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WO 2002/059701 A1 WO 2001/033529 A1
US 7551092 B1 US 20090267776 A1

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(54) Title of the Invention: **Monitoring handwashing**
Abstract Title: **Monitoring hand washing using an array of thermal detectors**

(57) A method of monitoring hand washing by individuals comprises monitoring the movements of individuals in an area using one or more sensors; identifying the performance of an act by an individual that requires the hands of the individual to be washed for example by detecting an individual has entered a predefined zone such as a patient's bedside or toilet cubicle; and determining whether the hands of the individual are washed after the performance of the act for example by providing a sensor on a soap dispenser or determining that an individual has spent a minimum amount of time at a hand washing station. Preferably the movement of the individuals is tracked with sensors comprising arrays of thermal pyroelectric detectors. The method may identify multiple acts that require the hands of an individual to be washed. The area may include multiple hand washing stations with separate appropriate hand-washing determination means.

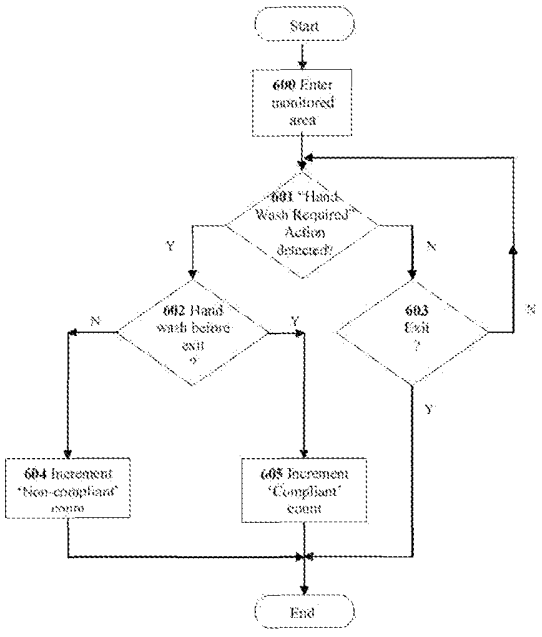

Fig 6

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Fig 1

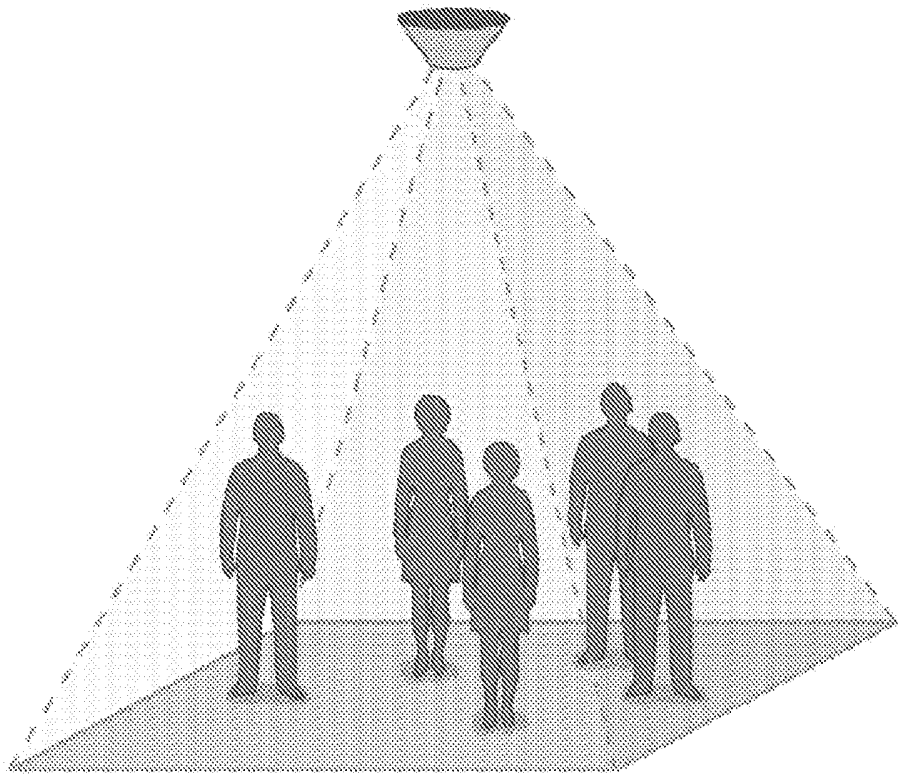

Fig 2

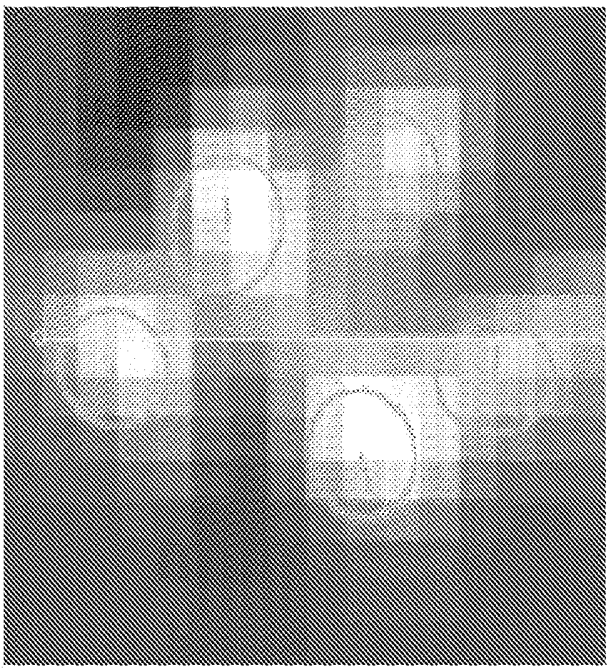

Fig 3

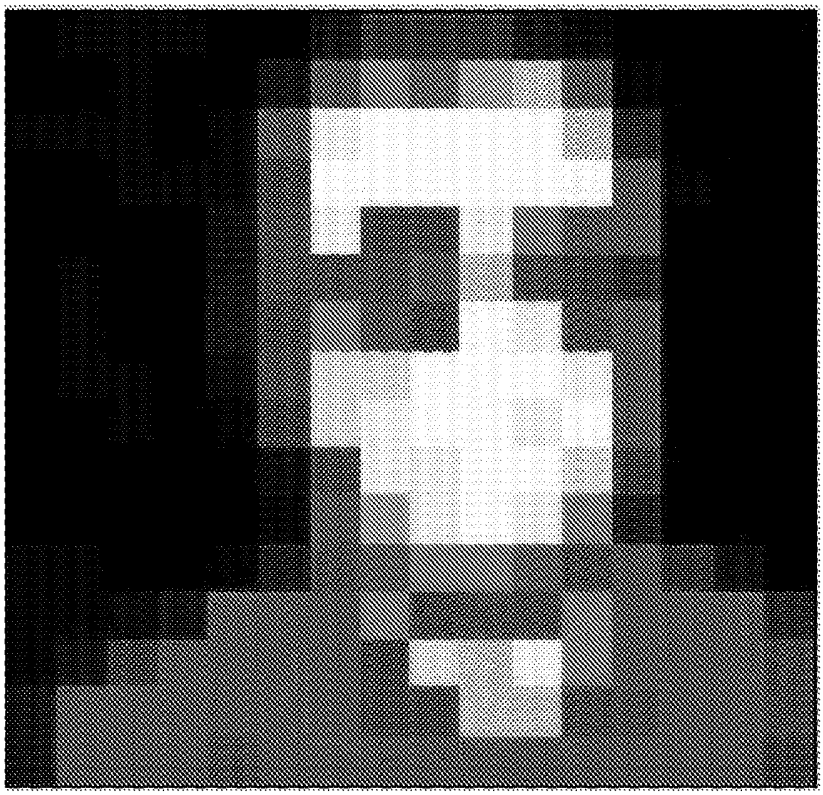

Fig 4

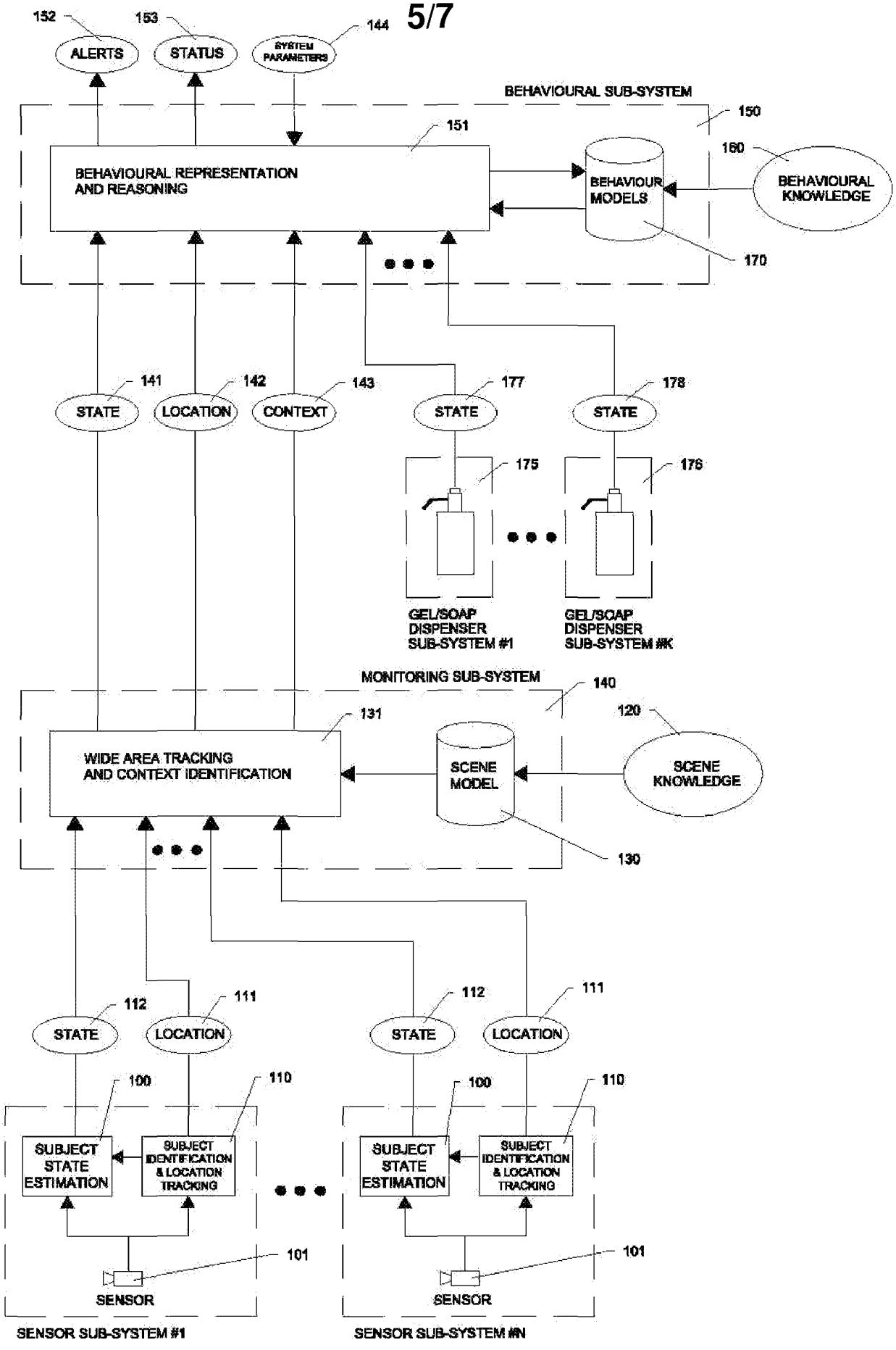

Figure 5

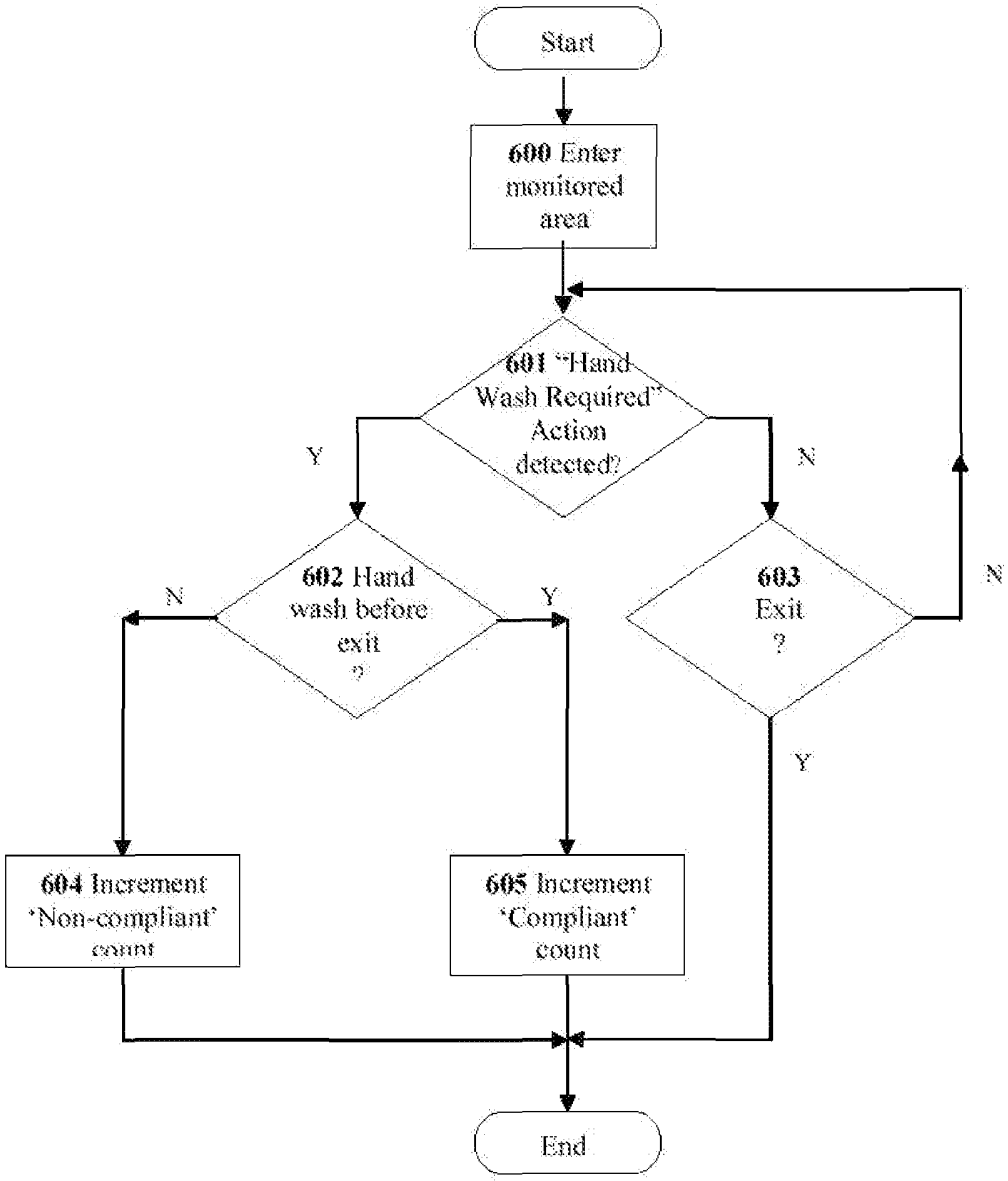
Start
600 Enter monitored area
601 "Hand Wash Required" Action detected?
Y
N
602 Hand wash before exit ?
N
Y
603 Exit ?
N
Y
604 Increment 'Non-compliant' count
605 Increment 'Compliant' count
End

Fig 6

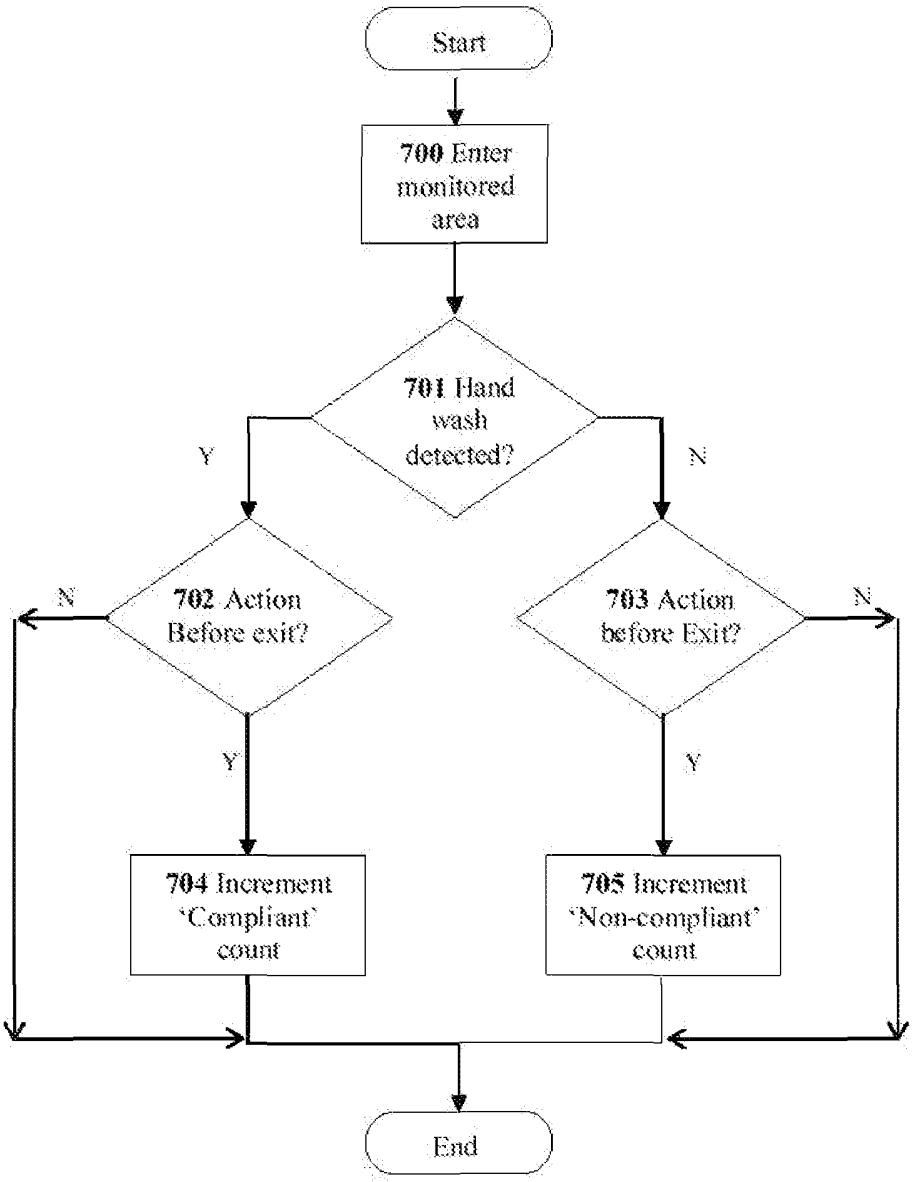
Start
700 Enter monitored area
701 Hand wash detected?
Y
N
702 Action Before exit?
N
Y
703 Action before Exit?
N
Y
704 Increment 'Compliant' count
705 Increment 'Non-compliant' count
End

Fig 7

MONITORING HAND WASHING

The present invention relates to the monitoring of hand washing.

There are numerous situations where hand washing is particularly important, such as in hospitals, food preparation areas and public toilets. Statistics show that people in general do not wash their hands as often as needed for infection control. Therefore it would be useful to be able to monitor the observance of hand washing requirements. However in the situations where this is likely to be most useful personal privacy is particularly important. Therefore it is preferable that any monitoring should be done in a non-intrusive way.

The frequency of hand washing by groups of people can be estimated from the amounts of soap used. This data does not correlate activities that require the hands to be washed with the amount of soap used.

In one aspect there is provided in the following a method of monitoring hand washing by individuals comprising monitoring the movements of individuals in an area using one or more sensors to track the motion of individuals, identifying the performance of an act by one of the individuals that requires the hands of the individual to be washed before and/or after the performance of the act and determining whether the hands of an individual are washed.

The one or more sensors may be used for identifying the performance of an act that requires the hands of an individual to be washed; and/or determining whether the hands of an individual are washed.

In the simplest case the method is used simply to count the number of “hand wash required” events and the number of instances of hand washing. These can then be compared to provide an indication as to whether hand wash rules are complied with. However it is possible to track particular individuals to determine whether an individual that has performed a “hand wash required” operation washes their hands prior to or subsequent to the “hand wash required” event.

For reasons to be explained below it is preferred that any sensor used to monitor the movements of the individuals should provide very low resolution by comparison to a

known CCTV camera. The number of detector elements in each sensor is preferably no more than 10,000.

Closed circuit television cameras (CCTV) have been used in video surveillance but are often deemed unacceptable because of intrusiveness. In other words, they provide such detailed information that they are not thought to be acceptable to persons whose behaviour might need to be monitored. Possibly "fuzziness" could be created to degrade a sharper image in a CCTV image. However, it is now known that such "artificial" blurring of an original clear image is capable in certain circumstances of being reversed by sophisticated digital means. Therefore for reasons of privacy for the individual it is preferred that the source of the data to be processed is very low in resolution. Thus information is not stored in the first place and could not therefore be digitally extracted later. Thermal sensors are ideal for this purpose and have other advantages. The preferred thermal sensor is made up of a two dimensional array of infrared sensitive detector elements, preferably pyroelectric detectors, with the number of elements in the array typically between 16×16 and 33×33, together with an optical lens which focuses an image of the scene onto the detector array. The sensor has readout means for monitoring signals from the detectors and means for interpreting such signals to determine the presence of selected targets and tracking their motion in time and space. The sensor has analysis means to further characterise this information as required for the invention described elsewhere. The preferred sensor is not chopped or shuttered to provide a comparison between a blank scene and the active scene to facilitate image difference processing (described elsewhere) but such a facility might be included in certain circumstances to assist in identification of, for example, stationary objects. A suitable sensor is described in EP-A-0853237.

The preferred thermal sensors comprise arrays of thermal detector elements, e.g. pyroelectric detector elements, which produce images that are blurred (fuzzy) in space. This is due in part to the low resolution of the arrays and to the use of low-cost optics which have limited acuity, but also to the fact that each detector element shows only changes in the images. In addition, the material that receives the infra-red signal 'bleeds' across its surface, so adding to the blurring. In this way, the anonymity and privacy of the individual are maintained.

As will be described in more detail below, using the preferred sensor, the nature of the thermal image obtained from a person moving around in the field of view of a detector is

such that there is no possibility of obtaining detail regarding what an individual looks like or is doing except in the most basic way. However for compliance enforcement an additional identification of the individual might be added such as an RFID tag.

Another advantage of thermal imagers over CCTV is that thermal detectors are able to work under varying light conditions including conditions that would make the use of CCTV extremely difficult. Working in the infra-red allows this system and method to work easily under any normal indoor lighting conditions, including complete darkness.

Another advantage is that a pyroelectric detector sees only changes in its field of view, so background clutter 'disappears', allowing the system to focus on the objects of interest. This coupled with the fact that a low resolution sensor is preferred leads to a great saving in terms of data to be processed.

In the preferred embodiment of the invention, the one or more sensors is/are used to identify the performance of an act that requires the hands of the individual to be washed. In some applications, such as hand washing after toilet use in which the wash basin is in the same enclosure as the toilet, entry of the individual into the enclosure might be deemed to be an act that requires the hands of the individual to be washed. In that case a door opening sensor might be used to identify the entry of the individual into the enclosure. With the use of sensors to track the motion of the individual it will be possible to discriminate between the door being opened and no-one entering the enclosure and the door being opened and a person entering the enclosure.

It is also preferable for the one or more sensors to be used to determine whether the hands of the individual are washed after the performance of the act. This could be done by, for example, simply determining that the individual has spent a minimum amount of time at a hand washing station. It will be appreciated that this is not an accurate determination since this does not confirm that the individual's hands have actually been washed. However it may provide a fair approximation.

It is possible to provide a sensor on a soap dispenser to give an indication of an instance of hand washing. Data from such a sensor could be used instead of or in addition to signals from the one or more sensors mentioned above to determine whether the hands of the user have been washed.

The method is particularly useful for obtaining data relating to compliance with hygiene regulations. Therefore it is useful to increment a counter for each identification of the performance of an act by an individual that requires the hands of the individual to be washed, and to increment a counter for each determination that an individual having performed an act that requires the hands to be washed then performs a hand washing operation. This then gives an indication of the percentage compliance with the regulations. Instead of incrementing a counter for each identification of the performance of an act by an individual that requires the hands of the individual to be washed the same statistics could be prepared from a count of the number of instances of such an act that are not followed by hand washing by the individual.

Thus a preferred embodiment of the invention comprises incrementing a compliance counter for each determination that an individual having performed an act that requires the hands to be washed is preceded or followed by a hand washing operation according to requirements associated with the act. In other words, for a "pre-wash required" event the compliance counter is incremented if hands are washed before the event and for a "post-wash required" event the compliance counter is incremented if hands are washed after the event. Otherwise a non-compliance counter may be incremented. For events that require both pre and post wash, a compliance counter can be incremented only if hands are washed before and after an event.

For some applications there are multiple different acts that require the hands of an individual to be washed and these can be separately identified. An example is the area around a hospital bed. World Health Organisation guidelines identify "5 Moments for Hand Hygiene" as:

1) before touching a patient (e.g. on entry into the bed area)
2) before any clean/antiseptic procedure
3) after body fluid exposure risk
4) after touching the patient
5) after touching the patient surroundings.

Some or all of these can be identified using the kinds of sensor described above.

The area under observation may include multiple hand washing stations and hand washing operations at the respective hand washing stations may be separately

determined in order to provide more detailed information relating to compliance with regulations.

There is also provided in what follows a system for monitoring hand washing by individuals configured to perform the steps of the method described above comprising one or more sensors, and one or more processors for processing signals from the sensors.

There is also provided a computer readable medium comprising instructions that when executed by a processor in a system comprising one or more sensors cause the system to execute the steps of the method described above.

An embodiment of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows, for the purpose of comparison, a comparatively high resolution image from a high resolution thermal imaging camera;
Figure 2 is a schematic diagram showing a ceiling mounted sensor comprising an array of thermal detector elements with its associated field of view;
Figure 3 shows a typical “un-chopped” image produced by a 16x16 array in the arrangement of figure 1;
Figure 4 shows a “chopped” image of a face using a 16x16 thermal imager with image difference processing;
Figure 5 is a schematic diagram of a system suitable for implementing the method of the invention;
Figures 6 and 7 are flowcharts for two possible methods according to the invention.

As noted above, it is preferred not to use high resolution imaging sensors. The reason for this will firstly be explained in more detail with reference to figures 1 to 4.

High quality thermal imagers produce movie-like images which will record the thermal scene in detail and in particular will “see” stationary targets in the field of view as well as moving objects. This combined with a higher resolution (pixels per unit field of view) makes facial identification possible, and could display detailed behaviour (scratching, nose picking etc). An example image from a high resolution thermal imager is shown in

figure 1. The sensor used to produce this image would typically have over 76,000 detector elements.

The system and method of the invention preferably use low element count thermal detector arrays which show insufficient detail to be intrusive. The arrays could use pyroelectric detectors or resistive bolometers for example.

Pyroelectric detectors produce a signal or image only when the incident infrared radiation is modulated, either by movement of the target or by means of a mechanical chopper. If a pyroelectric array "stares" through a suitable lens at a stationary scene, no image will be produced. In order to produce an image a mechanical chopper must be used with image difference processing to subtract the chopper-closed signal from the chopper-open signal.

The system and method of the invention can be implemented using low element count pyroelectric arrays without a chopper or image difference processing. As noted above pyroelectric detectors only respond to changes in the input radiation, so a moving target becomes a "blurred blob" in an otherwise uniform image. This "blob" can be tracked and identified as a target but only gross actions (walking, stopping, rapid speed changes etc) of the target can be seen. If the target remains motionless it disappears from the image altogether and it is by using a tracking algorithm that knowledge of the target's location can be retained and it can be picked up again when it moves. Figure 2 shows a ceiling-mounted 16x16 sensor viewing five people moving through the field of view and figure 3 shows an un-chopped image obtained from the sensor to illustrate how little resolution is needed in order to implement the method and system of the invention.

Notwithstanding the foregoing, for some applications it may be desirable to incorporate some image difference processing in order to collect limited additional information about fixed objects such as chairs and tables. By chopping the image on a pyroelectric detector it is possible to artificially create a time dependent signal and so stationary heat sources (targets) show up on the image. Even with such image difference processing low spatial resolution of sensors still ensures that the system is not undesirably intrusive.

It is clear from figure 3 that only 16×16 elements lead to an extremely coarse picture. . By comparison the "minimum" spatial resolution for a thermal imager of sufficient quality to "see" objects reasonably clearly is 160×120 and can be 384×288 or better as shown in

figure 1. Chopped imagers with 16×16 elements still show targets as animated "blobs" as can be inferred from the chopped image shown in figure 4. Of course the actual level of detail available from a sensor depends on its field of view and distance between the sensor and the target. Typically imagers have a 20° field of view but can have as narrow as 10° or as wide as 35° or more. The wider the angle the greater the area of scene transferred to the imaging plane and for objects at a similar distance the detail will be lower. However for a wide field of view a target could stand much closer to the sensor to be seen more clearly.

Referring now to figure 5, the illustrated system comprises one or more sensor sub-systems #1…#N which provide basic monitoring of individual areas within a monitored space. Each sensor sub-system comprises a sensor 101 comprising an array of thermal detectors together with subject identification, location and tracking system 110 and state estimation system 100. As shown in the figure, the state estimation system utilises information from the sensor 101 as well as the location and tracking system in order to estimate the state of the subject. Examples of "state" include speed of motion, orientation of body and "shape" of body (e.g. arms outstretched). Each sensor sub-system #1…#N provides rejection of noise and 'false-alarm' signals and outputs estimates of the location 111 and current state 112 of any subject within its field of view.

A monitoring sub-system 140 accepts subject location 111 and state 112 information from the one or more sensor sub-systems #1...#N. Sub-system 140 includes a scene model 130 compiled from a knowledge base 120 (which may be externally provided) of scene layout data. Wide area tracking and context identification processing 131 within sub-system 140 transforms the multiple location and state estimates from sensor sub-systems #1…#N into a more consistent, higher-level, description of the subject's state 141, location 142 within the entire monitored space, also adding contextual information 143 derived from the scene model 130. At this intermediate level, the system is also able to resolve issues associated with the presence of multiple subjects within the monitored area and provide more complex noise and 'false-alarm' rejection.

A behavioural sub-system 150 accepts high-level subject state 141, location 142, and context 143 information as well as system parameters 144 (such as the presence of a pet) and these are input to behavioural representation and reasoning processing 151. The system also includes gel or soap dispenser subsystems 175 and 176 (and possibly more) which output state information 177 and 178 respectively relating to the activation of

soap dispensers. The dispensers could have sensors that detect the activation of a push top or they could have level indicators that determine when a measure of soap is dispensed. The subsystems could be more complex and include video cameras checking whether hands are washed properly.

The purpose of behavioural sub-system 150 is to identify events that require hand washing and instances of hand washing. This is done using a database 170 containing models of events that require hand washing and instances of hand washing. Input data to behavioural representation and reasoning processing 151 relating to state, location and context from the dispenser subsystems 175, 176 and from the wide area tracking and context identification processing 131. This is processed and used in conjunction with the models of behaviour in database 170 to identify events. The database may use knowledge supplied from an external source 160 and/or learned behaviour from training the system in situ. The models may be updated from time to time based on current information, hence the two way flow of data between the models 170 and the behavioural representation and reasoning 151.

The various "systems" illustrated in figure 5 may be implemented using any suitable apparatus as will be apparent to a person skilled in the art. The state estimation systems 100 and tracking systems 110 may take the form of one or more signal processors housed with the sensors or may be remote from the sensors. The remaining systems 140 and 150 would typically be remote from the sensors themselves and may take the form of one or more suitably programmed computers with associated memory.

Two example methods are now explained with reference to figures 6 and 7.

The processes described with reference to figures 6 and 7 split naturally into 3 parts:

1. Detecting a hand wash requirement.
2. Detecting a hand wash event.
3. Compliance processing - storing and displaying the results.

<u>Detecting a hand wash requirement.</u>

The process typically begins when an individual is detected entering a predefined space or 'sensitive' zone (e.g. food preparation area, toilet cubicle, patient's bedside). After entry, the individual may or may not be required to wash their hands; this will depend on the nature of the application and on what happens next. For some applications, simple

entry to the sensitive zone (e.g. toilet cubicle) defines the wash criteria. In another application, an external input might also be required; for example, a signal from an electronic tag that is worn by certain categories of individuals (care workers, say). Other hand wash applications may also require evidence from the scene analysis algorithms that the subject's behaviour indicates an action that is associated with the need for a hand wash.

Detecting a hand wash event

Again the process typically begins with the entry of a individual into a predefined sensitive zone; in this case the zone would usually be of the hand wash type. Hand wash events take a number of forms: simple gel rubs are often used, in some cases a conventional soap and water wash is appropriate. Other variations occur when gloves are donned after washing and/or the individual may carry a personal gel dispenser. Gel and soap dispensers can be instrumented such that a signal is issued when the containers are used. The system can use these signals to help it decide when and where a hand wash event has taken place. The system can also identify a hand wash event from behavioural analysis of the individuals in the scene. For example, a minimum dwell time appropriate for the washing equipment within the hand wash zone (wash hand basins, gel bottles, etc) can be used to estimate the likelihood of a hand wash event having taken place.

Thus, a hand wash event can be detected by:

1. Scene analysis (dwell times etc), or
2. Signals from instrumented dispensers and/or instrumented individuals, or
3. A combination of both (this is likely to give the most robust estimates).

Compliance processing

Compliance processing can involve one or more of the following:

1. Estimate compliance statistics from the compliance counts.
2. Update database
3. Generate any alerts required.
4. Generate reports and update displays.

Examples:

Figures 6 and 7 show two examples of the logic that would be required to determine whether an individual has complied with a hand wash requirement that involves both the

movement of an individual into a sensitive zone and the performance of some action. The action might consist of a sequence of observed events that suggest that the monitored individual has touched a particular object: a piece of medical equipment (say).

In the flowchart of figure 6, the wash criteria are met after an individual has moved into the sensitive zone and has performed some predefined action.

The process starts and at step 600 an individual enters the monitored area. The system now waits at step 601 for an action to occur that has been predefined to require hand washing.

If the monitored individual exits the monitored area before step 601 is satisfied (as tested at step 603) then the process terminates. Otherwise, the logic follows the 'no' branch from step 603, and the system continues to wait for the action to occur at step 601.

If at step 601, the looked-for action is detected then the wash criteria have been met and at step 602 the system begins to look for exit events and hand wash events. If an exit is seen and no hand wash has been observed, then the individual has failed to comply with the wash requirements and a counter is incremented to reflect this. If, on the other hand, a hand wash event is observed before the exit, then the correct sequence of events has occurred and a 'compliance' counter is incremented.

The process terminates on exit of the individual from the monitored area.

In the flowchart of Figure 7, the hand wash event must precede a predefined action, so the compliance check is made retrospectively.

The process starts and at step 700 an individual enters the monitored area. The system now waits at step 701 for a hand wash event to occur.

If no hand wash event occurs at step 701 and the individual exits the monitored area without performing any action that requires hand washing, this will be detected at step 703 (the 'no' branch is taken) and the process terminates. In this case, the individual has not performed the "hand wash required" action, and so is

not required to wash. If on the other hand, the individual exits at step 703 and they *have* performed the "hand wash required" action (so taking the 'yes' branch), then they have failed to wash before the action so a count is incremented to record the transgression.

Look back now at step 701 and examine the case where a hand wash has been detected. If an exit is detected at step 702 but was not preceded by an action (so leaving 702 on the 'no' branch) then the hand wash event was not required and so it is disregarded and the process is terminated. Contrariwise, an exit from step 702 on the 'yes' branch would be taken if the sequence 'hand wash' then 'action' then 'exit' is detected'. In this case, the individual has been seen to have complied with the hand wash requirement of the action so a 'compliance' count is incremented to record this.

The process terminates on exit of the individual from the monitored area.

It will be appreciated that the methods illustrated in figures 6 and 7 can be combined to determine compliance with rules that require hands to be washed before and after a particular event.

Claims.

1. A method of monitoring hand washing by individuals comprising monitoring the movements of individuals in an area using one or more sensors to track the motion of individuals, identifying the performance of an act by one of the individuals that requires the hands of the individual to be washed before and/or after the performance of the act and determining whether the hands of an individual are washed.

2. A method as claimed in claim 1 wherein the one or more sensors are used for one or more of identifying the performance of an act that requires the hands of an individual to be washed.

3. A method as claimed in claim 1 or claim 2 wherein the one or more sensors are used for determining whether the hands of an individual are washed.

4. A method as claimed in claim 1, 2 or 3 in which the actions of an individual that has performed an act requiring hand washing are tracked to determine whether the hands of the same individual are washed.

5. A method as claimed in any preceding claim in one or more of the sensors is sensitive only to movements taking place within its field of view.

6. A method as claimed in any preceding claim in which one or more of the sensors comprises an array of detector elements.

7. A method as claimed in claim 6 in which the array of detector elements comprises no more than 10,000 detector elements.

8. A method as claimed in claim 6 or claim 7 in which the detector elements are thermal detector elements.

9. A method as claimed in claim 8 in which the detector elements are pyroelectric detector elements.

10. A method as claimed in claim 9 in which the sensors use image difference processing to determine the position of objects in the field of view of a sensor.

11. A method as claimed in any preceding claim in which if an individual spends more than a preset minimum amount of time at a hand washing station it is determined that the hands of the individual have been washed.

12. A method as claimed in any of claims 1 to 11 comprising processing signals from one or more dispensers of cleanser to identify that the hands of an individual are washed.

13. A method as claimed in any preceding claim comprising incrementing a compliance counter for each determination that an individual having performed an act that requires the hands to be washed is preceded or followed by a hand washing operation according to requirements associated with the act.

14. A method as claimed in any preceding claim comprising incrementing a non-compliance counter for each determination that an individual having performed an act is not followed by or preceded by an individual performing a hand washing operation according to the requirements of the act.

15. A method as claimed in any preceding claim comprising separately identifying multiple different acts that require the hands of an individual to be washed.

16. A method as claimed in any preceding claim in which the area includes multiple hand washing stations wherein hand washing operations at the respective hand washing stations are separately determined.

17. A system for monitoring hand washing by individuals configured to perform the steps of the method of any preceding claim comprising one or more sensors configured to track the motion of individuals, and one or more processors for processing signals from the sensors.

18. A system as claimed in claim 17 comprising additional sensors associated with one or more cleanser dispensers.

19. A computer readable medium comprising instructions that when executed by a processor in a system comprising one or more sensors cause the system to execute the steps of the method of any one of claims 1 to 16.

Application No:	GB1008830.0	**Examiner:**	Dr Susan Dewar
Claims searched:	1-19	**Date of search:**	8 July 2010

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-4, 11-14 & 16-19	EP 1872802 A1 (ETHICON) See Figs 1, 2 and paragraphs 0027-0032
X	1-10, 12 & 15-19	WO 02/059701 A1 (AMRON CORP) see Fig1 and related text
X	1-10, 12-14 & 16-19	WO 2009/097096 A1 (DEUTSCH) see pages 9 -11 and Fig 1
X	1-4 & 16-19	US 7551092 B1 (HENRY) Whole document relevant
X	1-4, 12-14 & 16-19	WO 2007/090470 A1 (HYLAND) See abstract
X	1-4 & 12-19	WO 01/33529 A1 (WILDMAN et al) See abstract and Fig 1
X	1-4 & 11-19	US 2009/0267776 A1 (GLENN et al) See abstract
X	1-4 & 11-19	WO 2007/127495 A2 (DUKE UNIVERSITY) see abstract and Fig 8

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

G01J; G08B

The following online and other databases have been used in the preparation of this search report

Online: EPODOC, WPI, TXTE

International Classification:

Subclass	Subgroup	Valid From
G01J	0005/34	01/01/2006
G01J	0005/00	01/01/2006
G08B	0021/24	01/01/2006