A second embodiment of the invention is a computer-implemented method for monitoring customer activity in a retail space, the method comprising the steps of: (a) mounting a plurality of lamp units in the retail space, each lamp unit including a power connecter, a lamp housing with a z-axis and a proximate face, a light source mounted within the lamp housing, a board with a microprocessor and a network module, and a thermal imager including an infrared sensor grid in electrical connection with the board; and (b) providing a server comprising a thermal history database, a map library, and a thermal mapping module.

A third embodiment of the invention is a lamp unit for monitoring customer activity in a retail space. The lamp unit comprises a power connecter, a lamp housing with a z-axis and a proximate face, a light source mounted within the lamp housing, a board with a microprocessor and a network module, and a thermal imager including an infrared sensor grid in electrical connection with the board.

In the first, second, and third embodiment of the invention, the light source is configured to project a light cone downward into the retail space through the proximate face of each lamp housing along the z-axis of the lamp housing. The infrared sensor grid of the thermal imager is directed downward along the z-axis of the lamp housing and configured to capture a plurality of thermal images of the customer activity in the retail space, each thermal image comprising a plurality of temperature readings captured by

the infrared sensor grid. The microprocessor of each board is configured to receive each of the thermal images captured by the thermal imager. Each lamp unit is configured to transmit the thermal images using the microprocessor of each lamp unit. The microprocessor transmits the temperature readings of each thermal image via the network module on the board to a gateway located within the retail space. The transmission of each thermal image is paired with an image timestamp for the thermal image and a lamp identifier of the lamp unit transmitting the thermal image.

In the first and second embodiment of the invention, the server is in data communication with the network and the server is configured to receive the thermal images from each of the network modules of the lamp units. The gateway is in data communication with a network. The server is configured to store each thermal image in a thermal record in the thermal history database, each thermal record including: (1) the temperature readings captured by the infrared sensor grid for the thermal image; (2) the image timestamp of the thermal image; and (3) the lamp identifier of the lamp unit transmitting the thermal image. The map library includes one or more floor plans for the retail space and a lamp record for each lamp unit. Each floor plan includes a coordinate system and a plurality of fixtures located within the floor plan. Each lamp record describes a set of lamp attributes of one lamp unit, the lamp attributes including the lamp identifier of the lamp unit and a lamp location for the lamp unit. Each lamp location for each lamp unit includes a first set of coordinates that locate the lamp unit within the coordinate system of the floor plan. The thermal mapping module is configured to create a heat map for each floor plan through an analysis of the thermal records. Each heat map summarizes customer activity in the retail space over a predetermined time window. The predetermined time window is designated by an administrator of the system via a user interface. The user interface is in data communication with the server.

Embodiments of the invention have the advantage of providing an accurate customer monitoring system or method for retail spaces at a low price. Integration of the thermal imager in the lamp unit provides a robust mounting location along with a dedicated powerline supply. Retail lighting is designed to highlight product items within the retail space and is turned on during customer hours. Hence, the placement of the lamp units is

inherently advantageous for monitoring customer interaction with the product items displayed on fixtures within the retail space. E.g., lamp units are typically mounted on or near the ceiling of a retail space, thus the thermal imagers have an effective vantage point from which to monitor customer interaction with the product items displayed.

Unlike intrusive use of video or other sensors mounted for observing customers, the invention's unobtrusiveness also avoids altering customer behavior. The thermal imagers are small in size and mounted directly above the customers. The Panasonic brand AMG8833 infrared grid sensors are, for instance, about 2.5 centimetres in width and length once mounted on a PCB,. Even if the customer were to actively search for the thermal imagers, the blinding light of the accompanying light cone from the light source effectively hides them from sight.

The infrared sensor grid used by the invention also has the technical benefit of supplying simple, organized numerical data (e.g., a matrix of temperature readings) for analysis by the thermal mapping module of the server. Unlike a review of video footage, which requires extensive memory and image processing, the infrared sensor grid data of the invention is easily adapted to statistical analysis algorithms of matrix data, such as a moving average convergence divergence (MACD) analysis.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure are described herein with reference to the drawings in which:

FIG. 1 is a block diagram illustrating a lamp unit integrated with a networked thermal imager in an embodiment of the invention.

FIG. 2 is a block diagram illustrating a system for monitoring customer activity in a retail space in an embodiment of the invention.

FIG. 3A is an illustration of a floor plan of a retail space overlaid with the placement of lamp units in an embodiment of the invention.

FIG. 3B is an illustration of floor plan of the retail space further including fixtures and overlaid with heat spot groupings in an embodiment of the invention.

FIG. 4 is a flowchart of a method for monitoring customer activity in a retail space using mounted lamp units integrated with networked thermal imagers in an embodiment of the invention.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. The illustrative embodiments described in the detailed description, drawings and claims are not meant to be limiting. Other embodiments can be utilized, and other changes can be made, without departing from the spirit or scope of the subject matter presented herein. Unless specified otherwise, the terms "comprising," "comprise," "including" and "include" used herein, and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, un-recited elements.

As used herein, the software and hardware of a "server" may be implemented within: a single stand-alone computer, a stand-alone server, multiple dedicated servers, and/or a virtual server running on a larger network of servers and/or a cloud-based service. As used herein, a database may store data to and access data from a single stand-alone computer, a data server, multiple dedicated data servers, a cloud-based service, and/or a virtual server running on a network of servers.

As used herein, a user interface may be implemented by a monitor with a display window, a keyboard, a mouse, a touch screen, a touch pad, and/or similarly directed means. The user interface may be configured by a laptop, a smart phone, a tablet, a single

stand-alone computer, a stand-alone server, multiple dedicated servers, and/or a virtual server running on a larger network of servers and/or a cloud-based service.

As used herein, a database may store data to and access data from a single stand-alone computer, a laptop, a tablet, a data server, multiple dedicated data servers, a cloud-based service, and/or a virtual server running on a network of servers. As discussed in the description, the use of the term "database" indicate a collection of tables, records, and/or linkage information for the data records. As depicted in the description and figures, each database can be maintained separately and/or maintained collectively in a single database or through linkages to other database. The databases depicted in the description and figures can be on the same server or on separate servers. Data records can be stored in one database or linked between separate databases.

FIG. 1 is a block diagram illustrating a lamp unit **1-00** integrated with a networked thermal imager **15A** in an embodiment of the invention. The lamp unit **1-00** includes a power connecter **11**, an LED driver **12**, an LED array **16A** mounted within a lamp reflector **16**, a board driver **13**, a board **14** with a microprocessor **14B** and a network module **14A**, and a thermal imager **15A** in electrical connection with the board **14**. The lamp housing **10** has a z-axis and a proximate face **16C**. The LED array **16A** is configured to project a light cone **16B** downward into a retail space through the proximate face **16C** of the lamp housing **10** along the z-axis of the lamp housing **10**.

In **FIG. 1**, the thermal imager **15A** is housed within an external casing **15** mounted on an outer surface of the lamp housing **10**. The thermal imager **15A** is also directed downward along the z-axis of the lamp housing **10** into the retail space. The thermal imager **15A** is configured to capture a plurality of thermal images **15B** comprising a plurality of temperature readings captured by the infrared sensor grid (illustrated in shades of gray in the thermal image **15B**) and transmit the temperature readings to the board **14**. The thermal imager **15A** receives its power from the board driver **13** indirectly through its connection with the board **14.** While illustrated as shades of gray, the infrared sensor grid provides a matrix of numerical temperature readings. This matrix can be

easily adapted to statistical analysis algorithms of matrix data, such as a moving average convergence divergence (MACD) analysis.

Note that the lamp housing **10** form factor in **FIG. 1** is not necessarily drawn to scale for some applications of the invention. Lamp units **1-00** with LED arrays **16A** composed of thin solid state surface mounted devices, for instance, could be much shorter in height (e.g., with the height measured along the z-axis height as illustrated in **FIG. 1**) in comparison to their width (e.g., with the width measured along the x-axis width as illustrated in **FIG. 1**). Lamp units **1-00** with compact fluorescent bulbs, on the other hand, could require a greater height dimension depending on the chosen form factor of the compact fluorescent bulb. An LED array **16A** can also be replaced with a single Chip-on-Board ("COB") device or other LED light source device.

Note also that, for high volume product sales using the invention, the board **14** could include the LED driver **12**, the board driver **13**, the microprocessor **14B**, and the network module **14A**. The board **14** could even include the LED array **16A** and/or the infrared grid sensor. The LED driver **12** and board driver **13** could also be implemented on a single integrated power chip. E.g., the various components of the invention can be possibly integrated together (or some intentionally not integrated together) based on manufacturing costs, quality control factors, and form factors for the lamp units **1-00**.

FIG. 2 is a block diagram illustrating a system **2-00** for monitoring customer activity **C0,C1,C2** in a retail space **20** in an embodiment of the invention. The retail space **20** includes a plurality of lamp units **1-00**, a gateway **21**, and product items displayed on a first sample fixture **FN**. The lamp units **1-00** each include a power connector **11**, a board driver **13**, a microprocessor **14B**, a network module **14A**, and a thermal imager. The thermal imager **15A** is directed downward along the z-axis of the lamp housing **10** with line-of-sight to the customers.

In **FIG. 2**, the gateway **21** is in data communication with a network **22**. The network **22** is in data communication with a user interface **24** and a server **23**. The server **23** includes a map library **23B**, a thermal history database **23A**, and a thermal mapping module **23C**.

FIG. 3A is a first illustration **3-01** of a floor plan of a retail space **20** overlaid with the placement of sample lamp units **L0-L7** in an embodiment of the invention. The floor plan has an x-y coordinate system indicating the x-y coordinates (**x_0, y_0 to x_7, y_7**) of the sample lamp units (**L0-L7**, respectively).

FIG. 3B is a second illustration **3-02** of the floor plan of the retail space **20** further including second sample fixtures **F0-F6** and overlaid with sample heat spot groupings **HS0-HS4** in an embodiment of the invention. Each heat spot grouping is represented by shades of gray, with darker shading indicating (according to the proxy measurement of customer heat by the thermal imagers **15A**) frequency and/or duration of customer presence in each specific location of the retail space **20**. Customer interest in product items (not illustrated in **FIG. 3B**) displayed on the second sample fixtures **F0-F6** can be correlated to the shading and/or width of the heat maps. While not illustrated in **FIG. 3B**, gradations of the heat spot groupings can also be displayed on a user interface **24** (or paper printout) in full colour.

FIG. 4 is a flowchart **4-00** of a method for monitoring customer activity **C0,C1,C2** in a retail space **20** using mounted lamp units **1-00** integrated with networked thermal imagers **15A** in an embodiment of the invention. Steps **4-01** to **4-06** are listed below.

- **4-01** mount a plurality of lamp units **1-00** in the retail space **20**, each lamp unit **1-00** including a power connecter, a lamp housing **10** with a z-axis and a proximate face **16C**, a light source mounted within the lamp housing **10**, a board **14** with a microprocessor **14B** and a network module **14A**, and a thermal imager **15A** including an infrared sensor grid in electrical connection with the board **14**
- **4-02** receive each of the thermal images **15B** captured by the thermal imager **15A**
- **4-03** transmit to a server **23** the thermal images **15B**, pairing each thermal image **15B** with an image timestamp for the thermal image **15B** and a lamp identifier of the lamp unit **1-00** transmitting the thermal image **15B**
- **4-04** store each thermal image **15B** in a thermal record in a thermal history database **23A**

4-05 create a heat map for each floor plan through an analysis of the thermal records for a predetermined time window

4-06 cross reference the heat maps to product items in the retail space **20**

Most generally, the invention monitors customer activity **C0,C1,C2** in a retail space **20** using a plurality of lamp units **1-00** mounted in the retail space **20**. Each lamp unit **1-00** includes a lamp housing **10** with a z-axis, a light source mounted within the lamp housing **10**, a board **14** with a microprocessor **14B** and a network module **14A** configured to connect to a server **23**, and a thermal imager **15A** including an infrared sensor grid in electrical connection with the board **14**. The infrared sensor grid of the thermal imager **15A** is directed downward along the z-axis of the lamp housing **10** and configured to capture a plurality of thermal images **15B** of the customer activity **C0,C1,C2** in the retail space **20**, each thermal image **15B** comprising a plurality of temperature readings captured by the infrared sensor grid. The server **23** comprises a thermal history database **23A**, a map library **23B**, and a thermal mapping module **23C**. Thermal images **15B** are stored in the thermal history database **23A**. The thermal mapping module **23C** is configured to create a heat map for each floor plan through an analysis of the thermal records.

A first embodiment of the invention is a system **2-00** for monitoring customer activity **C0,C1,C2** in a retail space **20**, comprising: (a) a plurality of lamp units **1-00** mounted in the retail space **20**, each lamp unit **1-00** including a power connecter **11**, a lamp housing **10** with a z-axis and a proximate face **16C**, a light source mounted within the lamp housing **10**, a board **14** with a microprocessor **14B** and a network module **14A**, and a thermal imager **15A** including an infrared sensor grid in electrical connection with the board **14**; and (b) a server **23** comprising a thermal history database **23A**, a map library **23B**, and a thermal mapping module **23C**.

A second embodiment of the invention is a computer-implemented method for monitoring customer activity **C0,C1,C2** in a retail space **20**, the method comprising the steps of: (a) mounting a plurality of lamp units **1-00** in the retail space **20**, each lamp unit **1-00** including a power connecter, a lamp housing **10** with a z-axis and a proximate

face **16C**, a light source mounted within the lamp housing **10**, a board **14** with a microprocessor **14B** and a network module **14A**, and a thermal imager **15A** including an infrared sensor grid in electrical connection with the board **14**; and (b) providing a server **23** comprising a thermal history database **23A**, a map library **23B**, and a thermal mapping module **23C**.

A third embodiment of the invention is a lamp unit **1-00** for monitoring customer activity **C0,C1,C2** in a retail space **20**. The lamp unit **1-00** comprises a power connecter **11**, a lamp housing **10** with a z-axis and a proximate face **16C**, a light source mounted within the lamp housing **10**, a board **14** with a microprocessor **14B** and a network module **14A**, and a thermal imager **15A** including an infrared sensor grid in electrical connection with the board **14**.

In the first, second, and third embodiment of the invention, the light source is configured to project a light cone **16B** downward into the retail space **20** through the proximate face **16C** of each lamp housing **10** along the z-axis of the lamp housing **10**. The infrared sensor grid of the thermal imager **15A** is directed downward along the z-axis of the lamp housing **10** and configured to capture a plurality of thermal images **15B** of the customer activity **C0,C1,C2** in the retail space **20**, each thermal image **15B** comprising a plurality of temperature readings captured by the infrared sensor grid. The microprocessor **14B** of each board **14** is configured to receive each of the thermal images **15B** captured by the thermal imager **15A**. Each lamp unit **1-00** is configured to transmit the thermal images **15B** using the microprocessor **14B** of each lamp unit **1-00**. The microprocessor **14B** transmits the temperature readings of each thermal image **15B** via the network module **14A** on the board **14** to a gateway **21** located within the retail space **20**. The transmission of each thermal image **15B** is paired with an image timestamp for the thermal image **15B** and a lamp identifier of the lamp unit **1-00** transmitting the thermal image **15B**.

In the first and second embodiments of the invention, the server **23** is in data communication with the network **22** and the server **23** is configured to receive the thermal images **15B** from each of the network modules **14A** of the lamp units **1-00**. The gateway

21 is in data communication with a network **22**. The server **23** is configured to store each thermal image **15B** in a thermal record in the thermal history database **23A**, each thermal record including: (1) the temperature readings captured by the infrared sensor grid for the thermal image **15B**; (2) the image timestamp of the thermal image **15B**; and (3) the lamp identifier of the lamp unit **1-00** transmitting the thermal image **15B**. The map library **23B** includes one or more floor plans for the retail space **20** and a lamp record for each lamp unit **1-00**. Each floor plan includes a coordinate system and a plurality of fixtures located within the floor plan. Each lamp record describes a set of lamp attributes of one lamp unit **1-00**, the lamp attributes including the lamp identifier of the lamp unit **1-00** and a lamp location for the lamp unit **1-00**. Each lamp location for each lamp unit **1-00** includes a first set of coordinates that locate the lamp unit **1-00** within the coordinate system of the floor plan. The thermal mapping module **23C** is configured to create a heat map for each floor plan through an analysis of the thermal records. The heat map summarizes the monitored customer activity **C0,C1,C2** in the floor plan over a predetermined time window. The predetermined time window is designated by an administrator via a user interface **24**. The user interface **24** is in data communication with the server **23**.

The analysis of the thermal records can include a moving average convergence divergence (MACD) analysis.

The lamp identifier can be a serial code of the thermal imager **15A**, infrared sensor grid, or network module **14A**. The lamp identifier can also be the MAC address of the network module **14A** or a programmable address.

In an alternative embodiment of the invention: (a) the map library **23B** further includes a plurality of product records; and (b) each product record includes a product identifier and a product location associated with at least one of: (i) a second set of coordinates within the coordinate system of one of the floor plans; and (ii) one of the fixtures located in one of the floor plans.

In an alternative embodiment of the invention, the fixtures in the floor plans include at least one of: (a) a plurality of exterior walls; (b) a plurality of display racks; and (c) a plurality of furniture items.

In an alternative embodiment of the invention: (a) each infrared sensor grid is an 8x8 grid of **64** temperature sensors; and (b) each thermal image **15B** comprises a table of **64** temperature measurements. An example off-the-shelf component for such an application of the invention is the Panasonic brand AMG8833 IR thermal camera. This thermal camera includes an 8x8 infrared sensor grid and provides an array of temperatures measurement readings every second in a table of **64** entries.

Example source code for a pixel text to achieve a right scale factor of heat sensor data relative to the floor area of a retail space **20** is as follows:

```
#include <Wire.h>
#include <Adafruit_AMG88xx.h>

Adafruit_AMG88xx amg;

float pixels[AMG88xx_PIXEL_ARRAY_SIZE];

void setup() {
  Serial.begin(9600);
  Serial.println(F("AMG88xx pixels"));

  bool status;

  // default settings
  status = amg.begin();
  if (!status) {
    Serial.println("Could not find a valid AMG88xx sensor, check wiring!");
    while (1);
```

```
    }

    Serial.println("-- Pixels Test --");

    Serial.println();

    delay(100); // let sensor boot up
}

void loop() {
    //read all the pixels
    amg.readPixels(pixels);

    Serial.print("[");
    for(int i=1; i<=AMG88xx_PIXEL_ARRAY_SIZE; i++){
      Serial.print(pixels[i-1]);
      Serial.print(", ");
      if( i%8 == 0 ) Serial.println();
    }
    Serial.println("]");
    Serial.println();

    //delay a second
    delay(1000);
}
```

In an alternative embodiment of the invention, the network module **14A** is a wireless transmitter in data communication with the gateway **21**. An example board **14** with an integrated microprocessor **14B** and wireless transmitter is the Arduino brand ESDUINO32 board.

The thermal history database **23A** can be implemented on the Amazon branded web service. Such a web services can be used to store the thermal records from multiple retail spaces **20**. Such a web service enables economies of scale for a Software as a Service business-to-business platform supporting multiple retail customers. Retail customers of the SaaS could, for instance, install preconfigured lamp units **1-00** at their location and then access heat maps analysis from a laptop as a user interface **24** to the server **23**.

Example source code for enabling the Arduino brand ESDUINO**32** board to dump data on the Amazon branded web services is as follows:

```
#include <WiFi.h>
#include <HTTPClient.h>
#include <Wire.h>
#include <Adafruit_AMG88xx.h>

Adafruit_AMG88xx amg;
float pixels[AMG88xx_PIXEL_ARRAY_SIZE];
const char* ssid = "iaspl";
const char* password = "penshirt59";
String postData = "";
HTTPClient http;

void setup() {
  // change serial connection if needed 115200
  Serial.begin(115200);
  WiFi.mode(WIFI_STA);
  //WiFi.disconnect();
  delay(100);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED)
  {
   delay(500);
```

```
    Serial.println("..");
    Serial.println(WiFi.status());
  }
  Serial.println("WiFi connected");

  bool status;
  // default settings
  status = amg.begin();
  if (!status) {
    Serial.println("Could not find a valid AMG88xx sensor, check wiring!");
    while (1);
  }
  delay(100); // let sensor boot up
}

void loop() {
  if(WiFi.status()== WL_CONNECTED)
  {
    Serial.println("Getting AMG Pixels  --");
    //read all the pixels
    amg.readPixels(pixels);
    postData= "action=savesensor&mac="+WiFi.macAddress()+"&data=";

    for(int i=0; i<AMG88xx_PIXEL_ARRAY_SIZE; i++)
    {
      postData += String(pixels[i])+",";
    }
    http.begin("http://54.255.33.252/service.php");  //Specify request destination
    http.addHeader("Content-Type", "application/x-www-form-urlencoded");
    http.addHeader("Content-Length", ""+postData.length());
    int httpCode = http.POST(postData);
    Serial.println("HTTP Response  --");
```

```
  Serial.println(httpCode);
  String payload = http.getString();
  Serial.println(payload);
  http.end();  //Close connection
 }
else
{
  Serial.println("WiFi not connected.");
}
//get data once in 15 seconds
delay(15000);
```

In an alternative embodiment of the invention: (a) each lamp unit **1-00** is in electrical connection with a powerline through the power connector **11**; and (b) each network module **14A** is a powerline network adapter in data communication with the gateway **21** through the powerline. In such a design, the thermal images **15B** data is transmitted through the powerline from each lamp unit **1-00** to a powerline network receiver which routes data packets received through the powerline to the server **23** through the gateway **21**.

In an alternative embodiment of the invention, the thermal imager **15A** is housed within an external casing **15** mounted to an outer surface of the lamp housing **10**. The external casing **15** mounting can be assisted also with an "L" shaped pin connector. The external casing **15** has an advantage of not interfering with the original design of a lamp unit **1-00**, as additional real estate is obtained outside the lamp housing **10**. Also any impact of heat from the light source on the infrared temperature readings of the thermal imager **15A** is minimized.

In an alternative embodiment of the invention: (a) the light source includes an LED array **16A** and a lamp reflector **16**; (b) the LED array **16A** is in electrical connection with an LED driver **12** and the LED driver **12** is in electrical connection with the power connector

11; and (c) wherein the thermal imager **15A** is housed within an internal casing mounted between an inner surface of the lamp housing **10** and the lamp reflector **16**.

Infrared sensor grids often have a modest operating temperature range in comparison with other solid state electronic devices. The Panasonic brand AMG8833, for instance, has an operating temperature range of 0 to 80 degrees Celsius. Given this relatively low operating temperature range, an LED array **16A** is the most preferable lighting source for the invention due to its low surface temperature (typically in the range of 20 to 35 degrees Celsius). Also preferable as a lighting source is a compact fluorescent bulb, which has a surface temperature in the general range of 30 to 50 degrees Celsius during operation. Incandescent and halogen bulbs are not preferred, as they have surface temperatures exceeding 150 degrees Celsius during operation, which could impact performance of an infrared sensor grid or require significant insulation of the infrared sensor grid within the lamp unit **1-00** design.

In an alternative embodiment of the invention: (a) the power connector **11** is in electrical connection with a powerline; and (b) the powerline is a direct current source.

In an alternative embodiment of the invention: (a) the power connector **11** is in electrical connection with a powerline; (b) the powerline is an alternating current source; and (c) the power connector **11** is in electrical connection with: (i) an LED driver **12**, the LED in electrical connection with an LED array **16A**; and (ii) a board driver **13**, the board driver **13** in electrical connection with the board **14**.

While various aspects and embodiments have been disclosed herein, it will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit of the invention being indicated by the appended claims.

CLAIMS

1. A system for monitoring customer activity in a retail space, comprising:

(a) a plurality of lamp units mounted in the retail space, each lamp unit including a power connecter, a lamp housing with a z-axis and a proximate face, a light source mounted within the lamp housing, a board with a microprocessor and a network module, and a thermal imager including an infrared sensor grid in electrical connection with the board;

(i) wherein the light source is configured to project a light cone downward into the retail space through the proximate face of each lamp housing along the z-axis of the lamp housing;

(ii) wherein the infrared sensor grid of the thermal imager is directed downward along the z-axis of the lamp housing and configured to capture a plurality of thermal images of the customer activity in the retail space, each thermal image comprising a plurality of temperature readings captured by the infrared sensor grid;

(iii) wherein the microprocessor of each board is configured to receive each of the thermal images captured by the thermal imager; and

(iv) wherein each lamp unit is configured to transmit the thermal images using the microprocessor of each lamp unit,

(1) wherein the microprocessor transmits the temperature readings of each thermal image via the network module on the board to a gateway located within the retail space;

(2) wherein the transmission of each thermal image is paired with an image timestamp for the thermal image and a lamp identifier of the lamp unit transmitting the thermal image; and

(3) wherein the gateway is in data communication with a network; and

(b) a server comprising a thermal history database, a map library, and a thermal mapping module,

(i) wherein the server is in data communication with the network and the server is configured to receive the thermal images from each of the network modules of the lamp units;

(ii) wherein the server is configured to store each thermal image in a thermal record in the thermal history database, each thermal record including:

(1) the temperature readings captured by the infrared sensor grid for the thermal image;

(2) the image timestamp of the thermal image; and

(3) the lamp identifier of the lamp unit transmitting the thermal image;

(iii) wherein the map library includes one or more floor plans for the retail space and a lamp record for each lamp unit,

(1) wherein each floor plan includes a coordinate system and a plurality of fixtures located within the floor plan;

(2) wherein each lamp record describes a set of lamp attributes of one lamp unit, the lamp attributes including the lamp identifier of the lamp unit and a lamp location for the lamp unit; and

(3) wherein each lamp location for each lamp unit includes a first set of coordinates that locate the lamp unit within the coordinate system of the floor plan; and

(iv) wherein the thermal mapping module is configured to create a heat map for each floor plan through an analysis of the thermal records,

(1) wherein the heat map summarizes the customer activity in the floor plan over a predetermined time window;

(2) wherein the predetermined time window is designated by an administrator via a user interface; and

(3) wherein the user interface in data communication with the server.

2. The system of claim 1,

(a) wherein the map library further includes a plurality of product records; and

(b) wherein each product record includes a product identifier and a product location associated with at least one of:

(i) a second set of coordinates within the coordinate system of one of the floor plans; and

(ii) one of the fixtures located in one of the floor plans.

3. The system of claim 1, wherein the fixtures in the floor plans include at least one of:

(a) a plurality of exterior walls;

(b) a plurality of display racks; and

(c) a plurality of furniture items.

4. The system of claim 1,

(a) wherein each infrared sensor grid is an 8x8 grid of 64 temperature sensors; and

(b) wherein each thermal image comprises a table of 64 temperature measurements.

5. The system of claim 1, wherein the network module is a wireless transmitter in data communication with the gateway.

6. The system of claim 1,

(a) wherein each lamp unit is in electrical connection with a powerline through the power connector; and

(b) wherein each network module is a powerline network adapter in data communication with the gateway through the powerline.

7. The system of claim 1, wherein the thermal imager is housed within an external casing mounted to an outer surface of the lamp housing.

8. The system of claim 1,

(a) wherein the light source includes an LED array and a lamp reflector;

(b) wherein the LED array is in electrical connection with an LED driver and the LED driver is in electrical connection with the power connector; and

(c) wherein the thermal imager is housed within an internal casing mounted between an inner surface of the lamp housing and the lamp reflector.

9. The system of claim 1,

(a) wherein the power connector is in electrical connection with a powerline; and

(b) wherein the powerline is a direct current source.

10. The system of claim 1,

(a) wherein the power connector is in electrical connection with a powerline;

(b) wherein the powerline is an alternating current source; and

(c) wherein the power connector is in electrical connection with:

(i) an LED driver, the LED in electrical connection with an LED array; and

(ii) a board driver, the board driver in electrical connection with the board.

11. A computer-implemented method for monitoring customer activity in a retail space, the method comprising the steps of:

(a) mounting a plurality of lamp units in the retail space, each lamp unit including a power connecter, a lamp housing with a z-axis and a proximate face, a light source mounted within the lamp housing, a board with a microprocessor and a network module, and a thermal imager including an infrared sensor grid in electrical connection with the board;

(i) wherein the light source is configured to project a light cone downward into the retail space through the proximate face of each lamp housing along the z-axis of the lamp housing;

(ii) wherein the infrared sensor grid of the thermal imager is directed downward along the z-axis of the lamp housing and configured to capture a plurality of thermal images of the customer activity in the retail space, each thermal image comprising a plurality of temperature readings captured by the infrared sensor grid;

(iii) wherein the microprocessor of each board is configured to receive each of the thermal images captured by the thermal imager; and

(iv) wherein each lamp unit is configured to transmit the thermal images using the microprocessor of each lamp unit,

(1) wherein the microprocessor transmits the temperature readings of each thermal image via the network module on the board to a gateway located within the retail space;

(2) wherein the transmission of each thermal image is paired with an image timestamp for the thermal image and a lamp identifier of the lamp unit transmitting the thermal image; and

(3) wherein the gateway is in data communication with a network; and

(b) providing a server comprising a thermal history database, a map library, and a thermal mapping module,

(i) wherein the server is in data communication with the network and the server is configured to receive the thermal images from each of the network modules of the lamp units;

(ii) wherein the server is configured to store each thermal image in a thermal record in the thermal history database, each thermal record including:

(1) the temperature readings captured by the infrared sensor grid for the thermal image;

(2) the image timestamp of the thermal image; and

(3) the lamp identifier of the lamp unit transmitting the thermal image;

(iii) wherein the map library includes one or more floor plans for the retail space and a lamp record for each lamp unit,

(1) wherein each floor plan includes a coordinate system and a plurality of fixtures located within the floor plan;

(2) wherein each lamp record describes a set of lamp attributes of one lamp unit, the lamp attributes including the lamp identifier of the lamp unit and a lamp location for the lamp unit; and

(3) wherein each lamp location for each lamp unit includes a first set of coordinates that locate the lamp unit within the coordinate system of the floor plan; and

(iv) wherein the thermal mapping module is configured to create a heat map for each of the one or more floor plans through an analysis of the thermal records,

(1) wherein the heat map summarizes the customer activity in the floor plan over a predetermined time window;

(2) wherein the predetermined time window is designated by an administrator via a user interface; and

(3) wherein the user interface in data communication with the server.

12. The method of claim 11,

(a) wherein the map library further includes a plurality of product records; and

(b) wherein each product record includes a product identifier and a product location associated with at least one of:

(i) a second set of coordinates within the coordinate system of one of the floor plans; and

(ii) one of the fixtures located in one of the floor plans.

13. The method of claim 11, wherein the fixtures in the floor plans include at least one of:

(a) a plurality of exterior walls;

(b) a plurality of display racks; and

(c) a plurality of furniture items.

14. The method of claim 11,

(a) wherein each infrared sensor grid is an 8x8 grid of 64 temperature sensors; and

(b) wherein each thermal image comprises a table of 64 temperature measurements.

15. The method of claim 11, wherein the network module is a wireless transmitter in data communication with the gateway.

16. The method of claim 11,

(a) wherein each lamp unit is in electrical connection with a powerline through the power connector; and

(b) wherein each network module is a powerline network adapter in data communication with the gateway through the powerline.

17. The method of claim 11, wherein the thermal imager is housed within an external casing mounted to an outer surface of the lamp housing.

18. The method of claim 11,

(a) wherein the light source includes an LED array and a lamp reflector;

(b) wherein the LED array is in electrical connection with an LED driver and the LED driver is in electrical connection with the power connector; and

(c) wherein the thermal imager is housed within an internal casing mounted between an inner surface of the lamp housing and the lamp reflector.

19. The method of claim 11,

(a) wherein the power connector is in electrical connection with a powerline; and

(b) wherein the powerline is a direct current source.

20. The method of claim 11,

(a) wherein the power connector is in electrical connection with a powerline;

(b) wherein the powerline is an alternating current source; and

(c) wherein the power connector is in electrical connection with:

(i) an LED driver, the LED in electrical connection with an LED array; and

(ii) a board driver, the board driver in electrical connection with the board.

21. A lamp unit for monitoring customer activity in a retail space, comprising a power connecter, a lamp housing with a z-axis and a proximate face, a light source mounted within the lamp housing, a board with a microprocessor and a network module, and a thermal imager including an infrared sensor grid in electrical connection with the board,

(a) wherein the light source is configured to project a light cone downward into the retail space through the proximate face of the lamp housing along the z-axis of the lamp housing;

(b) wherein the infrared sensor grid of the thermal imager is directed downward along the z-axis of the lamp housing and configured to capture a plurality of thermal images of the customer activity in the retail space, each thermal image comprising a plurality of temperature readings captured by the infrared sensor grid;

(c) wherein the microprocessor of the board is configured to receive each of the thermal images captured by the thermal imager; and

(d) wherein the lamp unit is configured to transmit the thermal images using the microprocessor of the lamp unit,

(i) wherein the microprocessor is configured to transmit the temperature readings of each thermal image via the network module on the board to a server through a gateway located within the retail space; and

(ii) wherein the transmission of each thermal image is paired with an image timestamp for the thermal image and a lamp identifier of the lamp unit transmitting the thermal image.

22. The lamp unit of claim 21,

(a) wherein the infrared sensor grid is an 8x8 grid of 64 temperature sensors; and

(b) wherein the thermal image comprises a table of 64 temperature measurements.

23. The lamp unit of claim 21, wherein the network module is a wireless transmitter configured for data communication with the gateway.

24. The lamp unit of claim 21,

(a) wherein the lamp unit is in electrical connection with a powerline through the power connector; and

(b) wherein the network module is a powerline network adapter configured for data communication with the gateway through the powerline.

25. The lamp unit of claim 21, wherein the thermal imager is housed within an external casing mounted to an outer surface of the lamp housing.

26. The lamp unit of claim 21,

(a) wherein the light source includes an LED array and a lamp reflector;

(b) wherein the LED array is in electrical connection with an LED driver and the LED driver is in electrical connection with the power connector; and

(c) wherein the thermal imager is housed within an internal casing mounted between an inner surface of the lamp housing and the lamp reflector.

27. The lamp unit of claim 21,

(a) wherein the power connector is in electrical connection with a powerline; and

(b) wherein the powerline is a direct current source.