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FLIR Systems

THERMAL IMAGING

The invention relates to methods and apparatus for automated thermal imaging, and in particular to ground-based thermal imaging for assessment of the thermal insulative properties of buildings.

Thermal imaging is a known non-contact technique for rapidly assessing the external temperature of an object. Cameras capable of taking images in the infrared region are widely available, and are typically capable of providing an output in the form of a digital signal.

It is known to provide aerial thermal imaging maps, for example to provide an overview of heat emitted over a broad area such as over a built-up area or to identify locations of raised temperature. Individual areas, objects, people or buildings can be readily identified using various techniques involving the use of aerial thermal imaging. For mapping purposes, a thermal image can be overlaid against a known map to identify and locate relevant locations or buildings for further investigation.

It is also known to thermally image buildings from ground level, for example to assess their insulative properties and for other purposes such as to determine water leaks or electrical faults.

A problem with existing solutions, however, is that aerial imaging is expensive, and may not be possible in certain locations or during certain times. Such imaging by its nature also only provides a broad view of an area, and cannot typically provide information regarding side walls of buildings, only roofs.

A further problem is that, although thermal imaging of individual buildings can be quick, assessment of many buildings is time consuming and the quality of the results can be dependent on the operator.

It is accordingly an object of the invention to overcome the aforementioned problems with previous solutions in determining insulative properties of buildings.

In accordance with a first aspect of the invention, there is provided a computerised method for automatically determining thermal insulation properties of a plurality of buildings, the method comprising, for each building:

acquiring a location from a position sensing unit;

determining the location of the position sensing unit in relation to the building;

acquiring a thermal image of an exterior view of the building;

processing the image to identify an area of the building; and

providing an output file comprising the location of the building and indications of the insulation properties of the area of the building,

wherein the steps of acquiring the thermal image and processing the image are automatically triggered for each of the plurality of buildings by the step of determining the location of the position sensing unit in relation to the building.

The invention according to the first aspect may include one or more of the following advantageous features.

The output file may comprise the processed image and address information derived from the acquired location, thus enabling a ready assessment of the building's insulation to be made.

The method is repeated for the plurality of buildings, and an output file provided for each building. The method thereby enables a large number of buildings to be automatically assessed in quick succession.

In accordance with a second aspect of the invention, there is provided a vehicle comprising an apparatus for automatically determining thermal insulation properties of a plurality of buildings, the apparatus comprising:

a position sensing unit for acquiring a location of the vehicle;

a thermal imaging camera for acquiring a thermal image of an exterior of the each building;

a computer connected to the position sensing unit and thermal imaging camera, the computer being configured to:

i) acquire a location of the vehicle from the position sensing unit;

ii) determine the location of the vehicle in relation to each of the plurality of buildings;

iii) acquire a thermal image of an exterior view of each building from the camera;

iv) process the image to identify one or more areas of each building; and

iii) provide an output file comprising indications of the insulation properties of the one or more areas of each building,

wherein the computer is configured to automatically acquire and process thermal images of each of the plurality of buildings while the vehicle is in motion using location information provided by the position sensing unit, the steps of acquiring the thermal image and processing the image being automatically triggered for each of the plurality of buildings by location information provided by the position sensing unit.

The invention according to the second aspect may include one or more of the following advantageous features.

The computer may be configured to provide an output file comprising one of more indications of an area of the building deficient in insulative properties.

The vehicle (e.g. a van) may be equipped with one or more thermal imaging cameras. The vehicle may comprise a left-facing and a right-facing thermal imaging camera, each camera being connected to the computer (or to respective computers) for providing thermal images of buildings on the left and right sides of the vehicle.

The invention will now be described by way of example, and with reference to the enclosed drawings in which:

figure 1 shows a schematic diagram of a computerised apparatus configured to acquire and process thermal images of buildings;

figure 2 shows a schematic plan view of a vehicle comprising the apparatus of figure 1 in position adjacent a building;

figure 3 shows a flow diagram of a method according to an aspect of the invention;

figure 4 shows an exemplary output file;

figure 5 shows a further exemplary output file showing a roof area identified as being deficient in insulation; and

figure 6 shows a further exemplary output file showing a roof area and wall area identified as being deficient in insulation.

Figure 1 illustrates schematically an apparatus 100 for implementing the invention. A computer 110 is connected to a thermal imaging camera 120, a positioning unit or location sensor 130 and a temperature sensor 140. The computer 110 may, for example, be a laptop (or notebook) type computer, or any other type suitable for mobile applications. A compact PXI-type computer is envisaged to be particularly suitable due to the ability to readily interface with other instrumentation and equipment.

The location sensor 130 preferably utilises GPS (Global Positioning System) to determine its location, although other means for determining location may alternatively be used, such as triangulation of ground-based radio signals or other satellite-based positioning systems, for example the forthcoming European Galileo satellite system, which is predicted to offer increased accuracy over the existing GPS, at least for non-military applications.

The thermal imaging camera 120 should be at least capable of accurately measuring temperature over a range of expected external ambient temperatures, such as within the range of -10 to +40°C, and is preferably able to detect temperature variations of around 1°C or less. The camera determines the temperature by recording wavelengths within a portion of the infrared part of the electromagnetic spectrum, e.g. within the range of 5 to 15 μm. An example of a suitable camera is the A40 type compact infrared camera available from FLIR Systems, which is capable of detecting infrared radiation over the range 7.5 to 13 μm.

The temperature sensor 140 may be a thermocouple or thermistor, which is connected to the computer for example by means of a sensing unit configured to provide a temperature reading to the computer 110.

The computer 110 is configured to communicate bi-directionally with the thermal imaging camera 120 and the location sensor 130, so as to issue controls and receive signals from each unit. Communication may be made by means of IEEE-1394, Ethernet or other types of wired or wireless links. Each thermal image from the camera 120 may be shown on a screen 111 of the computer 110 as it is acquired, or as part of a post-acquisition routine to review acquired images. Alternatively, the images are stored on a data storage medium on, or connected to, the computer 110 for future use.

In a preferred embodiment of the invention, the apparatus 100 is installed in a vehicle 200, as shown schematically in plan view in figure 2. The thermal imaging camera 120, which may be mounted external to the vehicle or within the vehicle behind a transparent window, is directed away from a side of the vehicle 200 to point towards a building 250. The camera 120 captures a thermal image of the walls of the property 250 and of any visible roof area. To allow for images to be acquired from both sides of the vehicle at the same time, thermal imaging cameras may be mounted on both the left and the right sides of the vehicle 200, and controlled by a single computer, or by separate respective computers if required. An advantage of such an arrangement is that, when assessing a street having buildings on both sides, the vehicle 200 will only need to pass down the street once, thus speeding up acquisition when covering a large area.

As the vehicle 200 travels, the computer 110 is configured (i.e. programmed) to automatically acquire and process thermal images of each building 250 coming into range of the thermal imaging camera 120 while the vehicle 200 is in motion. To do this, the computer 110 needs to continuously acquire accurate location information from the position sensing unit 130 (shown in figure 2 installed on the roof of the vehicle 200), acquiring images from the thermal imaging camera 120 at appropriate locations. For improved accuracy, particularly in built-up areas, the computer can determine the actual location of the building 250 from the measured location of the vehicle 200 and the relative location of the building. Preferably the image and the location are determined at the same time, or sufficiently close together in time to minimise errors in determining the location. A range finder 220 may be equipped to the vehicle 200, or alternatively to the camera 120. The range finder 220 may, for example, be a laser range finder or any other suitable non-contact means of determining the distance d between the vehicle 200 and an adjacent building 250. A calculation can then be made of the location of the building 250, from the known location and orientation of the vehicle and the range of the building relative to the vehicle 200, as indicated by the distance d in figure 2. The orientation of the vehicle 200 can be calculated from the velocity vector v of the vehicle 200, which is typically determined continuously by the position sensing unit 130 whilst the vehicle 200 is in motion. In a general aspect therefore, a location of the building is determined from a distance acquired from a range finder in combination with a location and orientation of the position sensing unit. For example, where the velocity vector v of the vehicle 200 is defined by a magnitude V and an orientation θ, the location of a building 250 can be determined in two-dimensional Cartesian co-ordinates (with θ being measured clockwise from the y axis) by $x + d\cos\theta$, $y - d\sin\theta$, where x and y are the co-ordinates of the range finder 220, which is in a fixed relation to the position sensing unit 130.

Figure 3 illustrates an exemplary series of method steps 300 outlining the invention. The computer is given a start signal (step 301), and awaits the next building to come into view (step 302). This may, for example, be determined by monitoring a signal from the range finder 220 (figure 2), which the computer can monitor for when an object of sufficient size comes within a specified distance of the vehicle. Alternatively, the computer may have a detailed stored route map, with defined locations indicating each building along a planned route. By determining where the positioning sensing unit will be in relation to each building, the location of which is known, the computer can be configured to trigger the camera at predefined locations along the route. The range finder 220 may in this case be unnecessary, provided the location information is sufficiently accurate.

Once the next building is reached, the computer acquires the location of the vehicle (step 303), and acquires one or more thermal images of the building (step 304). The computer then optionally processes the image (step 305), identifying an area of the building, such as a roof or a wall, by its temperature profile. The computer then generates an output file, and populates the file with the thermal image, address information for the building and insulation status derived from the image (step 309). The output file is then stored (step 306) in a form comprising the image(s) together with the address of the pictured building and indications of the insulation properties of relevant areas of the building. If there are more buildings on the planned route (step 307), the method repeats, and if there are no more buildings on the route the method ends (step 308).

In an exemplary embodiment, the vehicle 200 travels along a street at a speed of around 16-24 kilometres per hour, acquiring images on both sides of the street as the vehicle passes by each building on the street. At this speed, a suitably equipped computer 110 is able to acquire and process images of buildings as they pass by, while at the same time acquiring location information from the position sensing unit and recording the information together with the acquired images in a data storage unit (e.g. a hard disk of the computer). The vehicle does not need to stop at any point during the acquisition process. In a typical built-up suburban area, over 1000 properties can be surveyed each hour by this method.

Provided location information is available with each image acquired, processing of the images need not be carried out at the time of acquisition, but could be carried out later. Processing may however be carried out simultaneously with acquisition, and files relating to each building stored as the vehicle continues along its route.

A route plan is preferably worked out beforehand, in which a number of buildings are identified for analysis. With the route plan and associated location information uploaded to the computer 110, the vehicle then travels the route plan and the computer acquires images when each location is reached, the location triggering the computer to acquire one or more images when each building is calculated to be in view. The computer may be triggered by the location reading from the positioning unit being within a predetermined distance, e.g. a distance of a few metres, from a nominal ideal point. The images are preferably acquired during the hours of darkness, to minimise thermal effects from reflected and absorbed sunlight on buildings. It is also preferable to carry out the method during autumn or winter months, when households are more likely to have their central heating in operation, which will cause any poorly insulated areas to show up on thermal images.

Exemplary images as part of processed output files acquired from an apparatus according to the invention are shown in figures 4 to 6. Figure 4 shows a typical output file 400 comprising an image 410 of a house having adequate insulation, determined by a measured average temperature of the roof area 411 and the wall area 412. A reference temperature scale 440 is provided next to the image 410 to provide a visual indication of the measured temperature of different visible parts of the building.

In a typical domestic building, the internal temperature is maintained at around 20°C. If the building is well insulated, a temperature difference of 8°C or more can be maintained across the walls and roof of the building. Provided the external ambient temperature is 12°C or less, for example as measured by the temperature sensor 140 (figure 1), inadequate insulation can be determined by detecting areas of a building that have a measured temperature of over 12°C. More distinct measurements can be obtained when the external ambient temperature is lower, as this will reveal poor insulation better due to the increased thermal gradient across the walls and roof of the building. If, for example, the external ambient temperature is 5°C, an area of a building determined to have a temperature exceeding this by 7°C would indicate a need for improved insulation. In order to avoid the influence of solar gain on the external surfaces of the building, measurements should be taken at least 1 hour after sunset.

The location of the house is identified in a location field 420, the address having been determined by cross-referencing information provided by the position sensing unit with an address database. The time the image was taken is also recorded, as shown together with the location field 420. Other information such as the date and the external ambient temperature may also usefully be recorded in the output file 400. The external ambient temperature may also be recorded in the file 400, as this can be used to determine how well insulated the various areas of the building are, by determining a difference between a measured temperature of each area and the ambient temperature.

An information field 430 is also shown in the output file 400, a first part 432 of which provides a checklist for use during a follow-up contact with the householder, and a second part 431 providing general indications of whether insulation is estimated to be required on one or both of the roof and wall of the building. The indications may be in the form of highlighted fields, with the degree of insulation (or lack thereof) being indicated by different colour coding.

Figure 5 shows a further exemplary output file 500, in this case showing an image 510 of another building at a different address (indicated in the address field 420), the building having a lower degree of insulation on a roof area 511, while having an adequate degree of insulation on the wall area 512. The roof area 511 is identified by having a significantly higher average temperature than the external ambient temperature, as measured by the temperature sensor connected to the computer. An indication is provided in the relevant field 431 to highlight that the roof area requires further insulation.

Figure 6 shows a yet further exemplary output file 600, in this case showing an image 600 of another building at a different address (indicated in the address field 420), the building having a low degree of insulation on both a roof area 611 and a wall area 612, both of which are identified as having a significantly higher average temperature than the external ambient temperature. The indications provided in the relevant field 431 highlight that both the walls and the roof of the building should have further insulation. In this case, the wall insulation is determined to have poorer insulation, and is therefore highlighted as being of greater importance.

The output files 400, 500, 600 shown in figures 4-6 are in a form suitable for further use by surveyors, who can use the information provided to identify areas of the buildings in question for further analysis. The invention thereby provides a useful tool for identifying properties that may be substandard in their thermal insulation, so that these properties can be investigated further.

Other embodiments are intentionally within the scope of the invention as defined by the appended claims.

CLAIMS

1. A computerised method for automatically determining thermal insulation properties of a plurality of buildings, the method comprising, for each building:

acquiring a location from a position sensing unit;

determining the location of the position sensing unit in relation to the building;

acquiring a thermal image of an exterior view of the building;

processing the image to identify an area of the building; and

providing an output file comprising the location of the building and indications of the insulation properties of the area of the building,

wherein the steps of acquiring the thermal image and processing the image are automatically triggered for each of the plurality of buildings by the step of determining the location of the position sensing unit in relation to the building.

2. The method of claim 1 wherein the output file comprises the processed image and address information derived from the acquired location.

3. The method of any preceding claim wherein the area of the building is one or both of a roof and a wall.

4. A vehicle comprising an apparatus for automatically determining thermal insulation properties of a plurality of buildings, the apparatus comprising:

a position sensing unit for acquiring a location of the vehicle;

a thermal imaging camera for acquiring a thermal image of an exterior of each building;

a computer connected to the position sensing unit and thermal imaging camera, the computer being configured to:

i) acquire a location of the vehicle from the position sensing unit;

ii) determine the location of the vehicle in relation to each of the plurality of buildings;

iii) acquire a thermal image of an exterior view of each building from the camera;

iv) process the image to identify one or more areas of each building; and

v) provide an output file comprising indications of the insulation properties of the one or more areas of each building, wherein the computer is configured to automatically acquire and process thermal images of each of the plurality of buildings while the vehicle is in motion using location information provided by the position sensing unit, the steps of acquiring the thermal image and processing the image being automatically triggered for each of the plurality of buildings by location information provided by the position sensing unit.

5. The vehicle of claim 4 comprising a first left-facing thermal imaging camera and a second right-facing thermal imaging camera, each camera being connected to the computer for providing thermal images of buildings on the left and right of the vehicle respectively.

6. A computer program for instructing a computer to perform the method of any of claims 1 to 3.

7. A computerised method substantially as described herein, with reference to the accompanying drawings.

8. A vehicle comprising an apparatus for automatically determining thermal insulation properties of a plurality of buildings, the apparatus being substantially as described herein, with reference to the accompanying drawings.

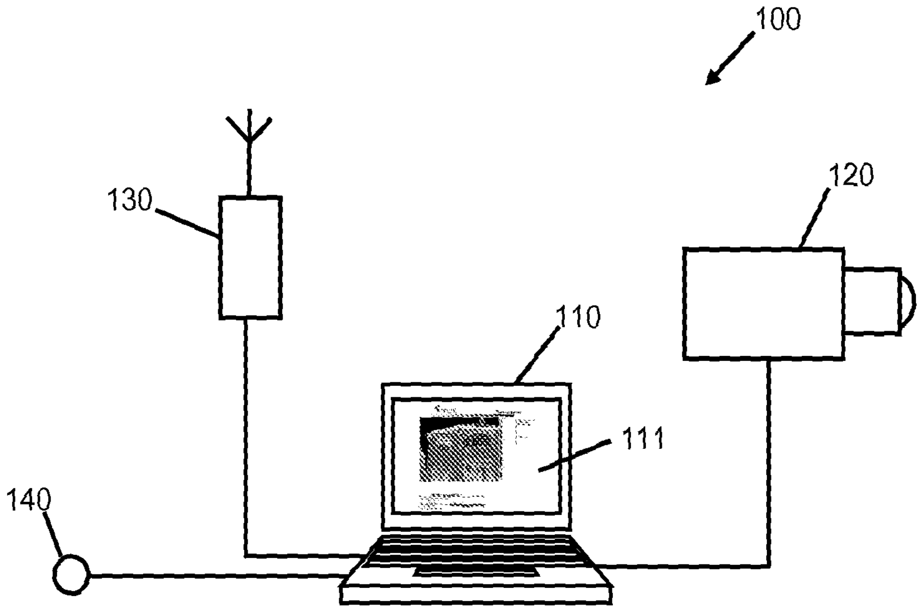


Fig. 1

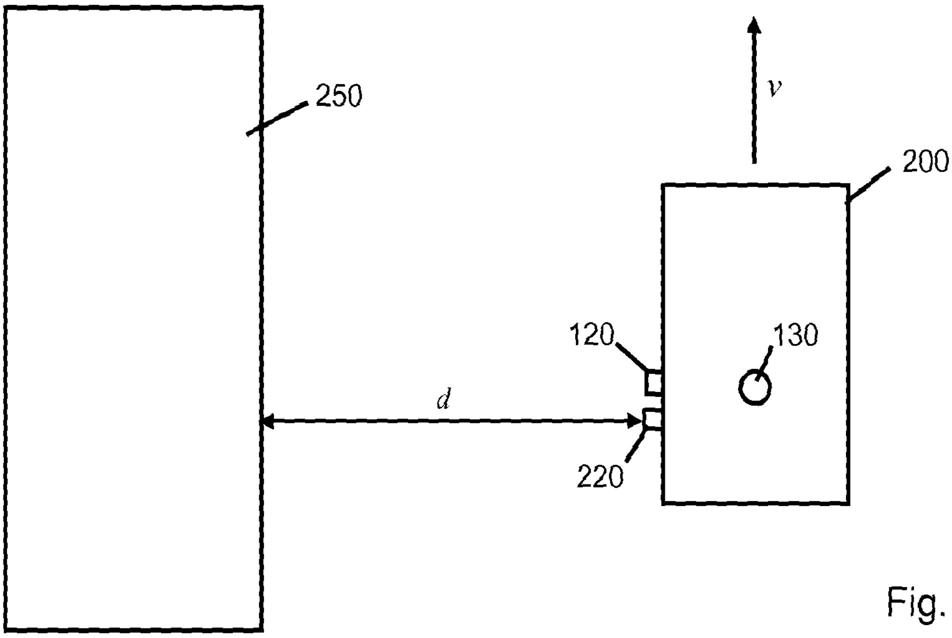


Fig. 2

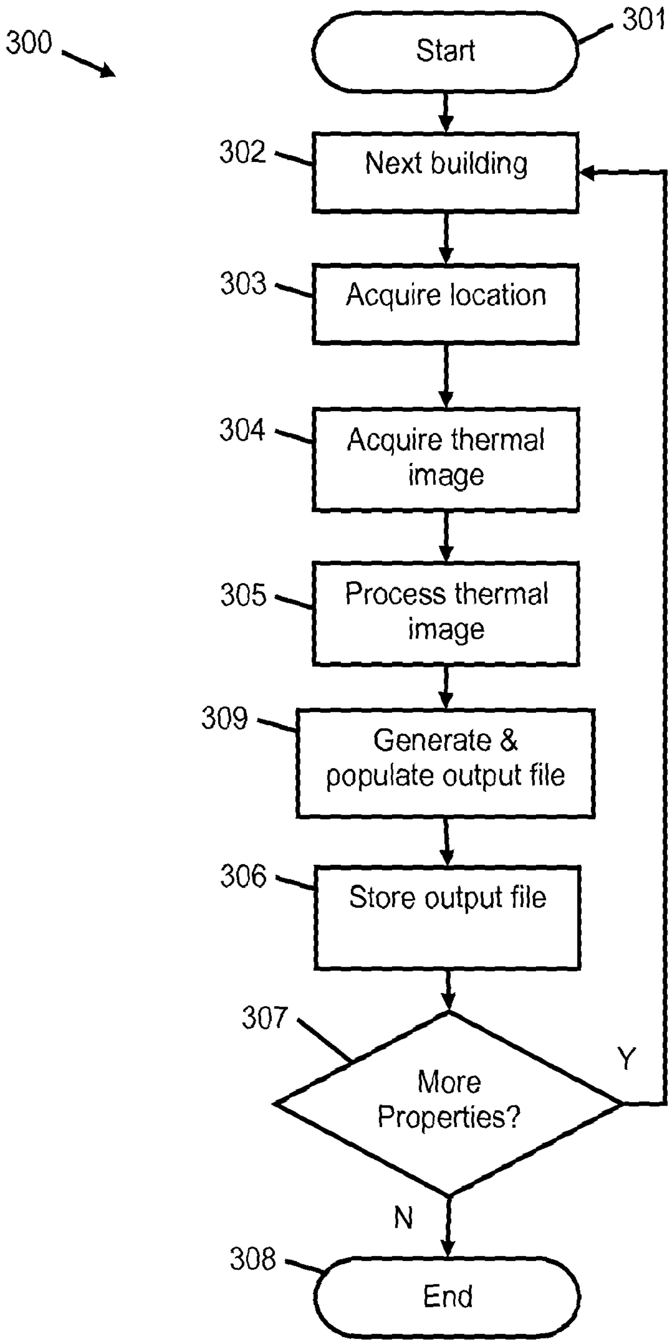

300
301
Start
302
Next building
303
Acquire location
304
Acquire thermal image
305
Process thermal image
309
Generate & populate output file
306
Store output file
307
More Properties?
Y
N
308
End

Fig. 3

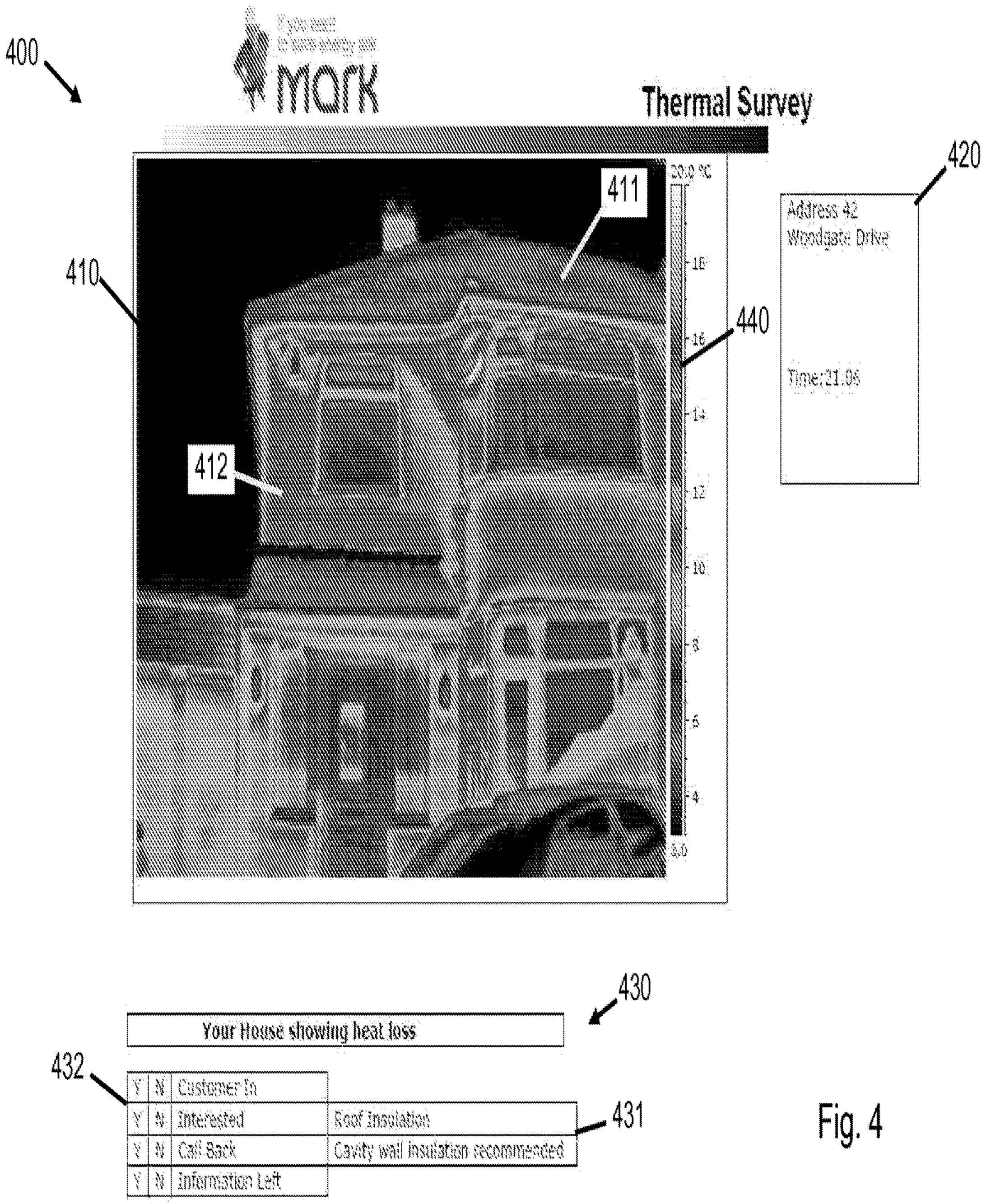
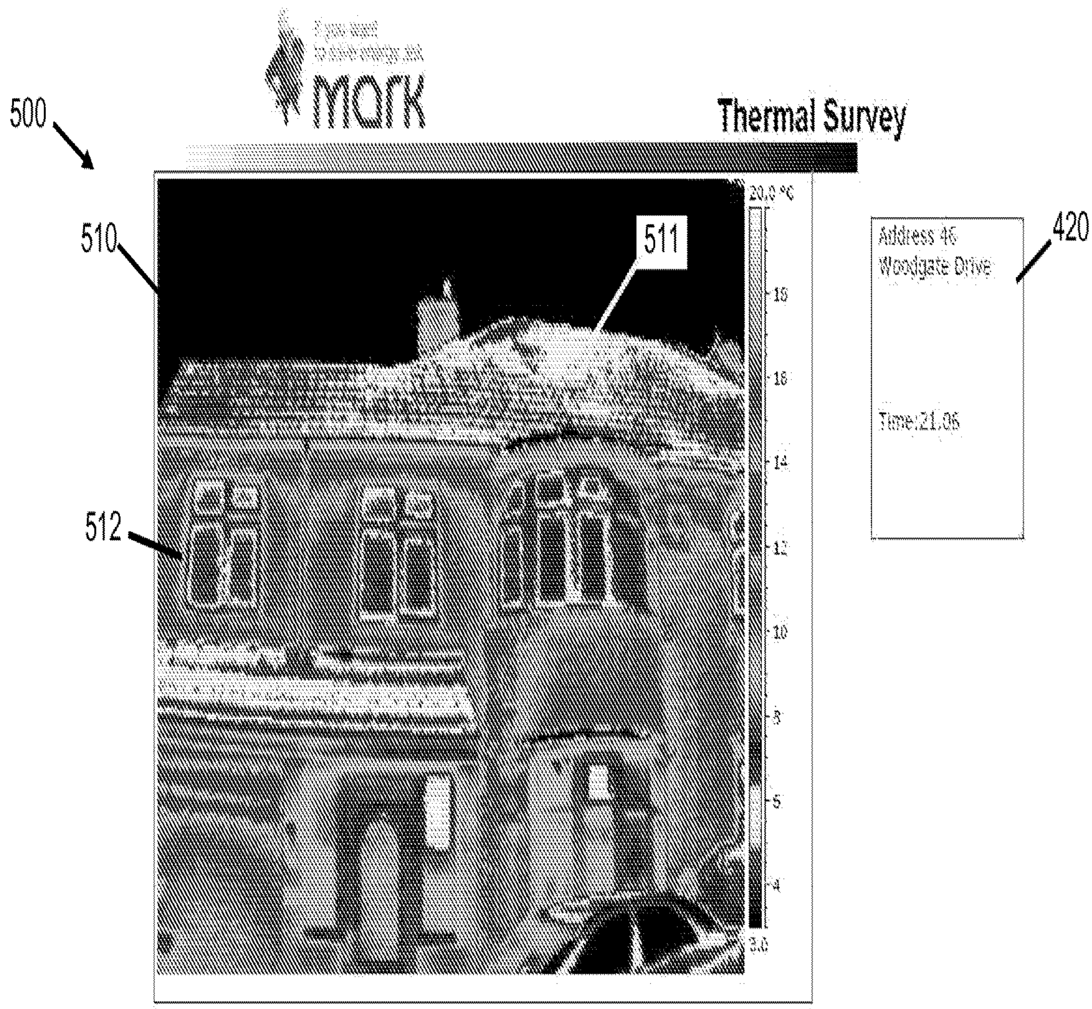

400
mark
Thermal Survey
411
410
412
440
420
Address 42
Woodgate Drive
Time:21.06
430
Your House showing heat loss
432
Y N Customer In
Y N Interested
Roof Insulation
Y N Call Back
Cavity wall insulation recommended
Y N Information Left
431

Fig. 4



430

Your House showing heat loss			
Y	N	Customer In	
Y	N	Interested	Roof insulation
Y	N	Call Back	Cavity wall insulation recommended
Y	N	Information Left	

432 431

Fig. 5

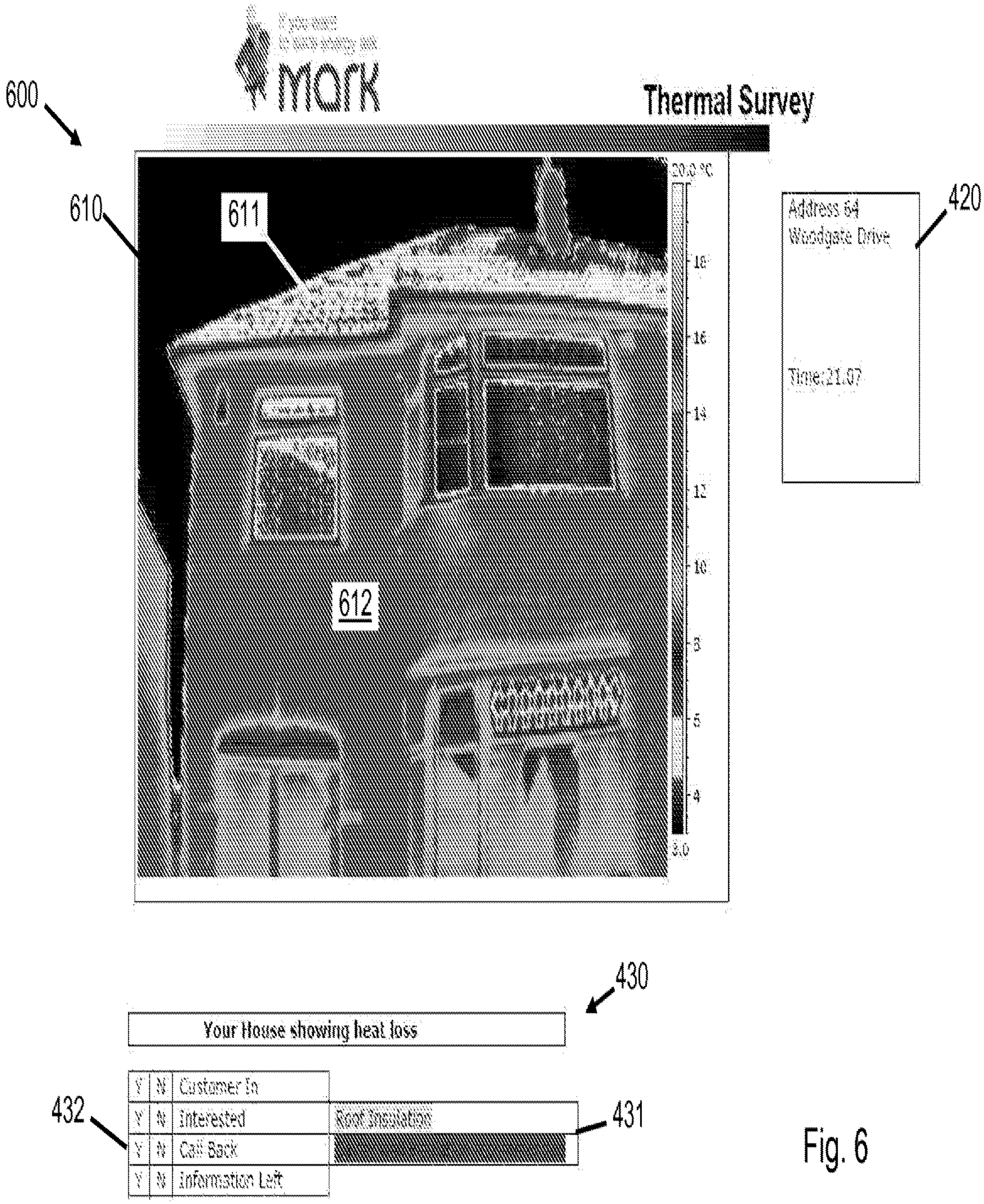

mark
Thermal Survey
600
610
611
612
20.0 °C
18
16
14
12
10
8
6
4
3.0
Address 64
Woodgate Drive
Time:21.07
420
430
Your House showing heat loss
Y N Customer In
Y N Interested
Roof Insulation
Y N Call Back
Y N Information Left
432
431

Fig. 6