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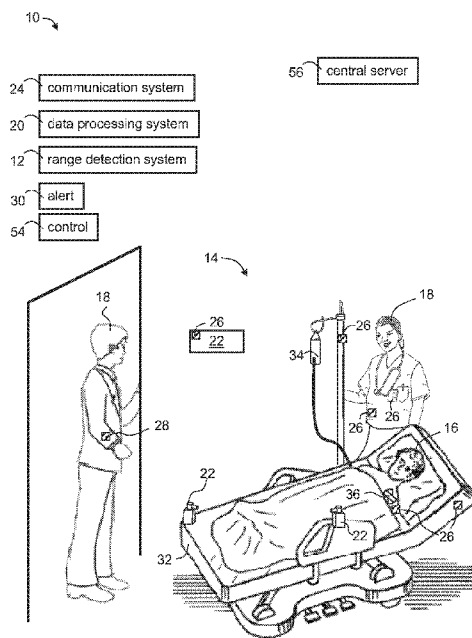


FIG. 1

(57) Abstract: A monitoring system is disclosed. The system comprises a range detection system, configured for scanning a scene to provide range data arranged gridwise over a plurality of picture elements, and a data processing system configured for processing the range data to monitor hygienic activity, preferably hand hygienic activity, of an individual in the scene. Preferably, the picture elements are devoid of any color data and any gray-scale data. In some embodiments of the present invention the data processing system identifies one or more of the moments for hand hygiene as defined by the World Health Organization, and monitors the hygienic activity in relation to these five moments.



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METHOD AND SYSTEM FOR MONITORING ACTIVITY OF AN INDIVIDUAL

RELATED APPLICATIONS

This application claims the benefit of priority of U.S. Provisional Patent
5 Application Nos. 61/963,644 filed December 11, 2013, 61/964,904 filed
January 17, 2014, and 62/071,926 filed October 7, 2014, the contents of which are
incorporated herein by reference in their entirety.

FIELD AND BACKGROUND OF THE INVENTION

10 The present invention, in some embodiments thereof, relates to monitoring and,
more particularly, but not exclusively, to a method and system for monitoring activity,
e.g., hygienic activity of an individual.

Individuals in need of medical attention for a variety of ailments or conditions
typically seek clinical treatment from a healthcare provider, nursing homes *etc.* Such
15 treatment may include a combination of procedures, medications or other therapies to
stabilize and/or improve the health of an individual or patient. However, the process of
providing clinical treatment brings with it the risk of side effects. One such side effect
of significant concern when patients seek procedure-related treatments from a healthcare
provider is infections.

20 Substantial literature exists on infections, including nosocomial infections, which
are prevalent in all patient care facilities including hospitals and nursing homes. These
infections pose a significant health risk to hospitalized patients by delaying healing,
extending the length of hospitalization and increasing the human and financial cost of
care. Research reveals that several types of microorganisms can be transferred by hand
25 to live hosts, thereby producing nosocomial infections.

Whether resulting from clinical issues such as contaminated equipment,
individual patient health conditions, or other factors, infections can have a serious
impact on the stability of a patient's health status and affect their ability to recover from
a health condition. As a result, infections related to healthcare treatment delivery
30 represent an increased risk to public health, and create a significant clinical and financial
burden to society.

Moreover, due to economic pressure from health care reforms paired and a steady increase in demand for hospital services, hospitals are forced to do more with less. This places emphasis on controlling infection rates which are known to be a major reason for increment of hospitalization length of stay (LOS) and patient readmissions.

5 U.S. Published Application No. 20100073162 discloses a method for ensuring hand hygiene compliance. The method comprises the steps of sensing whether a person has washed their hands, determining a hand wash state of the person's hands, indicating the hand wash state of the person's hands; and alerting an individual of the hand wash state of the person's hands.

10 SUMMARY OF THE INVENTION

According to an aspect of some embodiments of the present invention there is provided a monitoring system. The system comprises: a range detection system configured for scanning a scene and to provide range data arranged gridwise over a plurality of picture elements; and a data processing system configured for processing the
15 range data to monitor hygienic activity of an individual in the scene.

According to some embodiments of the invention the picture elements are devoid of any color data and any grayscale data.

According to some embodiments of the invention the system wherein the range detection system provides range imaging data, and the data processing system is
20 configured for removing from each picture-element any color data or grayscale data.

According to some embodiments of the invention the data processing system is configured to identify the hygienic activity during at least one time interval selected from the group consisting of (i) a time interval ending before the individual contacts a patient in the scene, (ii) a time interval ending before the individual performs an aseptic
25 task, (iii) a time interval ending after the individual performs the aseptic task, (iv) a time interval beginning after the individual is exposed to a body fluid of the patient, (v) a time interval beginning after the individual contacts the patient, and (vi) a time interval beginning after the individual contacts objects nearby the patient.

According to some embodiments of the invention the data processing system is
30 configured to identify hand rubbing motion of the individual.

According to some embodiments of the invention the data processing system is configured to identify glove wearing motion of the individual.

According to some embodiments of the invention the data processing system is configured to identify glove removal motion of the individual.

5 According to some embodiments of the invention the data processing system is configured to identify operation of a hand cleansing device by the individual.

According to some embodiments of the invention the data processing system is configured to identify access of the individual to a patient in the scene, and to determine a time window encompassing both the hygienic activity and the access.

10 According to some embodiments of the invention the data processing system is configured to classify interaction of the individual with a patient in the scene, and to determine a time window encompassing both the hygienic activity and the interaction.

According to some embodiments of the invention the data processing system is configured to identify a medical treatment device in the scene, and contact events
15 between the individual and the medical treatment device, and determining a time window encompassing both the hygienic activity and the contact events.

According to some embodiments of the invention the data processing system is configured to identify contact events between the individual and an organ of a patient in the scene, and to issue a notification when the contact events are not preceded by the
20 hygienic activity.

According to some embodiments of the invention the data processing system is configured to identify points of contact between the individual and objects in the scene, and to map the points of contact over the scene.

According to some embodiments of the invention the data processing system is configured to track a cleansing device in the scene and to update the map responsively to the tracking.
25

According to some embodiments of the invention the system comprises a control circuit configured to signal a robotic cleansing device to access and disinfect the points of contact.

30 According to some embodiments of the invention the system comprises a communication system configured to communicate with a sensor mounted on the individual, and to receive from the sensor signals pertaining to hygienic activity or lack

thereof, wherein the data processing system is configured for determining the hygienic activity based, at least in part, on the signals.

According to some embodiments of the invention the data processing system is configured to log statistics pertaining to the hygienic activity and to store the statistics on a non-transitory computer readable medium and/or to transmit the statistics to a central computation server.

According to an aspect of some embodiments of the present invention there is provided a method of monitoring. The method comprises: scanning a scene and provide range data arranged gridwise over a plurality of picture elements; and processing the range data to monitor hygienic activity of an individual in the scene.

According to some embodiments of the invention the scanning comprises generating a range image of the scene, and wherein the processing comprises removing from each picture-element any color data or grayscale data.

According to some embodiments of the invention the method identifies the hygienic activity during at least one time interval selected from the group consisting of (i) a time interval ending before the individual contacts a patient in the scene, (ii) a time interval ending before the individual performs an aseptic task, (iii) a time interval ending after the individual performs the aseptic task, (iv) a time interval beginning after the individual is exposed to a body fluid of the patient, (v) a time interval beginning after the individual contacts the patient, and (vi) a time interval beginning after the individual contacts objects nearby the patient.

According to some embodiments of the invention the method identifies hand rubbing motion of the individual. According to some embodiments of the invention the method identifies glove wearing motion of the individual. According to some embodiments of the invention the method identifies glove removal motion of the individual. According to some embodiments of the invention the method identifies operation of a hand cleansing device by the individual. According to some embodiments of the invention the method identifies access of the individual to a patient in the scene, and determining a time window encompassing both the hygienic activity and the access.

According to some embodiments of the invention the image processing method classifies interaction of the individual with a patient in the scene, and determining a time window encompassing both the hygienic activity and the interaction.

According to some embodiments of the invention the method identifies a medical treatment device in the scene and contact events between the individual and the medical treatment device, and determining a time window encompassing both the hygienic activity and the contact events.

- 5 According to some embodiments of the invention the method identifies contact events between the individual and an organ of a patient in the scene, and issuing a notification when the contact events are not preceded by the hygienic activity.

 According to some embodiments of the invention the method identifies points of contact between the individual and objects in the scene, and mapping the points of
10 contact over the scene. According to some embodiments of the invention the processing comprises tracking a cleansing device in the scene and updating the map responsively to the tracking. According to some embodiments of the invention the method comprises controlling a robotic cleansing device to access and disinfect the points of contact.

 According to some embodiments of the invention the method comprises
15 communicating with a sensor mounted on the individual, receiving from the sensor signals pertaining to hygienic activity or lack thereof, and determining the hygienic activity based, at least in part, on the signals.

 According to some embodiments of the invention the method comprises collecting statistics pertaining to the hygienic activity and storing the statistics on a non-
20 transitory computer readable medium and/or transmitting the statistics to a central computation server.

 According to an aspect of some embodiments of the present invention there is provided a method of monitoring a condition of a medical environment. The method comprises: obtaining a map of the environment, the map comprising locations in the
25 environment identified as being infected; receiving tracking data pertaining to motion of a cleansing device in relation to the locations; and updating the map based, at least in part, on the tracking data.

 According to some embodiments of the invention the method comprises generating the map by monitoring points of contact between individuals and objects in
30 the environment.

 According to some embodiments of the invention the method comprises transmitting the updated map to a central computation server.

According to some embodiments of the invention the receiving the tracking data comprises receiving signals generated by the cleansing device.

According to some embodiments of the invention the receiving the tracking data comprises receiving signals reflected by the cleansing device.

5 According to some embodiments of the invention the receiving the tracking data comprises optically scanning the environment to determine a location of the cleansing device.

 According to some embodiments of the invention the cleansing device is a robotic cleansing device and the method further comprises controlling the robotic
10 cleansing device to access and disinfect the points of contact.

 According to an aspect of some embodiments of the present invention there is provided a method of monitoring hygienic condition of an individual. The method comprises: receiving from a sensor mounted on the individual signals pertaining to a hygienic activity of the individual or lack thereof; receiving proximity data including a
15 proximity event between the individual and a patient or a medical device; and determining time window encompassing both the hygienic activity and the proximity event.

 According to some embodiments of the invention the sensor is a chemical sensor.
 According to some embodiments of the invention the sensor is an optical sensor.
20 According to some embodiments of the invention the sensor is a mechanical sensor.

 According to some embodiments of the invention the receiving the proximity data comprises receiving signals generated by the medical device.

 According to some embodiments of the invention the receiving the proximity data comprises receiving signals reflected by the medical device.

25 According to some embodiments of the invention the receiving the proximity data comprises optically scanning the environment to determine a location of the individual and a location of at least one the patient and the medical device.

 According to an aspect of some embodiments of the present invention there is provided a method of analyzing a regiment of hand hygiene for a plurality of individuals
30 in a medical facility. The method comprises: receiving from a plurality of monitoring systems data pertaining to hand cleansing events of the individuals, and classified contact events between the individuals and patients and/or medical devices; at a central

computation server, analyzing the events to determine, for each individual, whether two contact events are separated by at least one hand cleansing event, and issuing report regarding the analysis.

According to some embodiments of the invention the method comprises
5 calculating a medical facility hand hygiene score based on the analysis.

According to an aspect of some embodiments of the present invention there is provided a method of ranking a plurality of medical facilities. The method comprises calculating the medical facility hand hygiene score for each medical facility, thereby providing a plurality of scores, and ranking the medical facilities according to the scores.

10 According to an aspect of some embodiments of the present invention there is provided a method of monitoring. The method comprises: scanning a scene of a medical facility to provide range data arranged gridwise over a plurality of picture elements, processing the range data to monitor contact events between an individual and a medical treatment device or a patient, analyzing the contact events to determine productivity of
15 the individual.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention,
20 exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a
25 combination thereof. Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

For example, hardware for performing selected tasks according to embodiments
30 of the invention could be implemented as a chip or a circuit. As software, selected tasks according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system.

In an exemplary embodiment of the invention, one or more tasks according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIG. 1 is a schematic illustration of a monitoring system, according to some embodiments of the present invention;

FIGs. 2A-C are schematic illustration of a mapping process, according to some embodiments of the present invention;

FIG. 3 is a flowchart diagram describing a map updating procedure according to some embodiments of the present invention;

FIG. 4 is a flowchart diagram of a method suitable for monitoring a condition of a medical environment, according to some embodiments of the present invention;

FIG. 5 is a flowchart diagram of a method suitable for monitoring a hygienic condition of an individual, according to some embodiments of the present invention; and

FIG. 6 is a flowchart diagram of a method suitable for monitoring a hygienic condition of an individual, according to some embodiments of the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to monitoring and, more particularly, but not exclusively, to a method and system for monitoring activity, *e.g.*, hygienic activity of an individual.

5 Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various
10 ways.

Computer programs implementing the technique of the present embodiments can commonly be distributed to users on a distribution medium such as, but not limited to, a floppy disk, a CD-ROM, a flash memory device and a portable hard drive. From the distribution medium, the computer programs can be copied to a hard disk or a similar
15 intermediate storage medium. The computer programs can be run by loading the computer instructions either from their distribution medium or their intermediate storage medium into the execution memory of the computer, configuring the computer to act in accordance with the method of this invention. All these operations are well-known to those skilled in the art of computer systems.

20 The technique of some embodiments of the present invention can be embodied in many forms. For example, it can be embodied in on a tangible medium such as a computer for performing the method operations. It can be embodied on a computer readable medium, comprising non-volatile computer readable instructions for carrying out the method operations. In can also be embodied in electronic device having digital
25 computer capabilities arranged to run the computer program on the tangible medium or execute the instruction on a computer readable medium.

Referring now to the drawings, FIG. 1 is a schematic illustration of a monitoring system **10**, according to some embodiments of the present invention. System **10** optionally and preferably includes a range detection system **12** configured for scanning a
30 scene **14** and provide range data corresponding to the scene. Scene **14** is preferably a medical environment, such as, but not limited to, a hospital room, a intensive care units, neonatal intensive care units, nursing homes, ambulatory care clinics, dialysis units,

cardiac catheterization units, surgical suites, isolations rooms, burn centers, skin grafting centers or the like. The environment **14** is typically occupied by a patient **16**, and one or more individuals **18** such as a medical practitioner or a guest. Other objects and devices may also be present in environment **14**. When environment **14** is a medical environment, *e.g.*, a hospital room, these objects may include at least one of: a medical device **34** positioned nearby patient **16**, a medical device **36** in contact with patient **16**, a hand cleansing device **22** (either wall-mounted or mobile), a support structure **32** and the like. In the schematic illustration of FIG. 1, which is not to be considered as limiting, medical device **34** is shown as an infusion bag, medical device **36** is shown as an attachable patch, and support structure **32** is shown as a hospital bed, but other types of medical devices, support structures, as well as other objects are also contemplated.

A non-exhaustive list of objects that may be present in environment **14** includes, a audiometer, a sterilizer, a bed pan, a urinal, a blood drawing chair, a blood pressure monitor, a bowl, a basin, a bucket, a cabinet, a cart, a casting equipment, a catheter tray, a centrifuge, a chair, a cholesterol monitor, a colposcope, a containment system, a couches, a recovery crib, a cryosurgical equipment, a defibrillator, a diagnostic station, a dispenser, an ECG monitor, ECG electrodes, electrosurgery accessories, an electrosurgery generator, a endoscope, a endoscopy video system, a exam table, a fetal monitor, a furniture, a medical gel warmer, a glucose monitor, a hamper, a height rod, a hemoglobin test, a holter monitor, a illuminator, an infantometer, a INR testing instrument stand, a instrument table, a instrument tray, a instrument, a IV pole, a jar, a cup, a laryngoscope, a lift, a lighting mattresses, a overbed table, a patient monitor, a patient positioning equipment, a phlebotomy cabinet, a pinwheel, a pressure infusion bag, a privacy screen, a pulse oximeter, a recliner, a reflex hammer, a refrigerator, a freezer, a respiratory analyzer, a restraint board, a room signal flag, a scale, a sharps container, a smoke evacuator, a sink, a suction device, a spirometer, a stadiometer, a step stool, a sterilization tray, a sterilization basket, a stethoscope, a stool, a stress test, a thermometer, a transport chair, a transport stretcher, a trapeze, a trash can, a treadmill, a ultrasound device, a vital signs monitor, a wall desk, a wall socket, a warmer, a water distiller and a wheelchair.

The range data provided by system **12** are arranged gridwise over a plurality of picture elements (*e.g.*, pixels). Preferably, but not necessarily, the picture elements are

devoid of any color data and any grayscale data, so as to protect the visual privacy of patient **16** and/or individual **18**.

Range detection system **12** can employ any known range detection technique, including active illumination technique and passive techniques. Active illumination techniques suitable for the present embodiments including, without limitation, laser strip techniques [A. Clark, M. Wallace, and G. L. Pronzato, "Measuring range using a triangulation sensor with variable geometry," IEEE Trans. Rob. Autom. 14, 60–68 (1998)], laser propagation time techniques [M.D. Adams, "Lidar Design, Use and Calibration Concepts for Correct Environmental Detection", IEEE Transactions on Robotics and Automation, Vol 16(6), December 2000], time-of-light (ToF) sensing techniques [A. Kolb, E. Barth and R. Koch: "ToF-Sensors: New Dimensions for Realism and Interactivity," Proc. IEEE Comp. Soc. Conf. on Computer Vision and Pattern Recognition (CVPR), 1518-1523 (2008)], profile from focus techniques [A. M. Loh and P. D. Kovesi, "Estimation of surface normal of a curved surface using texture," In Proc. of the 7th Australian Pattern Recognition Society Conference – Digital Image Computing: Techniques and Applications, 155–164 (2003)], and structured light techniques [David Catuhe "Programming with the Kinect for Windows Software Development Kit, Add gesture and posture recognition to your applications", Microsoft Press].

Also contemplated are depth from motion techniques [R. C. Bolles, H. H. Baker, D. H. Marimont, "Epipolar-plane image analysis: An approach to determining structure from motion," International Journal of Computer Vision 1(1): 7-55 (1987)], stereoscopic techniques [E. Trucco, A. Verri, "Introductory techniques for 3D computer vision," Prentice Hall, 140 – 143 (1998)].

Additionally contemplated are the techniques disclosed in Irshad Ali, 2009, "Detection and Tracking of Multiple Humans in High-Density Crowds," Thesis, Department of Computer Science Engineering, Asian Institute of Technology School of Engineering and Technology, Thailand; Bo Wu and Nevatia R., Detection of Multiple Partially Occluded Humans in a Single Image by Bayesian Combination of Edgelet Part Detectors, In 10th IEEE International Conference on Computer Vision, ICCV'05, Volume 1, Pages 90-97, 2005; Saad M. Khan and Mubarak Shah, A Multiview Approach to Tracking People in Crowded Scenes using a Planar Homography

Constraint, In IEEE International Conference on Computer Vision, ECCV'06, Volume 3954, Pages 133-146, 2006; Cheriyyadat, A.M., Bhaduri B.L. and Radke R.J., Detecting multiple moving objects in crowded environments with coherent motion regions, in IEEE Computer Society Conference, Pages: 1-8, 2008; and Marchand E., Bouthemy P.,
5 Chaumette F. and Moreau V., Robust real-time visual tracking using a 2D-3D model-based approach. In Proc. Of the 7th IEEE International Conference on Computer Vision, ICCV'99, Volume 1, Pages 262–268, Kerkira, Greece, September 1999; C. Regazzoni, A. Cavallaro, Y. Wu, J. Konrad, A. Hampapur, Video Analytics for Surveillance: Theory and Practice, IEEE Signal Processing Magazine, September 2010; Fisher, J.
10 2003. "A Line Calling System to Improve Line Umpire Performance." In, ed. Stuart Miller. International Tennis Federation; Kai-Che Liu, Fu-Chiang Jan, Wen-Chao Chen, Cheng-Feng Wu, Tsu-Han Chen, Qi Wu, "Example-Based Two-Dimensional to Three-Dimensional Image Conversion Method, Computer Readable Medium Therefore, and System", U.S. Published Application No. 2010014781; Chien-Hung, Chen, Chun-Chieh
15 Chiu and Yue-Li Chao, "Method for generating 3D image", U.S. Published Application No. 2011090318; and Barak Katz and Oded Zahavi, method and system for extracting three-dimensional information, International Publication No. WO2012029058, the contents of which are hereby incorporated by reference.

Range detection system **12** can also employ other technologies, optionally and
20 preferably in combination with the above techniques, which technologies include, but are not limited to, WiFi location technology, Bluetooth, Ultra wideband and RF tagging technologies, and sensor technologies such as, but not limited to, accelerometers and gyroscopes.

Volume sensors can also be employed, for example, for determining presence of
25 individuals in areas without imaging coverage.

Also contemplated are commercially available depth sensors, such as, but not limited to, DepthSense® 311 by Softkinetic Ltd., and SR4000 or SR4500 by MESA Imaging Ltd.

In various exemplary embodiments of the invention range detection system **12**
30 employs active infrared illumination technique for generating the range data. In some embodiments of the present invention system **12** is or comprises a structured illumination Kinect camera such as the camera installed in the commercial Xbox™ and

Xbox 360™ systems, and/or TOF camera such as the camera installed in the commercial Xbox One™ system, all of which are marketed by Microsoft Corporation.

In some embodiments of the present invention system **12** comprises two or more range detection systems that operate according to different principles. For example,
5 system **12** can include a structured illumination system and a TOF system that are viewing the environment simultaneously. The advantage of these embodiments is that they reducing light ambiguity among different sensors.

When system **12** comprises a camera that can provide range data as well as color or grayscale data, the color or grayscale sensors in the camera are optionally and
10 preferably blocked so as to prevent the camera from providing any color data and any grayscale data.

System **10** optionally and preferably comprises a data processing system **20** configured for processing the range data provided by system **10**. System **20** can be dedicated circuitry or, in some embodiments, a general purpose computer, configured
15 for receiving the range data, and executing at least some of the operations described herein. When range detection system **12** provides range imaging data, data processing system **20** optionally and preferably removes from each picture-element of the data any color data or grayscale data.

Thus, the present embodiments contemplate processing of a plurality of picture
20 elements wherein each picture-element stores a range value, but does not store light intensity value, neither in the form of a grayscale value nor in the form of a plurality of intensity values corresponding to a respective plurality of colors (*e.g.*, a plurality of RGB values). Such exclusive range data can either be provided directly by system **12** or be prepared from the data received by system **12**.

25 System **12** or system **20** optionally and preferably builds a skeleton range image of patient **16** and individual **18** from the range data. Since there is no light intensity information in the range data, patient **16** and optionally also individual **18** cannot be identified from the depth image or skeleton range image. However, it was found by the present Inventors that such an image can be processed to classify skeleton movements
30 and/or postures, for the purpose of monitoring the hygienic activity of an individual in the scene. In particular, the present Inventors found that classification of hand gestures

allows identifying touch events and also hand hygiene operations performed by the individual.

Preferably, one or more objects or individuals within environment **14** are tagged by markers **26** that are detectable by system **12**, and also identifiable by system **20**. The tagged objects can include clothing, glove boxes, medical devices, textiles, towels, bed lining, hand cleansing devices, support structures, wall-mounted sockets, computers, monitors, doors, door handles, furniture items *etc.*

The markers can be of any machine-readable type known in the art, such as, but not limited to, a barcode (*e.g.* a QR tag), an RFID and an RTLS. When the marker **26** is a barcode, it is adapted to be identified by the wavelength detectable by system **12**. For example, when system **12** employs active infrared illumination technique, the barcode is adapted to be readable under infrared illumination.

The markers can optionally and preferably be objects having a unique three-dimensional shape (*e.g.*, star, diamond, chevron, toothed stripe, *etc.*). The spatial resolution of the marker's shape is compatible with the identifiable resolution of system **12** so that the structural features of the marker are acquired while system **12** scans scene **14**. The structural characteristics of the three-dimensional shape, optionally and preferably including its size, can be stored in a computer readable library accessible by system **20**. Once an image of scene **14** is obtained, system **20** identifies the marker by extracting its structural characteristics from the image and comparing to the entries in the library.

The marker can alternatively or additionally be coated with a material having a sufficiently high (*e.g.*, higher than that of the object or individual being tagged by the marker) infrared reflectivity. These embodiments are particularly useful when system **12** employs active infrared illumination technique for generating the range data. Infrared reflective materials suitable for the present embodiments are disclosed in U.S. Patent Nos. 3,711,176, 5,103,337, 6,174,360, in U.S. Published Application No. 20030215627, and in Ashwini K. Bendiganavale and Vinod C. Malshe, "Infrared Reflective Inorganic Pigments", Recent Patents on Chemical Engineering, 2008, 1, 67-79, and is commercially available from 3M™, USA.

The marker can be mounted (*e.g.*, attached) on the external surface of the respective object. When the object is other than the skin of the individual, the marker

can be embedded in the external surface of the object or be an integral part of the surface of the object. The marker can also be mounted nearby the object, for example, on a wall nearby a socket, or on a pillow nearby the head of the patient. The respective object can also serve as marker by itself, provided its three-dimensional shape is stored in the library. The marker can also be attached to the body or clothing of patient **16** so as to allow system **20** to identify certain parts of the patient's body. Typically, but not necessarily, the marker is attached to the skin or clothing at the vicinity of a region having a high likelihood to contain infection, or a high likelihood to cause infectious disease once becoming infected. Such regions are typically near wound dressings, open wounds, near the entry points of minimally invasive medical devices into the body, and near natural openings of the body.

In some embodiments of the invention data processing system **20** monitors the hygienic activity of individual **18** in scene **14**, and in some embodiments of the invention data processing system **20** identifies physical contact between individual **18** and patient **16** and/or between individual **18** and objects in scene **14** and/or between patient **16** and/or objects in scene **14**.

Hand hygiene activities identifiable by system **20** include, but are not limited to, hand cleansing, gloves wearing and gloves removals. Hand cleansing can be detected, for example, by identifying rubbing motion of individual. The identification of rubbing motion can be preceded or replaced by identification of a contact between the individual and a hand cleansing device.

Glove wearing can be detected, for example, by identifying finger stretching of a first hand while the fingers of the second hand are not stretched and are in proximity to the wrist of the first hand. The identification of glove wearing can be preceded or replaced by identification of a contact between the individual and a glove box. Glove removal can be identified by identifying motion of the palm of one hand over the palm of the other hand, from the wrist to the fingers. The identification of glove removal can be followed or replaced by identification of a throwing gesture near a waste container. The identification of glove wearing and/or removal can be context-based identification. For example, identification of a medical procedure performed by individual **18** that is likely to precede or follow glove wearing and/or glove removal, can be weighed by system **20** in the determination that a particular gesture corresponds to glove wearing

and/or glove removal. For example, when system **20** identifies an operation of fluid extraction performed by individual **18**, and then identifies a gesture that may correspond to glove removal, system **20** can determine that it is likely that a glove removal event has been identified. When system **20** identifies a gesture that may correspond to glove wearing, and then identifies an operation of fluid extraction performed by individual **18**, system **20** can determine that it is likely that a glove wearing event has been identified.

Generally, a library of gestures corresponding to a plurality of hand hygiene activities can be stored in the memory of system **20** and the identification can be done by comparing the skeleton range image of individual **18** to the gestures of the library.

Physical contact between individuals and/or between an individual and an object can be identified directly and/or by motion analysis. For example, system **20** can analyze the motion characteristics of an individual in the direction of an object or another individual and also analyze the proximity between the two individuals or between the individual and the object.

In some embodiments of the present invention data processing system **20** identifies operation of hand cleansing device **22** by individual **18**. This can be done by identifying proximity events between individual **18** and device **22**. System **20** can also identify contact events between individual **18** and device **22**. When a proximity or contact event is sufficiently prolonged, namely when individual **18** remains in close proximity to device **22** for a time-period that is above a predetermined time-period threshold, system **20** can identify that individual **18** operates device **22**. The time-period threshold can be set according to a hand cleansing protocol that is in effect at the facility employing system **10**.

The location of device **22** can be determined in more than one way. In some embodiments, system **20** is provided with information regarding the location of device **22** within the environment **14** *e.g.*, during calibration. In these embodiments, system **20** employs image processing to monitor the motion of individual **18** relative to the input location of device **22**. In some embodiments, system **20** identifies the location of device **22** by image processing. For example, a marker **26** can be attached to or embedded in device **22** to allow its identification. In these embodiments system **20** employs image processing to determine the locations of individual **18** as well as device **22** so as to monitor the motion of individual **18** relative to device **22**.

Device **22** can also be configured to transmit signals pertaining to its operation. For example, device **22** can transmit a signal upon dispensing of cleansing fluid, *e.g.*, a disinfection gel or the like. In these embodiments, system **10** optionally and preferably receives the signals from device **22**, for example, via a communication system **24**, and
5 determine that individual **18** operates device **22** based on these signals. These embodiments can be combined with the above image processing technique so as to reduce false positive identification. Communication system **24** can employ any type of communication, including, without limitation, WiFi, NFC, Bluetooth, RF, infra red and the like.

10 Optionally, system **20** identifies individual **18** while individual **18** operates device **22**. Since the range image is typically a skeleton range image that does not include light intensity values, the identification is optionally and preferably by means of tagging. In these embodiments, marker **26** is attached to individual **18**. During the operation of device **22** individual **18** is identified by system **20** so that the hand cleansing
15 operation can be associated with a particular individual. In some embodiments of the present invention device **22** identifies the marker **26** on individual **18**. In these embodiments, marker **26** is adapted to be identified by the wavelength detectable by device **22**. For example, when device **22** can detect RF waves, marker **26** can be an RFID. Optionally, device **22** transmits the identification of individual to system **20**.

20 In some embodiments, a sensor **28** is mounted on individual **18**. Sensor **28** can be, for example, an alcohol tester that senses the presence of alcohol and transmits a signal responsively to the sensing. Alcohol testers are known in the art and are commercially available, for example, from Dart Sensors Ltd, England. Sensor **28** preferably has a unique ID that is associated with individual **18**. The signal transmitted
25 by sensor **28** can include binary information (*e.g.*, 1 for positive sensing and 0 for no-sensing). System **20** communicates with sensor **28**, *e.g.*, via communication system **24**, and determines whether individual **18** operates device **22** based on the binary information received from sensor **28**.

30 In some embodiments, sensor **28** comprises a movement detector such as a gyroscope and/or accelerometer. In case there is a change in the alcohol level the alcohol sensor sense as well as and there is a movement signature that can be related to a rubbing hands procedure detected by the movement sensors, it can be concluded that

individual **18** indeed performs a alcohol hand hygiene procedure. In order to improve reduce energy consumption, the movement detector can be operational at all times while being attached to individual **18**, but the alcohol sensing capability is preferably switched off. In these embodiments sensor **28** optionally and preferably comprises a controller.

5 When the movement detector detects a movement that resembles a hand rub movement, the controller switches on the alcohol sensing capability. The alcohol sensor then senses the surroundings and by comparing the current alcohol level in the air to a baseline alcohol level, it can determine whether a hand hygiene procedure is performed. The baseline can be obtained by switching the alcohol sensor periodically in situations that
10 the motion detector does not identify hand rub movement signature. Since sensor **28** is attached to a specific individual, hand rubbing motion that is specific to that individual can be recorded on a memory medium of sensor **28** during calibration.

The data from sensor **28** can be transmitted to system **20** or directly to a central server **56** or it can be transmitted and stored and processed on the Smartphone of the
15 individual. In some embodiments of the present invention sensor **28** is plugged directly to the Smartphone. In this case some of the computational procedures, analytics and storage can be performed on the mobile device and only a portion of the data can be transmitted to the central server by the mobile device.

In some embodiments, sensor **28** also provides location information, so that once
20 the sensor decides that there has been an alcohol hand hygiene procedure, it can signal to system **20** also the location of individual **18** at which the procedure was performed.

In embodiments in which sensor **28** is employed, it is not necessary for system
10 to include range detection system **12**, since information pertaining to the activity of individual **18** can be provided by sensor **28**. Nevertheless, in various exemplary
25 embodiments of the invention system **10** comprises range detection system **12** and is also communicating with sensor **28**. In this respect, combination of range detection system **12** and sensor **28** can be used to aid the tracking of a certain individual within a plurality of individuals in the same scene. This can be done by correlating the signals received from the motion detectors of sensor **28** with the motion characteristics extracted
30 by system **20** from the range data.

System **10** can therefore relate between an identified individual **18** and location and time at which the identified individual **18** operates device **22**. System **10** can

optionally and preferably also evaluate the quality of the operation by comparing the duration of the operation with hand cleansing protocol that is in effect at the facility employing system **10**.

System **20** can be fed with information regarding how many times, and/or at
5 which times, individual **18** should operate device **22** during the presence of individual **18** in the environment **14**. System **20** can log the events at which operations of device **22** are identified and compare the number of events to that information. Based on the comparison system **20** can estimate if individual **18** fulfils the protocol requirements.

In some embodiments of the present invention system **20** identifies access of
10 individual **18** to patient **16**, and determines a time window encompassing both the hygienic activity and the access. These embodiments can be employed for determining whether individual **18** has cleaned his hands before accessing patient **16**, and also after leaving the patient's bed. Identification of access of individual **18** to patient **16** can be achieved by processing the image and identifying motion of individual **18** in the
15 direction of patient **16** and/or proximity event between individual **18** and patient **16**.

As a representative example, when individual **18** belongs to a medical personnel at a hospital room, system **10** can be fed with information that individual **18** should operate device **22** before approaching patient **16**, or while moving from one patient to the other. Based on the locations of individual **18** and patient **16** system **10** determines
20 the distance between individual **18** and patient **16** and the duration individual **18** spends near patient **16**. System **20** can also determine whether or not individual **18** operates device **22** immediately after entering the environment, and alert when individual **18** fails to do so.

In some embodiments a marker such as marker **26** is attached to the bed **32** of
25 patient **16**. In these embodiments, system **20** can identify marker **26** and can determine when individual **18** moves from one identified bed to the other. System **20** can then determine whether individual **18** operates device **22** before approaching the other patient and alert when individual **18** fails to do so.

In some embodiments of the present invention system **20** classifies the
30 interaction of individual **18** with patient **16**, and determines a time window encompassing both the hygienic activity and the interaction. The present embodiments contemplate several classes of interaction. A first class of interaction is a contact

between the hand of individual **18** and the skin of patient **16**. The first class of interaction can be further classified according to the location on the skin at which a contact was identified. Thus, one subclass is a contact with a predetermined organ (*e.g.*, face, lumbus), another is a contact with a wound or other type of opening in the skin. A second class of interaction is a contact between the hand of individual **18** and a medical device **34** nearby patient **16**. A third class of interaction is a contact between the hand of individual **18** and a medical device **36** that is in contact with the skin of patient **16**. As a representative example, system **20** can identify when a medical personnel member replaces the patient's urine bag by identifying a proximity event or contact between the hand of the medical personnel member and the urine bag.

The above classes of interaction can be identified by image processing, preferably with the aid of one or markers such as marker **26**. Specifically, a marker can be attached to the skin of patient **16**, to allow system **20** to employ image processing so as to determine a proximity event or contact between the hand of individual **18** and the skin near the marker. Similarly, a marker can be mounted on or be an integral part of device **34** and/or **36** to allow system **20** to employ image processing so as to determine a proximity event or contact between the hand of individual **18** and device **34** and/or **36**.

Depending on the identified medical device, the above classification can be used to determine whether individual **18** performs an aseptic task, such as, but not limited to, oral care, dental care, aspiration of secretion, skin lesion care, wound dressing, subcutaneous injection, catheter insertion, opening a vascular access system, preparation of food, preparation of medication, and preparation of dressing sets. In various exemplary embodiments of the invention system **20** determines a time window encompassing both the hygienic activity and the aseptic task, for example, for the purpose of determining whether individual **18** has operated device **22** before performing the aseptic task. Verification of identification of aseptic task can be archived by monitoring the activity of individual **18** before or after an event that is candidate to be aseptic task is identified. For example, when system **20** identifies a glove wearing before such a candidate event and/or glove removal after such a candidate event, system **20** can determine that it is likely that the candidate event is an aseptic task performed by individual **18**.

Depending on the identified medical device, the above classification can be used to determine whether individual **18** is exposed to body fluids of the patient. Such exposure can occur, for example, during oral care, dental care, secretion aspiration, skin lesion care, wound dressing, subcutaneous injection, drawing and manipulating of a fluid sample, opening draining system, endotracheal tube insertion, endotracheal tube removal, clearing up urines, clearing up faeces, clearing up vomit, handling waste (*e.g.*, bandages, napkin, incontinence pads), cleaning of contaminated material, and cleaning of areas, such as, but not limited to, lavatories and medical instruments. In various exemplary embodiments of the invention system **20** determines a time window encompassing both the hygienic activity and the exposure to body fluid, for example, for the purpose of determining whether individual **18** has operated device **22** after exposure to body fluids.

In various exemplary embodiments of the invention system **10** is configured to monitor whether the requirements set forth by the hand hygiene protocol published by the World Health Organization known as “five moments for hand hygiene” (see, *e.g.*, Sax H, et al., J Hosp Infect 2007, 67(1): 9-21). According to this protocol hand cleansing is executed at least at the following moments: (i) before patient contact, (ii) before an aseptic task, (iii) after body fluid exposure risk, (iv) after patient contact, and (v) after contact with patient surroundings. Therefore, system **10** optionally and preferably issues an alert when a contact between individual **18** and patient **16** has been identified before or sufficiently long time after (*e.g.*, above 5 minutes after) individual **18** has operated device **22**, and/or when individual **18** has not operated device **22** within a sufficiently short time-interval (*e.g.*, less than 5 minutes) after such contact. System **10** optionally and preferably issues an alert when system **20** identifies that individual **18** is performing or is about to perform an aseptic task before or sufficiently long time after (*e.g.*, above 5 minutes after) individual **18** has operated device **22**. System **10** optionally and preferably issues an alert when system **20** identifies that individual **18** was exposed to body fluid of patient **16** but has not operated device **22** immediately thereafter. System **10** optionally and preferably issues an alert when system **20** identifies a contact between individual **18** and the objects near patient **16**, but does not identify that individual **18** operates device **22** within a sufficiently short time-interval (*e.g.*, less than 5 minutes) after such contact.

In any of the above embodiments, when system **20** determines that the requirements of the hand cleansing protocol that is in effect at the facility employing system **10** are not fulfilled, system **10** can issue an alert signal, using an alert device **30**. The alert can be addressed to individual **18**, for example, by sending an alert signal to a
5 mobile device (*e.g.*, Smartphone, a designated beeper, a designated visual indicator display, *etc.*) carried by individual **18**, and/or to a central monitoring location that supervises fulfillments of procedures and protocols. System **20** can also log statistics pertaining to hygienic activity, store the statistics on a non-transitory computer readable medium, and/or to transmit the statistics to a central computation server. For example,
10 system **20** can log events at which hand cleansing is identified, and also log failures to perform hand cleansing for further analysis.

The events collected by system **20** can be used for analyzing the regiment of hand hygiene for all or some of the individuals in the medical facility. Thus, a plurality of systems such as system **10** can be deployed in the facility (*e.g.*, at separate hospital
15 rooms). Each system can transmit data pertaining to hand cleansing events of the individuals, and also data pertaining to classified contact events between the individuals and the patients and/or individuals and medical devices, as further detailed hereinabove. At a central computation server **56**, the events can be analyzed to determine, for each individual, whether two contact events are separated by at least one hand cleansing
20 event. Server **56** can be a local server or it can be a cloud computing resource of a cloud computing facility, in which case server **56** communicates with system **10** via a communication network.

A report regarding the analysis can be then be issued and displayed on a display device or stored on a computer readable medium. In some embodiments of the present
25 invention the server also calculates a score based on the analysis. For example, the score can reflect the number of identified failures to perform hand cleansing (a penalty score), or the number of identified hand cleansing events (a credit score) or a combination of a penalty score and a credit score as known in the art. For example, denoting the penalty score by P and the credit score by C , where P and C are non-negative and at most 1, a
30 total credit score can be proportional to $P + (1-C)$. The score can be used, for example, for ranking a plurality of medical facilities.

In some embodiments of the present invention the hand hygiene performances and achievements are collected from different healthcare units and facilities, substantially in real time. The server can store and analyze the collected data, for example, from the standpoint of the five moments for hand hygiene (5MOHH) protocol.

5 The server can track changes in the amount of Healthcare-associated Infections (HAI) of each facility and the like. Once all this data is analyzed, this information (the entire information, or only part of it, based on the definitions each healthcare facility will choose) can be sent back to the facilities for presentation on interactive screens placed in different locations in the facilities. The information can also be presented to the

10 individuals and patient visitors in the facilities. The information can be in the form of graphs, graphical images, text, animations and the like.

A facility employing system **10** can present information pertaining to the analysis on displays in its unit wards. Each display can present the 5MOHH performances, 5MOHH hand hygiene counters, and hand hygiene statistics of a specific unit, optionally

15 and preferably in real time, compared with the relevant performances and achievements of other facilities that use system **10**. In such a way the employees and visitors can see how they contribute to the performances of the local facility as compared to other facilities. Creating a constructive positive competition among the healthcare facilities allows to increase compliance with the 5MOHH hand hygiene procedures, to keep the

20 workers awareness to the hand hygiene always high, and eventually to reduce HAI and infections rate low. Healthcare providers and workers can be rewarded for their proper hand hygiene improvement and achievements with accordance to the 5MOHH standard. Such interactive platform can keep the employees and visitors awareness to the 5MOHH standard for a long period of time, and can improve healthcare employee compliances

25 with the 5MOHH standard. The different data types presented on the displays can be also be presented or sent to employee's mobile phones or to their personal computers.

The events collected by system **20** can also be used for determining the productivity of individual **18**. For example, the number of contacts between individual **18** and patients and/or the number of contacts between individual **18** and medical

30 devices over a time period (*e.g.*, several hours) can be determined. The numbers can be compared to a predetermined threshold or to the average numbers obtained for other individuals in the same or other facilities. Based on the comparison, the productivity of

individual **18** can be determined. Optionally, a productivity score that relates to the number of contacts is calculated and assigned to individual **18** to quantify the productivity. The procedure can be executed for a plurality of individuals that are employed in the same or different facility, and the individuals can be ranked according to their productivity scores.

In some embodiments of the present invention system **20** identifies points of contact between an individual (e.g., individual **18** patient **16**) and objects in scene **14**, and maps these points of contact over scene **14**. A representative example of such a mapping is illustrated in FIGs. 2A-C. Shown in FIGs. 2A-C is a map **40** of scene **14** including some objects **42**, **44** and **46**, any one of which can be any of the objects described above. Objects **42**, **44** and **46** are detectable by system **12**, hence can be mapped by system **20** in relation to the borders of scene **14**. Objects **42**, **44** and **46** can be detectable either by virtue of their surface reflectivity and/or by means of markers such as maker **26** (not shown, see FIG. 1) that may be attached to the external surface of the respective objects. Once system **20** identifies a contact between the individual and one of objects **42**, **44** and **46**, system **20** preferably marks the point of contact on map **40**. Such markings are shown in FIG. 2A at **48** and **50**.

Objects **42**, **44** and **46** can also be detectable by virtue of their height. The range image provided by system **12** can be analyzed to identify the floor level, and a contact between the individual and any object that has a height above the floor level which is above a predetermined height threshold can be marked. The predetermined height threshold can be zero in which case any contact between the individual and an object that is not at the floor level is marked.

Map **40** therefore represents the condition of the environment from the standpoint of infectious areas. Since hands collect bacteria at almost every touch and can move the bacteria from one place to another, increasing the number of hand contacts in a specific location increases the probability that this area may contain infection and bacteria. Thus, the shape, color and/or size of the markings on map **40** is optionally and preferably selected based on a statistics regarding the number of identified contacts with or near the respective point-of contacts. For example, a location at which a higher number of contact events can be marked with darker color, and a location with fewer number of contact events can be marked with a brighter color. The shape, color and/or

size of the markings on map **40** can also optionally and preferably vary with time, according to an expected bacteria growth rate.

Map **40** can be used in more than one way.

In some embodiments, system **20** transmits map **40** to a central location thereby providing a report regarding the condition of the respective environment. In some
5 embodiments, system **20** tracks a cleansing device **52** in the scene and updates map **40** responsively to the tracking. Cleansing device **52** can be a hand held cleansing tool, or controlled propelled device or an autonomous device, such as a robot or a robotic arm. Cleansing device **52** preferably comprises an antiseptic or antibacterial material, that can
10 be in the form of a fabric loaded with an antiseptic or antibacterial agent, an aerosol device having container filled with the antiseptic or antibacterial agent, and the like. When system **20** identifies contact between cleansing device **52** and one of the marked points of contacts (FIG. 2B), system **20** removes the respective marking (marking **48** in the present example) from map **40** (FIG. 2C).

15 When map **40** is provided to an autonomous system, the autonomous system can react to the contact history. System **20** can detect period of times where there are no visitors or other individuals in the environment. In order to allow the robot or autonomous system perform its duties without interacting with the individuals, the autonomous system or robot can be programmed in such a way that it starts to perform
20 its duties only after all the individuals leave the environment. Alternatively the autonomous system can decide where to perform its disinfection operations in areas that are sufficiently far from the location of the individuals.

A flowchart diagram describing such a procedure is provided in FIG. 3. At **60**, hand and/or body contacts are detected, at **61** the contact points are related to locations
25 in the environment, at **62** a map is generated, at **63** a cleaning procedure is employed and at **64** the map is updated.

In these embodiments, cleansing device **52** is identifiable by system **20**. For example, device **52** can be made of a material and shape detectable by system **12**, and system **20** can identify device **52** by means of image processing as further detailed
30 hereinabove. Alternatively or additionally a marker such as marker **26** can be mounted on device **52**, so that device **52** is identified through the marker attached thereto. In some embodiments, device **52** is equipped with an indoor position sensing system that

allows device **52** to transmit its location to system **20**. System **20** can receive the location information from device **52**, register the information with respect to map **40** and update map **40** accordingly.

In some embodiments of the present invention a motion detector is mounted on or attached to cleansing device **52**. The motion detector can transmit signals to system **20** that can process these signals to determine the location of device **52** based on its motion characteristics. Preferably, the data from the motion detector is correlated with the data from system **12**. Such correlation can provide a more accurate determination of device **52** in the environment.

When cleansing device **52** is a controlled propelled device, or an autonomous device or a robotic device, system **10** optionally and preferably signals device **52**, for example, via a control circuit **54** (see FIG. 1), to access and disinfect the points of contact at **48** and **50**.

Map **40** can optionally and preferably be overlaid on top of a 3D model of the environment, or on top of an image acquired by one or more of the cameras views. Map **40** can be used as a directive to healthcare personal to the location where infection may be exist and grow. An individual that cleans the respective environment can receive a signal from system **10** when the individual is near a location that corresponds to a marked spot on map **40**.

FIG. 4 is a flowchart diagram of a method suitable for monitoring a condition of a medical environment, according to some embodiments of the present invention. The method begins at **70** and continues to **71** at which a map of the environment such as map **40** is obtained. The map comprising locations in the environment identified as being infected. The method continues to **72** at which tracking data pertaining to motion of a cleansing device, such as device **52** in relation to the locations is received. The method continues to **73** at which the map is updated based, at least in part, on the tracking data, as further detailed hereinabove. The method ends at **74**.

In some embodiments of the present invention the method generates the map by monitoring points of contact between individuals and objects in the environment. In some embodiments of the present invention the method transmits the updated map to a central computation server. In some embodiments of the present invention the method receives the tracking data by receiving signals generated by the cleansing device. In

some embodiments of the present invention the method receives the tracking data by receiving signals reflected by the cleansing device. In some embodiments of the present invention the method receives the tracking data by optically scanning the environment to determine a location of said cleansing device. In some embodiments of the present invention the cleansing device is a robotic cleansing device and the method controls the robotic cleansing device to access and disinfect the points of contact.

FIG. 5 is a flowchart diagram of a method suitable for monitoring a hygienic condition of an individual, according to some embodiments of the present invention. The method begins at **80** and continues to **81** at which signals pertaining to a hygienic activity of the individual or lack thereof are received from a sensor mounted on the individual. The sensor can be of any type including, without limitation, a chemical sensor, an optical sensor and a mechanical sensor. In some embodiments of the present invention the sensor is sensor **28** as further detailed hereinabove.

The method continues to **82** at which proximity data including a proximity event between the individual and a patient or a medical device is received. The method can receive the proximity data by receiving signals generated or reflected by the medical device. The method can receive the proximity data by optically scanning the environment to determine a location of the individual and a location of the patient and/or the medical device, as further detailed hereinabove. The method continues to **83** at which a time window encompassing both the hygienic activity and the proximity event is determined, as further detailed hereinabove. The method ends at **84**.

FIG. 6 is a flowchart diagram of a method suitable for analyzing a regiment of hand hygiene for a plurality of individuals in a medical facility, according to some embodiments of the present invention. The method begins at **90** and continues to **91** at which data pertaining to hand cleansing events of the individuals, and classified contact events between the individuals and patients and/or medical devices is received from a plurality of monitoring systems, as further detailed hereinabove. The method continues to **92** at which the events are analyzed, for example, at a central computation server, to determine, for each individual, whether two contact events are separated by at least one hand cleansing event. The method continues to issue a report regarding the analysis issued. The method optionally and preferably continues to **93** at which a score is calculated based on the analysis. The method is optionally and preferably executed for a

plurality of medical facilities. In these embodiments, the method can continue to **94** at which the medical facilities are ranked according to the scores. The method ends at **95**.

As used herein the term "about" refers to $\pm 10\%$.

The word "exemplary" is used herein to mean "serving as an example, instance
5 or illustration." Any embodiment described as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

The word "optionally" is used herein to mean "is provided in some embodiments and not provided in other embodiments." Any particular embodiment of the invention
10 may include a plurality of "optional" features unless such features conflict.

The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to".

The term "consisting of" means "including and limited to".

The term "consisting essentially of" means that the composition, method or
15 structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at
20 least one compound" may include a plurality of compounds, including mixtures thereof.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should
25 be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies
30 regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases "ranging/ranges

between” a first indicate number and a second indicate number and “ranging/ranges from” a first indicate number “to” a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

5 It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described
10 embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

 Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations
15 will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

 All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same
20 extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

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- [23] U.S. Patent No. 3,711,176

WHAT IS CLAIMED IS:

1. A monitoring system, comprising:
a range detection system configured for scanning a scene and to provide range data arranged gridwise over a plurality of picture elements; and
a data processing system configured for processing said range data to monitor hygienic activity of an individual in said scene.
2. The system of claim 1, wherein said picture elements are devoid of any color data and any grayscale data.
3. The system of claim 1, wherein said range detection system provides range imaging data, and said data processing system is configured for removing from each picture-element any color data or grayscale data.
4. The system according to any of claims 1-3, wherein said data processing system is configured to identify said hygienic activity during at least one time interval selected from the group consisting of (i) a time interval ending before said individual contacts a patient in said scene, (ii) a time interval ending before said individual performs an aseptic task, (iii) a time interval ending after said individual performs said aseptic task, (iv) a time interval beginning after said individual is exposed to a body fluid of said patient, (v) a time interval beginning after said individual contacts said patient, and (vi) a time interval beginning after said individual contacts objects nearby said patient.
5. The system according to any of claims 1-3, wherein said data processing system is configured to identify hand rubbing motion of said individual.
6. The system according to any of claims 1-3, wherein said data processing system is configured to identify glove wearing motion of said individual.

7. The system according to any of claims 1-3, wherein said data processing system is configured to identify glove removal motion of said individual.

8. The system according to any of claims 1-3, wherein said data processing system is configured to identify operation of a hand cleansing device by said individual.

9. The system according to any of claims 1-3, wherein said data processing system is configured to identify access of said individual to a patient in said scene, and to determine a time window encompassing both said hygienic activity and said access.

10. The system according to any of claims 1-3, wherein said data processing system is configured to classify interaction of said individual with a patient in said scene, and to determine a time window encompassing both said hygienic activity and said interaction.

11. The system according to any of claims 1-3, wherein said data processing system is configured to identify a medical treatment device in said scene, and contact events between said individual and said medical treatment device, and to determine a time window encompassing both said hygienic activity and said contact events.

12. The system according to any of claims 1-3, wherein said data processing system is configured to identify contact events between said individual and an organ of a patient in said scene, and to issue a notification when said contact events are not preceded by said hygienic activity.

13. The system according to any of claims 1-3, wherein said data processing system is configured to identify points of contact between said individual and objects in said scene, and to map said points of contact over said scene.

14. The system according to claim 11, wherein said data processing system is configured to track a cleansing device in said scene and to update said map responsively to said tracking.

15. The system according to claim 13, further comprising a control circuit configured to signal a robotic cleansing device to access and disinfect said points of contact.

16. The system according to any of claims 1-3, further comprising a communication system configured to communicate with a sensor mounted on said individual, and to receive from said sensor signals pertaining to hygienic activity or lack thereof, wherein said data processing system is configured for determining said hygienic activity based, at least in part, on said signals.

17. The system according to any of claims 1-3, wherein said data processing system is configured to log statistics pertaining to said hygienic activity and to store said statistics on a non-transitory computer readable medium and/or to transmit said statistics to a central computation server.

18. The system according to any of claims 1-3, wherein said data processing system is configured to identify contact events between said individual and a medical treatment device or a patient, and to analyze said contact events to determine productivity of said individual.

19. The system according to claim 4, wherein said data processing system is configured to identify hand rubbing motion of said individual.

20. The system according to claim 19, wherein said data processing system is configured to identify glove wearing motion of said individual.

21. The system according to any of claims 19-20, wherein said data processing system is configured to identify glove removal motion of said individual.

22. The system according to any of claims 19-21, wherein said data processing system is configured to identify operation of a hand cleansing device by said individual.

23. The system according to any of claims 19-22, wherein said data processing system is configured to identify access of said individual to a patient in said scene, and to determine a time window encompassing both said hygienic activity and said access.

24. The system according to any of claims 19-23, wherein said data processing system is configured to classify interaction of said individual with a patient in said scene, and to determine a time window encompassing both said hygienic activity and said interaction.

25. The system according to any of claims 19-24, wherein said data processing system is configured to identify a medical treatment device in said scene, and contact events between said individual and said medical treatment device, and to determine a time window encompassing both said hygienic activity and said contact events.

26. The system according to any of claims 19-25, wherein said data processing system is configured to identify contact events between said individual and an organ of a patient in said scene, and to issue a notification when said contact events are not preceded by said hygienic activity.

27. The system according to any of claims 19-26, wherein said data processing system is configured to identify points of contact between said individual and objects in said scene, and to map said points of contact over said scene.

28. The system according to claim 25, wherein said data processing system is configured to track a cleansing device in said scene and to update said map responsively to said tracking.

29. The system according to claim 27, further comprising a control circuit configured to signal a robotic cleansing device to access and disinfect said points of contact.

30. The system according to any of claims 19-29, further comprising a communication system configured to communicate with a sensor mounted on said individual, and to receive from said sensor signals pertaining to hygienic activity or lack thereof, wherein said data processing system is configured for determining said hygienic activity based, at least in part, on said signals.

31. The system according to any of claims 19-30, wherein said data processing system is configured to log statistics pertaining to said hygienic activity and to store said statistics on a non-transitory computer readable medium and/or to transmit said statistics to a central computation server.

32. The system according to any of claims 19-30, wherein said data processing system is configured to identify contact events between said individual and a medical treatment device or a patient, and to analyze said contact events to determine productivity of said individual.

33. A method of monitoring, comprising:
scanning a scene and provide range data arranged gridwise over a plurality of picture elements; and
processing said range data to monitor hygienic activity of an individual in said scene.

34. The method of claim 33, wherein said picture elements are devoid of any color data and any grayscale data.

35. The method of claim 33, wherein said scanning comprises generating a range image of said scene, and wherein said processing comprises removing from each picture-element any color data or grayscale data.

36. The method according to any of claims 33-35, wherein said processing comprises identifying said hygienic activity during at least one time interval selected from the group consisting of (i) a time interval ending before said individual contacts a

patient in said scene, (ii) a time interval ending before said individual performs an aseptic task, (iii) a time interval ending after said individual performs said aseptic task, (iv) a time interval beginning after said individual is exposed to a body fluid of said patient, (v) a time interval beginning after said individual contacts said patient, and (vi) a time interval beginning after said individual contacts objects nearby said patient.

37. The method according to any of claims 33-35, wherein said processing comprises identifying hand rubbing motion of said individual.

38. The method according to any of claims 33-35, wherein said processing comprises identifying glove wearing motion of said individual.

39. The method according to any of claims 33-35, wherein said processing comprises identifying glove removal motion of said individual.

40. The method according to any of claims 33-35, wherein said processing comprises identifying operation of a hand cleansing device by said individual.

41. The method according to any of claims 33-35, wherein said processing comprises identifying access of said individual to a patient in said scene, and determining a time window encompassing both said hygienic activity and said access.

42. The method according to any of claims 33-35, wherein said processing comprises classifying interaction of said individual with a patient in said scene, and determining a time window encompassing both said hygienic activity and said interaction.

43. The method according to any of claims 33-35, wherein said processing comprises identifying a medical treatment device in said scene and contact events between said individual and said medical treatment device, and determining a time window encompassing both said hygienic activity and said contact events.

44. The method according to any of claims 33-35, wherein said processing comprises identifying contact events between said individual and an organ of a patient in said scene, and issuing a notification when said contact events are not preceded by said hygienic activity.

45. The method according to any of claims 33-35, wherein said processing comprises identifying points of contact between said individual and objects in said scene, and mapping said points of contact over said scene.

46. The method according to any of claims 33-35, wherein said processing comprises identifying contact events between said individual and a medical treatment device or a patient, and analyzing said contact events to determine productivity of said individual.

47. The method according to claim 45, wherein said processing comprises tracking a cleansing device in said scene and updating said map responsively to said tracking.

48. The method according to claim 45, further comprising controlling a robotic cleansing device to access and disinfect said points of contact.

49. The method according to any of claims 33-35, further comprising communicating with a sensor mounted on said individual, receiving from said sensor signals pertaining to hygienic activity or lack thereof, and determining said hygienic activity based, at least in part, on said signals.

50. The method according to any of claims 33-35, further comprising collecting statistics pertaining to said hygienic activity and storing said statistics on a non-transitory computer readable medium and/or transmitting said statistics to a central computation server.

51. The method according to claim 36, wherein said processing comprises identifying hand rubbing motion of said individual.

52. The method according to any of claims 36 and 51, wherein said processing comprises identifying glove wearing motion of said individual.

53. The method according to any of claims 51-52, wherein said processing comprises identifying glove removal motion of said individual.

54. The method according to any of claims 51-53, wherein said processing comprises identifying operation of a hand cleansing device by said individual.

55. The method according to any of claims 51-54, wherein said processing comprises identifying access of said individual to a patient in said scene, and determining a time window encompassing both said hygienic activity and said access.

56. The method according to any of claims 51-55, wherein said processing comprises classifying interaction of said individual with a patient in said scene, and determining a time window encompassing both said hygienic activity and said interaction.

57. The method according to any of claims 51-56, wherein said processing comprises identifying a medical treatment device in said scene and contact events between said individual and said medical treatment device, and determining a time window encompassing both said hygienic activity and said contact events.

58. The method according to any of claims 51-57, wherein said processing comprises identifying contact events between said individual and an organ of a patient in said scene, and issuing a notification when said contact events are not preceded by said hygienic activity.

59. The method according to any of claims 51-58, wherein said processing comprises identifying points of contact between said individual and objects in said scene, and mapping said points of contact over said scene.

60. The method according to claim 59, wherein said processing comprises tracking a cleansing device in said scene and updating said map responsively to said tracking.

61. The method according to claim 59, further comprising controlling a robotic cleansing device to access and disinfect said points of contact.

62. The method according to any of claims 51-61, further comprising communicating with a sensor mounted on said individual, receiving from said sensor signals pertaining to hygienic activity or lack thereof, and determining said hygienic activity based, at least in part, on said signals.

63. The method according to any of claims 51-62, further comprising collecting statistics pertaining to said hygienic activity and storing said statistics on a non-transitory computer readable medium and/or transmitting said statistics to a central computation server.

64. The method according to any of claims 51-63, wherein said processing comprises identifying contact events between said individual and a medical treatment device or a patient, and analyzing said contact events to determine productivity of said individual.

65. A method of monitoring a condition of a medical environment, comprising:

obtaining a map of the environment, said map comprising locations in the environment identified as being infected;

receiving tracking data pertaining to motion of a cleansing device in relation to said locations; and

updating said map based, at least in part, on said tracking data.

66. The method according to claim 65, further comprising generating said map by monitoring points of contact between individuals and objects in the environment.

67. The method according to any of claims 65 and 66, further comprising transmitting said updated map to a central computation server.

68. The method according to any of claims 65 and 66, wherein said receiving said tracking data comprises receiving signals generated by said cleansing device.

69. The method according to any of claims 65 and 66, wherein said receiving said tracking data comprises receiving signals reflected by said cleansing device.

70. The method according to any of claims 65 and 66, wherein said receiving said tracking data comprises optically scanning the environment to determine a location of said cleansing device.

71. The method according to any of claims 65 and 66, wherein said cleansing device is a robotic cleansing device and the method further comprises controlling said robotic cleansing device to access and disinfect said points of contact.

72. The method according to claim 67, wherein said receiving said tracking data comprises receiving signals generated by said cleansing device.

73. The method according to claim 67, wherein said receiving said tracking data comprises receiving signals reflected by said cleansing device.

74. The method according to any of claims 72-73, wherein said receiving said tracking data comprises optically scanning the environment to determine a location of said cleansing device.

75. The method according to any of claims 72-74, wherein said cleansing device is a robotic cleansing device and the method further comprises controlling said robotic cleansing device to access and disinfect said points of contact.

76. A method of monitoring hygienic condition of an individual, comprising:
receiving from a sensor mounted on said individual signals pertaining to a hygienic activity of said individual or lack thereof;
receiving proximity data including a proximity event between the individual and a patient or a medical device; and
determining time window encompassing both said hygienic activity and said proximity event.

77. The method according to claim 76, wherein said sensor is a chemical sensor.

78. The method according to claim 76, wherein said sensor is an optical sensor.

79. The method according to claim 76, wherein said sensor is a mechanical sensor.

80. The method according to any of claims 76-79, wherein said receiving said proximity data comprises receiving signals generated by said medical device.

81. The method according to any of claims 76-79, wherein said receiving said proximity data comprises receiving signals reflected by said medical device.

82. The method according to any of claims 76-79, wherein said receiving said proximity data comprises optically scanning the environment to determine a location of the individual and a location of at least one said patient and said medical device.

83. The method according to any of claims 80-81, wherein said receiving said proximity data comprises optically scanning the environment to determine a location of the individual and a location of at least one said patient and said medical device.

84. A method of analyzing a regiment of hand hygiene for a plurality of individuals in a medical facility, comprising:

receiving from a plurality of monitoring systems data pertaining to hand cleansing events of the individuals, and classified contact events between said individuals and patients and/or medical devices;

at a central computation server, analyzing said events to determine, for each individual, whether two contact events are separated by at least one hand cleansing event, and issuing report regarding said analysis.

85. The method according to claim 84, further comprising calculating a score based on said analysis.

86. A method of ranking a plurality of medical facilities, comprising:
executing the method according to claim 85 for each medical facility, thereby providing a plurality of scores; and

ranking the medical facilities according to said scores.

87. A method of monitoring, comprising:
scanning a scene of a medical facility to provide range data arranged gridwise over a plurality of picture elements;

processing said range data to monitor contact events between an individual and a medical treatment device or a patient;

analyzing said contact events to determine productivity of said individual.

88. The method of claim 87, wherein said picture elements are devoid of any color data and any grayscale data.

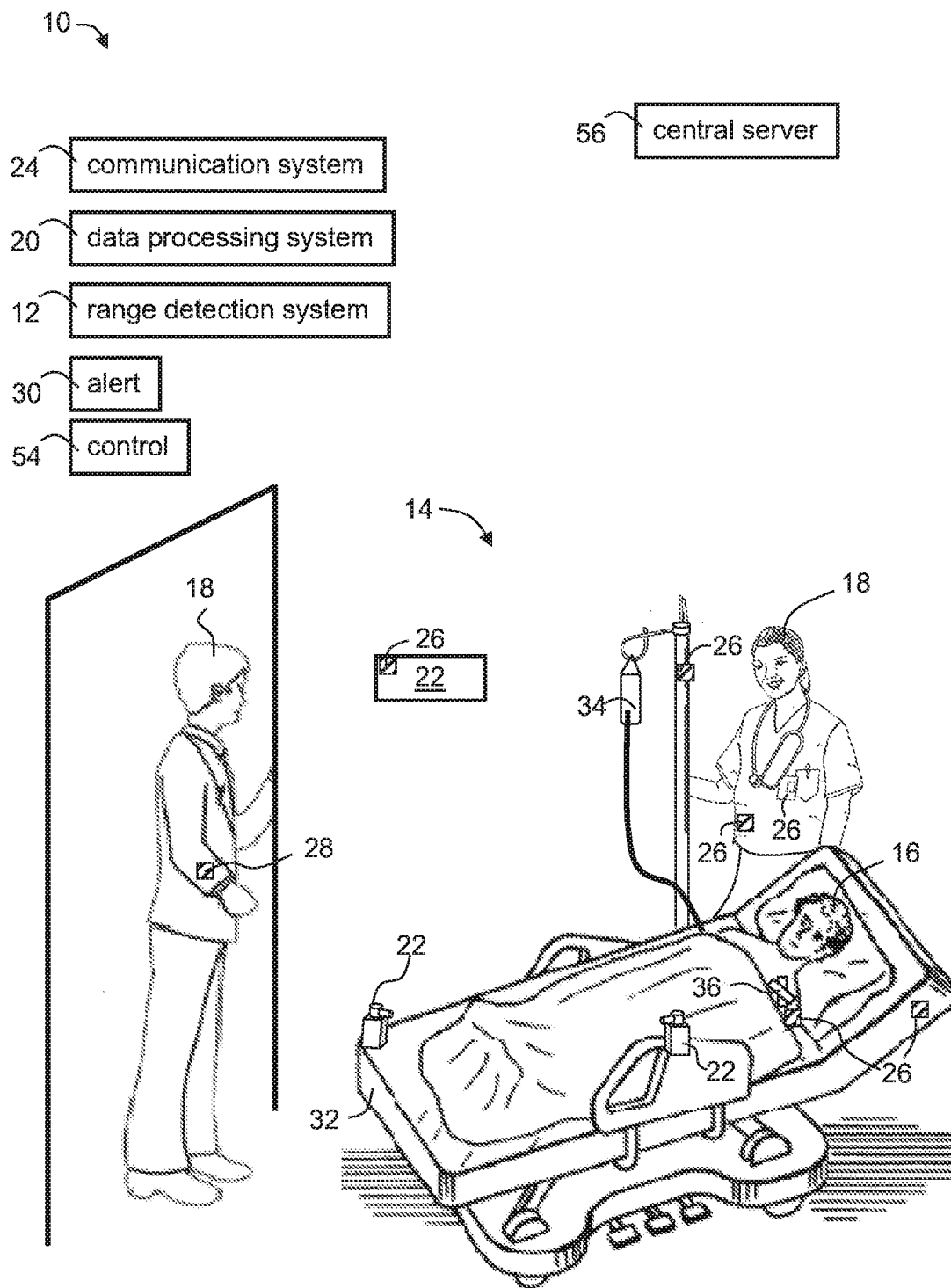


FIG. 1

FIG. 2A

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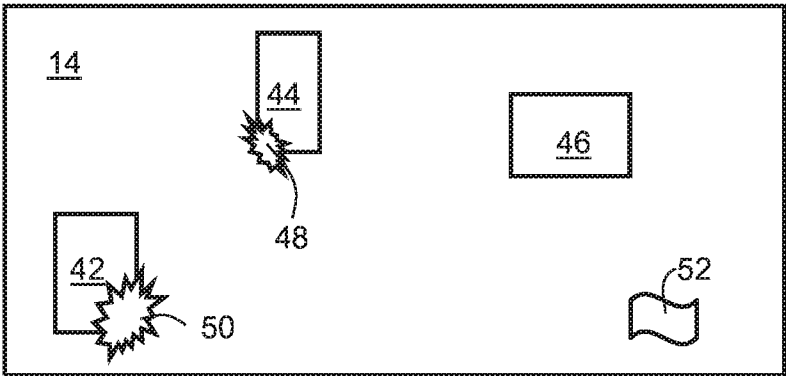


FIG. 2B

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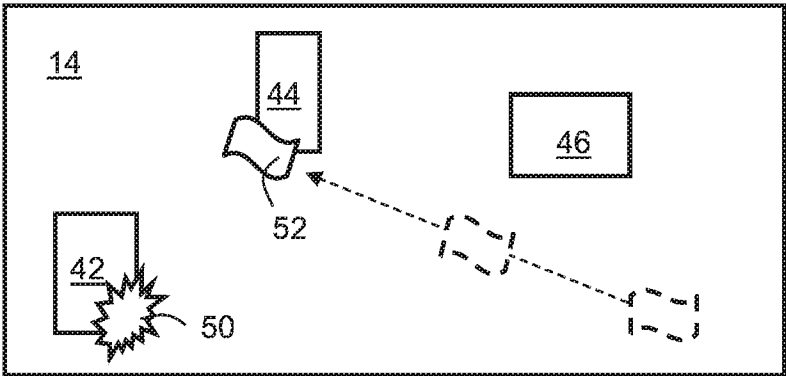
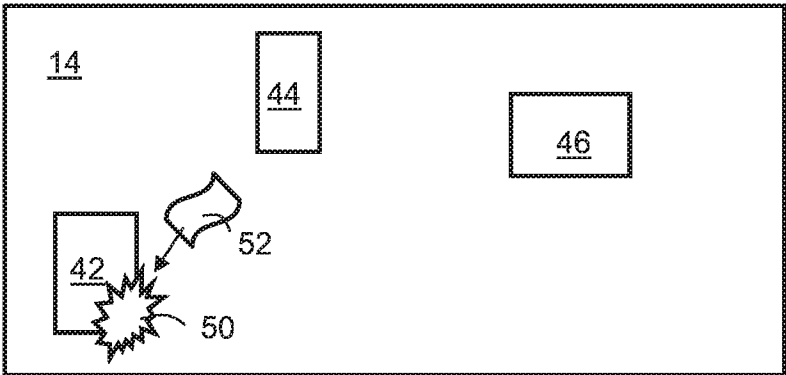


FIG. 2C

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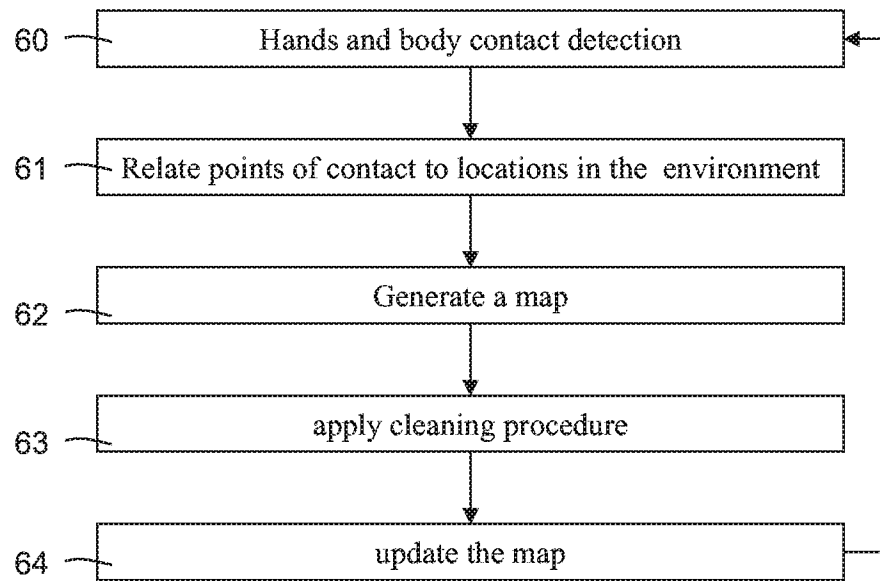


FIG. 3

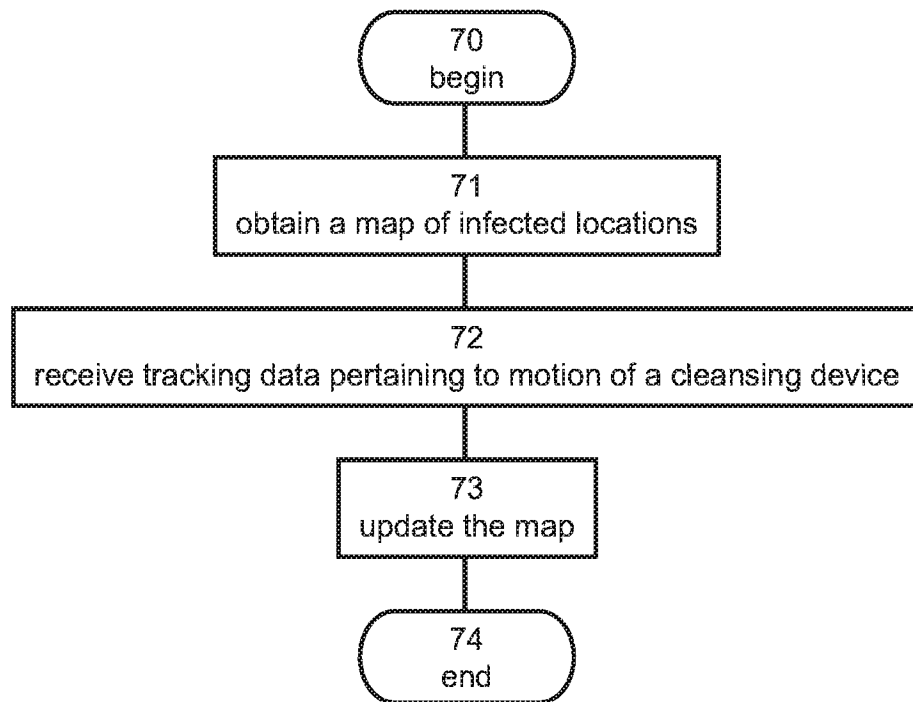


FIG. 4

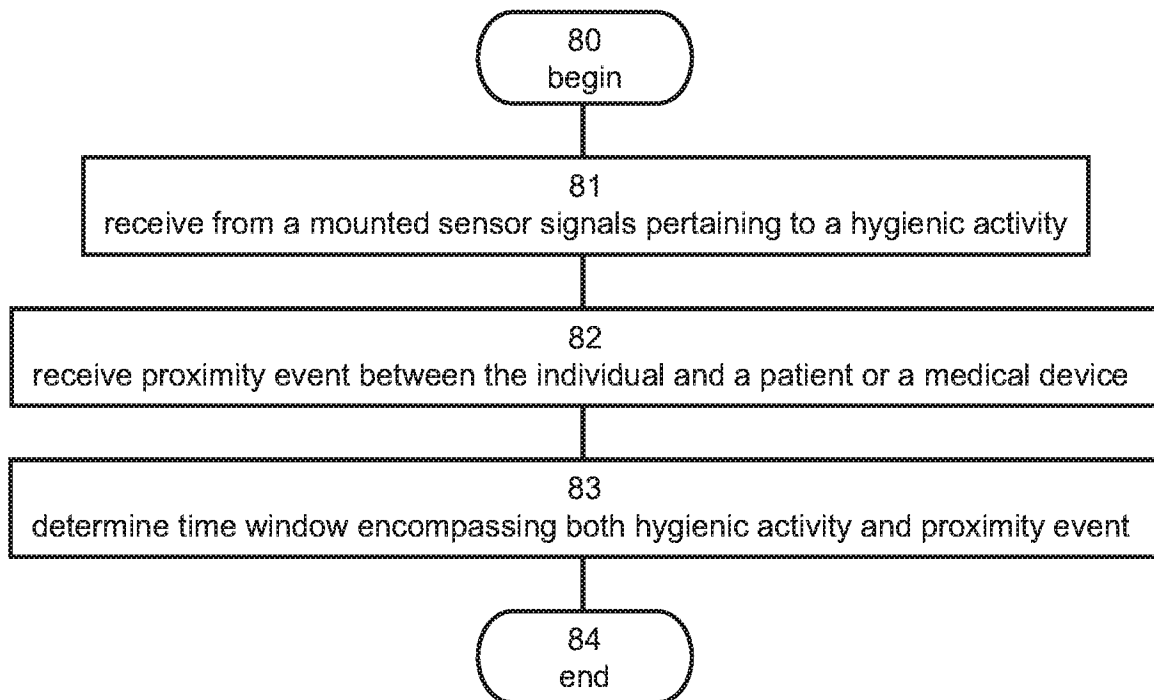


FIG. 5

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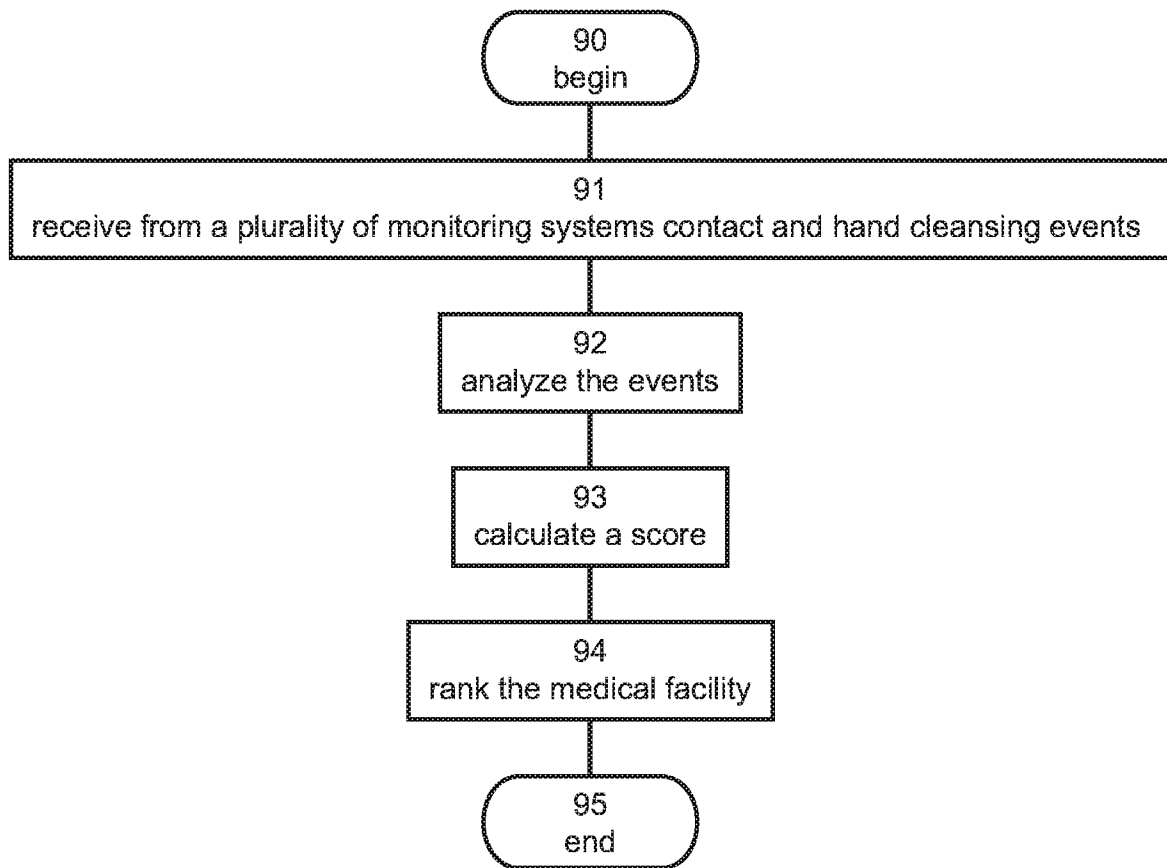


FIG. 6

INTERNATIONAL SEARCH REPORT

4/05/2014 30-04-2015

International application No.

PCT/IL2014/051084

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H04B 5/00 (2015.01)

CPC - G06F 19/327 (2014.12)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - H04B 5/00, H04N 7/18, G08B 1/08 (2015.01)

USPC - 348/143, 340/603, 222/23

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G06F 19/327, G06Q 50/22, H04B 5/0062 (2014.12) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google.

Search terms used: range detection system, monitoring, hygienic, hygiene, pixels, activity, identifying.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 2013/0122807 A1 (TENARVITZ et al) 16 May 2013 (16.05.2013) entire document	1, 4-12, 16-17, 19-20, 33, 36-44, 49-51 ----- 2-3, 13-15, 18, 34-35, 45-48, 87-88
Y	US 2012/0002066 A1 (WANG) 05 January 2012 (05.01.2012) entire document	2-3, 34-35, 88
Y	US 2012/0112883 A1 (WALLACE et al) 10 May 2012 (10.05.2012) entire document	13-15, 45, 47, 48
Y	US 2013/0113931 A1 (ALPER) 09 May 2013 (09.05.2013) entire document	18, 46, 87-88
Y	US 2013/0270459 A1 (FONTANI) 17 October 2013 (17.10.2013) entire document	15, 48

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 April 2015

Date of mailing of the international search report

30 APR 2015

Name and mailing address of the ISA/US

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Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 21-32, 52-64
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-20, 33-51, 87-88

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-20,33-51,87, 88, drawn to a system and method for monitoring.

Group II, claims 65-73, drawn to a method of monitoring a condition of a medical environment.

Group III, claims 76-82, drawn to a method of monitoring hygienic condition of an individual.

Group IV, claims 84-86, drawn to a method of analyzing a regiment of hand hygiene for a plurality of individuals in a medical facility.

The inventions listed as Groups I, II, III or IV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: a range detection system configured for scanning a scene and to provide range data arranged gridwise over a plurality of picture elements as claimed therein is not present in the invention of Groups II, III or IV. The special technical feature of the Group II invention: obtaining a map of the environment, said map comprising locations in the environment identified as being infected as claimed therein is not present in the invention of Groups I, III or IV. The special technical feature of the Group III invention: receiving proximity data including a proximity event between the individual and a patient or a medical device as claimed therein is not present in the invention of Groups I, II or IV. The special technical feature of the Group IV invention: receiving from a plurality of monitoring systems data pertaining to hand cleansing events of the individuals, and classified contact events between said individuals and patients and/or medical devices as claimed therein is not present in the invention of Groups I, II or III.

Groups I, II, III, and IV lack unity of invention because even though the inventions of these groups require the technical feature of monitor hygienic activity of an individual, this technical feature is not a special technical feature as it does not make a contribution over the prior art.

Specifically, US 2010/0153374 A1 (LEBLOND et al) 17 June 2010 (17.06.2010) teaches monitor hygienic activity of an individual (a method of assessing behavior of a group as an indication of overall hygiene performance, abstract).

Since none of the special technical features of the Group I, II, III, or IV inventions are found in more than one of the inventions, unity of invention is lacking.