HAND HYGIENE DEVICE, SYSTEM, AND METHOD

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CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application No. 63/003,514 filed April 1, 2020, the entire contents of which is hereby incorporated by reference as if fully set forth herein.

TECHNICAL FIELD

The present disclosure generally relates to sensor systems and sensor analytics. More specifically, embodiments of the disclosure relate to devices, systems, and methods for hand hygiene.

BACKGROUND

Regular hand washing is considered the most important precaution to reduce the chances of contamination from germs and viruses, such as the coronavirus known as COVID-19, lingering on surfaces. In the era of reducing the spread of germs and viruses, there is a heightened interest in improving compliance with this form of personal hygiene - sometimes referred to as hand hygiene. Indeed, the U.S. Centers for Disease Control and Prevention (CDC) states handwashing is one of the most effective ways to cut the spread of infectious diseases. Dirty hands are estimated to contribute to 50 percent of all foodborne illness outbreaks.

Most handwashing facilities today are actually quite antiquated, with many washrooms simply including a sink, soap, and some form of mechanism for drying one's hands (e.g., towels, air dryers, etc.). However, new opportunities now exist to modernize such facilities, thanks to the recent proliferation of sensor technologies. In addition to introducing new sensor systems for handwashing facilities, custom data analytic techniques are also introduced herein that work in conjunction with these sensor systems, to improve today's handwashing facilities and can greatly help to reduce the spread of contagious diseases.

BRIEF DESCRIPTION OF DRAWINGS

The example embodiment(s) of the present disclosure are illustrated by way of example, and not in way by limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements and in which:

Figures 1a and 1b illustrate, respectively, a frontal and side view of an exemplary embodiment of a device embodying the present disclosure.

Figure 1c illustrates an example location of the device relative to a washroom sink.

Figure 2 illustrates a wearable embodiment of the device.

Figure 3a illustrates a block diagram of an embodiment of the device.

Figure 3b illustrates a block diagram of the monitoring of an ambient environment.

Figure 4a contains a table illustrative of exemplary of trigger/event sounds and motions in the ambient environment of a washroom.

Figure 4b contains a table illustrative of exemplary of the device output reinforcement according to one or more embodiments.

Figure 4c contains a table illustrative of the voice messages the device may detect and recognize according to one or more embodiments.

Figure 5a illustrates an exemplary flow chart of the device in operation determining whether user activity is related to hand hygiene.

Figure 5b illustrates an exemplary flow chart of the processes of a first embodiment of the device in operation.

Figures 6a and 6b illustrate an exemplary flow chart of the processes of a second embodiment of the device in operation.

Figures 7a-7m illustrate exemplary display outputs of the device.

Figure 8 illustrates a flow chart of the configuration processes of the device.

Figures 9a-9c illustrate exemplary user interfaces for a companion mobile app.

Figures 10a-10e illustrate exemplary audio profiles of various washroom elements.

While each of the figures illustrates a particular embodiment for purposes of illustrating a clear example, other embodiments may omit, add to reorder, and/or modify any of the elements show in the figures.

DETAILED DESCRIPTION

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the example embodiment(s) of the present disclosure. It will be apparent, however, that the example embodiment(s) may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the example embodiment(s).

As would be appreciated, sensor systems are introduced herein that can be deployed to handwashing facilities, to capture various sensor data. According to various embodiments, as detailed further below, machine learning, statistical, and/or heuristic techniques can be used on the captured sensor data for purposes of ensuring compliance with recommended handwashing guidelines, reporting, and/or other functions.

In general, machine learning is concerned with the design and the development of techniques that recognize complex patterns in a set of input data, such as sensor data captured by the sensor systems herein. In various embodiments, example machine learning techniques that can be used to implement the techniques herein may include, but are not limited to, nearest neighbor (NN) techniques (e.g., k-NN models, replicator NN models, etc.), statistical techniques (e.g., Bayesian networks, etc.), clustering techniques (e.g., k-means, mean-shift, etc.), neural networks (e.g., reservoir networks, artificial neural networks, etc.), support vector machines (SVMs), logistic or other regression, Markov models or chains, principal component analysis (PCA) (e.g., for linear models), singular value decomposition (SVD), multi-layer perceptron

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(MLP) artificial neural networks (ANNs) (e.g., for non-linear models), deep learning neural networks (DNNs), replicating reservoir networks (e.g., for non-linear models, typically for time series), random forest classification, convolutional networks (CNN), or the like.

In various embodiments, the data analytics techniques herein may be performed using one or more supervised, unsupervised, or semi-supervised machine learning models. Generally, supervised learning entails the use of a training set of data that is used to train the model to apply labels to the input data. For example, the training data may include sample sensor that has been labeled as being indicative of compliant or non-compliant with acceptable handwashing protocols. On the other end of the spectrum are unsupervised techniques that do not require a training set of labels. Notably, while a supervised learning model may look for previously seen patterns that have been labeled as such, an unsupervised model may instead look to whether there are sudden changes or patterns in the behavior of the metrics. The unsupervised models may learn from data it takes in but not train prior to deployment. Semi-supervised learning models take a middle ground approach that uses a greatly reduced set of labeled training data, allowing training data to be extrapolated from a smaller set of labeled data.

Handwashing appears to be a simple well-bounded problem; however, depending on the accuracy of ensuring a user's compliance with recommended handwashing protocol, the problem becomes a more complex and challenging technical problem. There are, in fact, several actions a user may take that deviate from the recommended handwashing protocol. Static signage describing the protocol is sometimes not sufficiently understood, and users are not held accountable in real-time to comply when they deviate from the recommended handwashing protocol. One or more goals of the present disclosure are to increase hand hygiene compliance, namely: (1) to encourage a user to wash his/her hands in a particular environment where the device is situated, and (2) to guide users to wash their hands in the recommended protocol.

Some handwashing actions a user may take include: start the handwash; stop the handwash; proper lathering; improper lathering; touching of faucet handles with hands; touching of a tap handles with something other than hands such as an elbow; touching of faucet tap handles with a towel; use of soap; handwashing with no use of soap; drying hands with a towel

or hand air-dryer; not drying hands with a towel or hand air dryer, etc. However, the user's behavior is influenced by numerous factors. Factors may include the social need to participate in the need to help the collective good to stop the spread of viruses, and diseases; the cleanliness of the washroom; the availability of soap, towels and/or air dryers; user knowledge of recommended handwashing protocol; accountability imposed on the user; some form of influence/oversight that encourages the user to comply with a recommended handwashing protocol, or some combination thereof.

The device, system, and method described herein describe techniques to help encourage compliance with a recommended handwashing protocol by instructing the user on the protocol steps by displaying appropriate instructions in real-time when the user is about to wash his/her hands. Depending on the embodiment of the present disclosure, various advantages may result. The protocol instructions may be in the form of images, animations, video, or some combination thereof. This output assists certain types of learners to better understand and comply with the recommended handwashing protocol. Advantageously, the device is programmed or configured to provide this protocol instruction contemporaneously when the user is or about to wash his/her hands.

Further, functioning washrooms elements such as toilets, faucets, soap dispensers, and sinks do not necessarily require replacement or modification. Also, the device requires limited space and provides the intended compliance without requiring physical interaction with the device. Further advantageously, the user need not be expected to remember the best steps to properly wash his/her hands but is reminded of these recommended steps contemporaneously when washing his/her hands. When the user deviates from the recommended handwashing protocol, the device may be programmed or configured to modify its behavior to encourage the user to comply with the recommended handwashing protocol. For instance, the system may evaluate compliance with the recommended handwashing protocol set out by the World Health Organization (WHO):

Step 1: Wet hands with safe running water

Step 2: Apply enough soap to cover wet hands

Step 3: Scrub all surfaces of the hands for at least 20 seconds

Step 4: Rinse thoroughly with running water

Step 5: Dry hands with a clean, dry cloth, single-use towel, or hand drier as available

Step 6: Turn off water with a towel or elbow.

Step 3 above is broken into substeps to ensure the cleaning of all surfaces by recommending the following scrubbing steps:

Step 3a: Rub hands palm to palm;

Step 3b: Rub right palm over left dorsum with interlaced fingers and vice versa;

Step 3c: Rub palm to palm with fingers interlaced;

Step 3d: Rub backs of fingers to opposing palms with fingers interlocked;

Step 3e: Rotational rubbing of left thumb clasped in right palm and vice versa; and,

Step 3f: Rotational rubbing, backward and forwards with clasped fingers of the right hand in left palm and vice versa.

Alternatively, the techniques herein may be used to enforce other hand hygiene protocols, as desired.

Figures 1a-c

Figure 1a is an example of a physical embodiment of device **300** in a frontal view. The display **320** presents an illustrative example of one step of several recommended steps to properly wash hands, namely Step 2: Apply soap to the hands. Figure 1b illustrates an example of the side view of device **300** showing the housing **302**, display **320**, wall bracket mechanism **303**, audio capture device (microphone) **310**, an audio output device (speaker) **315** according to one or more embodiments. Figure 1c illustrates the placement of device 300 relative to the sink **150** and mirror **175** according to one or more embodiments. Device **300** may be installed in various locations, including on or in the mirror, on the sink counter, or affixed to an adjacent wall

to the sink. A goal is to ensure the user has a visual line of sight to the display **320** of the device when in operation.

Figure 2

Figure 2 shows a user wearable embodiment of the present disclosure – namely, a smartwatch device **200**. The smartwatch device **200** may work as a companion device with other devices such as a mobile phone (not shown) or device **300**. The device **200** is programmed with the functions described herein and may use information communicated by the user's mobile phone to cause certain output behavior. For example, with location-based services are shared by the mobile phone with the device **200**, the device **200** recognizes when the user returns to his/her home after an outdoor trip, thereby outputting instructions to the user to wash his/her hands upon arrival home. The wearable device **200** also detects handwashing motion to trigger output to encourage adherence to the recommended time for washing the user's hands. While Figure 2 depicts a smartwatch device **200**, in other embodiments, the present disclosure's techniques can be implemented with different types of wearables instead, such as smart glasses, a fitness tracker, a smart ring, etc.

Figures 3a and 4a

Figure 3a illustrates a block diagram of example device **300** in which the techniques described herein may be practiced, according to some embodiment. Device **300** is programmed or configured to encourage handwashing and compliance with a recommended handwashing protocol. Figure 3a illustrates only one of many possible arrangements of components configured to execute the programming or functionality described herein. Other arrangements of components, and the division of work between the components may vary depending on the arrangement. The diagram systematically illustrates a device **300** to receive movement/audio input sensor data and to process the sensor data through analytics according to one or more embodiments. Figure 3a shows a system for detecting certain sounds and/or motions by the device according to one aspect of the present disclosure. The system includes an electronic device **300** that may be executing software that is monitoring for a trigger. The term trigger or event is used generically here as referring to any sound and/or motion input that may be detected

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by one or more I/O Device Interfaces **325** and that may cause, based on that detection, the software programmed in the device **300** to respond or take specific actions to encourage hand hygiene compliance.

With reference to Figure 4a, a table contains examples of trigger sounds, in the first column, in the ambient environment. These sounds are those typically found near a washbasin/sink, such as in a washroom. The terms washroom, bathroom, toilet room, and water closet are used interchangeably herein and refer generally to a space including at least a handwashing sink or basin. One skilled in the art appreciates many other sounds may be recognized and are within the scope of the present disclosure. If, for example, the device **300** is set next to the entryway of a home, the trigger sounds include entryway doors and garage doors opening and closing. Figure 4a also includes in the second column of the table examples of trigger motions in the ambient environment that may recognized by the device **300**. The listed motions do not necessarily have any relation to the first column of sounds. Further examples of trigger motions recognized by device **300** may include the hand motions illustrated in Figures 7a – 7l.

The block diagram of device **300** is not limited to the existing components illustrated in Figure 3a. For example, although not shown, the device will preferably include a power source, such as a rechargeable/disposable battery or connection to the building's AC/DC power system, to power the device **300**. The current components may be used in the construction of the device **300**. The device **300** may also not be limited to just the quantity of components displayed in Figure 3a. The device **300** could be subject to multiple audio capture devices **310**, multiple controllers/processors **330**, and multiple device interfaces **325** to improve device **300** performance if needed. The device **300** may also be constructed in a way to have the components connected and/or communicating to the "cloud."

Device **300** may contain a motion detector capture device **305** that will detect motion in and around device **300**. Various types of sensors may be used for this purpose, including passive motion sensors (such as PIR sensors) and active motion sensors (such as LIDAR (Light Detection and Ranging) sensors).

Device **300** may contain an audio capture device **310**. The audio capture device **310** may contain one or more microphones (e.g., an array of microphones) which are transducers configured to receive a sound field in the ambient environment of the device **300**, and in response, provide one or more audio signals corresponding to it.

Device **300** may also contain audio output devices **315** for producing notification sounds and/or audio messages and/or instructions. The device 3**00** may contain a video output device **320,** such as e-ink display, LCD, LED and projection displays, to display images, video, and/or text.

Device **300** may include an address/data bus **365** to transfer information throughout all components within the device **300**. Each component within the device **300** will be connected to other components across the address/data bus **365**. The device **300** may include a controller/processor **330**, which may serve as the central processing unit for processing data and computer-readable instructions. The memory within the device **300** may include RAM, ROM, and other types of memory. The device **300** may also contain a data storage **340** component for storing instructions and data. The device **300** may also be connected to removable or external memory storage (not shown) through input/output device interfaces. The wireless communications circuitry **342** may be one or more integrated circuits and/or other hardware components configured to transmit and/or receive data with a cellular network, a short-range network (such as Bluetooth)/or a WiFi network. Thus, the wireless communications circuitry **342** may include components (such as one or more baseband processors, digital signal processing (DSP) circuits, transceivers, radio frequency (RF) front ends, and/or other components) that are configured for communication with the appropriate network. In various embodiments, the wireless communications circuitry **342** may include components for communicating (a) only with cellular networks, (b) only with short-range networks such as Bluetooth, (c) only with WiFi networks, or (d) for communicating with some combination thereof. The wireless communications circuitry **342** may be coupled to one or more antennas **344**. Whenever it is described herein that the device **300** communicates data to/from a wireless network to another network such as the "cloud," communication may be performed using one or more antennas. The device **300** includes input/output device interfaces **325** in communication

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with various input/output devices. The device **300** and its various components may be executed by the controller/processor and be stored in the memory, storage, an external device, or in memory/storage included in an Audio Recognition module (ARM) **345** discussed below.

The ARM **345** is a system within the device **300** used for processing audio signals from sounds into triggering software in the controller/processor **330** to activate certain responsive outputs by device **300**. Outputs comprise informational displays (shown in Figures 7a-7m) via the video output device **320** and/or audio output device **315**. The ARM **345** may include a sound classifier system **350** based on a machine learning (ML) model **355** configured to recognize different audio signals detected in the ambient environment of the device **300**. ARM **345** may store the audio signals in a sound storage **360** to improve the device's **300** sound recognition quality.

Although not shown, the system includes a plurality of feature extractors or feature extraction components or modules that may be in the form of software stored in the memory of the device **300** and is executed by the processor **330**. The feature extractors digitally process the audio signals so as to determine various features (characteristics) of the audio signal. Extracted audio features may be used to classify certain sounds to determine whether user is following the recommended handwashing protocol by the CDC. These features may also be described as those of the sound or sound field picked up in the audio signals associated with those trigger sounds, such as those set out in the table in Figure 4a.

The system's classifier **350** or sound classification module as software being executed by the processor, employs or otherwise includes a machine learning model **355**, though other statistical models and algorithms can be used without departing from the scope of the present disclosure. Also, the system includes a database **360** that stores historical sound data or information, such as previously stored sound metadata, that can be accessed by the classifier **350**. The classifier **350** determines a classification of the audio signal based upon the audio signal's determined features and, preferably, also based on the localized and labeled sound samplings provided at the installation of various trigger sounds in the ambient environment of the device **300**'s installation location. In one variation, the classifier **350** makes a binary classification and

determines whether the audio signal relates to a trigger sound versus a non-trigger sound. However, the classifier could also classify a sound as being one of a number of other classifications (e.g., one or more of three or more classifications) or sub-classifications without departing from the scope of the present disclosure.

The device **300** may train on an audio signal dataset to enhance its precision in methods to encourage compliance with recommended handwashing protocol. By way of example, when the ARM **345** recognizes the sound of water flowing, ARM **345** triggers software in the processer 330 to display what could be shown in Fig. 7b - namely: "Apply soap to hands." The ARM advantageously also provides insight to device's 3**00** hand hygiene compliance algorithm where ambient environment motion cannot be detected by the field of sight of the motion detector capture device **305**. For example, the ARM may be programmed to recognize the use of a toilet by just the sound of the flush of the toilet cistern well before any motion can be detected by the Motion Recognition Module (MRM) of a user walking past the device **300** after the toilet use – to be discussed next.

Although not shown, an MRM is used for processing motion detected in the ambient environment into triggering software in the controller/processor **330** to activate certain responsive outputs by device **300**, including but not limited to the informational displays (as shown in Figures 7a-7m) via the video output device **320** and/or audio output device **315**. Data associated with motion detected by the motion detector capture device **305** is input for the MRM. The MRM may include a machine learning classifier system configured to recognize different motions found in the washroom. MRM may store the motion in motion storage (not shown) to improve the device's **300** motion recognition quality. Set-up of the ML implementation for enhancing motion recognition would include a dataset of thousands of recordings of different motions commonly found in and around the washbasin area. As shown in Figure 8 (to be described in later detail), device **300** is preferably initialized during the set-up with motions commonly found in a particular washroom. The device trains on a motion dataset to enhance its precision to better recognize when a certain triggering motion occurs. Device **300** could be further enhanced by the correlation and/or associations of detecting specific sounds and movements through the implementation of machine learning of recognizing particular sounds

and motion to trigger proactive output behavior by the device **300** to encourage hand hygiene compliance. By way of example, when the ARM recognizes the sound of the toilet flush and the MRM recognizes the motion of a user is about to exit the washroom facility without the ARM recognizing the sound of water at the sink before the attempted exit, these conditions trigger software in the processer **330** to activate audio and/or visual reminder to "Wash Your Hands". The reminder may also be triggered at a second device in communication with a first device. The second device may be configured to include a limited set of componentry found in the first device.

Privacy

There is a natural expectation by users of privacy and anonymity in many private environments – especially a washroom environment. Naturally, the use of any electronics in such environments may raise escalate the privacy concern. One aspect of the present disclosure is the gathering and use of data available from various sources including the ambient environment where the device **300** is situated to classify sounds and motions, and to improve the accuracy of classifying those sounds and motions as being hand hygiene-related activities. When not permitted to do so under applicable rules and regulations, the present disclosure, in one aspect, mitigates the risk of obtaining personally identifiable information (PII) of a user in the ambient environment of the device **300**. In another variation of the present disclosure, it contemplates that in some instances, this gathered data may include PII data that uniquely identifies or can be used to contact or locate a specific person. The present disclosure recognizes that the use of such personal information data, in the present technology, can be used to the benefit of users. For example, the personal information data can be used to provide customized learning opportunities/feedback to a specific user to better adhere to acceptable hand hygiene protocols. For a specific user, the disclosure considers reducing expectations for a user that has historically was the least compliant user out of a larger known set of users. In that instance, the system outputs hand hygiene compliance that would gradually bring the particular user to full compliance over a longer period of instances where the device recognizes the user.

The present disclosure contemplates that the entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities should implement and consistently use privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining personal information data private and secure. Such policies should be easily accessible by the entity that installs the present device and should be updated as the collection and/or use of data changes. Personal information from users should be collected for legitimate and reasonable uses of the entity and not shared or sold outside of those legitimate uses. Further, such collection/sharing should occur after receiving the informed consent of the users. Additionally, such entities should consider taking any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices. In addition, policies and practices should be adapted for the particular types of personal information data being collected and/or accessed and adapted to applicable laws and standards, including jurisdiction-specific considerations. For instance, in the US, collection of or access to certain health data may be governed by federal and/or state laws, such as the Health Insurance Portability and Accountability Act (HIPAA); whereas health data in other countries may be subject to other regulations and policies and should be handled accordingly. Hence different privacy practices should be maintained for different personal data types in each country.

Despite the foregoing, the present disclosure also contemplates embodiments in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, in the case of continuous audio collection ("always listening") and storage of historical sound data, the present technology can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services or anytime thereafter.

Moreover, in an embodiment, personal information data should be managed and handled in a way to minimize risks of unintentional or unauthorized access or use. Risk can be minimized by limiting the collection of data and deleting data once it is no longer needed. In one variation, the present disclosure utilizes digital obfuscation to abstract away any actual or potential PII of users using privacy-enhancing technology (PET). PETs are a broad range of technologies (hardware and/or software) that are designed to extract data value in order to unleash its full commercial, scientific and social potential, without risking the privacy and security of this information. Two major types of PETs are cryptographic algorithms and data masking techniques. Cryptographic algorithms include homomorphic encryption, secure multi-party computation (SMPC), differential privacy, and zero-knowledge proofs (ZKP). Data masking techniques include obfuscation, pseudonymization, data minimization and communication anonymizers. Any of the aforementioned PETs may be utilized in the present disclosure.

The ARM and MRM are programmed to filter any PII data artifacts captured in the raw audio and motion input by utilizing a PET (see discussion in Figure 3b regarding the PET component **410** and **430**). Component choice may help mitigate these risks. For example, using LIDAR sensor technology as part of the motion detector capture device **305** can be set to remove all PII. A point cloud sensor data, generated by the LIDAR, is inherently anonymous to protect users' privacy while also giving the device's MRM a high-resolution image to work with. To add layer of privacy, the device uses edge computing systems to process data in the field and pass on anonymized object data to the cloud-based networks only if necessary. In addition, and when applicable, data de-identification can be used to protect a user's privacy. De-identification may be facilitated, when appropriate, by removing specific identifiers (e.g., name, etc.), controlling the amount or specificity of data stored (e.g., collecting location data a city level rather than at an address level), controlling how data is stored (e.g., aggregating data across users), and/or other methods.

Therefore, although the present disclosure broadly covers use of personal information data to implement one or more various disclosed embodiments, the present disclosure also contemplates that the various embodiments can also be implemented without the need for accessing such personal information data. That is, the various embodiments of the present

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technology are not rendered inoperable due to the lack of all or a portion of such personal information data. For example, sound and motion classification can be performed based on non-personal information data or a bare minimum amount of personal information.

Figure 3b

Monitoring of Ambient Environment

With reference to Figure 3b, a block diagram representing the logical, algorithmic components the device will execute when monitoring the ambient environment for hand hygiene non-compliance. It is be understood; the reverse could be monitored – namely, monitoring the ambient environment for hand hygiene compliance. For brevity, the former is what is described herein. Figure 3b shows a monitoring system receiving audio signals **405** from at least one audio sensor, such as a microphone, **310** and motion signals **420** from at least one motion detection sensor **305**. The monitoring system comprises an Audio Recognition Module for classifying audio signals and a Motion Recognition Module for classifying motion signals according to one aspect of the present disclosure. Although shown in Figure 3b as a single component, the system can include a plurality of feature extractors **410** or one or more feature extraction or detection components or modules that perform specific signal processing on received audio signals **405** to determine specific features, aspects, or characteristics thereof. The plurality of feature extractors **410** can apply algorithms or modeling (e.g., including machine learning modeling) to the audio signals (e.g., components thereof) to determine their specific features. The plurality of feature extractors **410** may include a sound class feature extractor, a directional information feature extractor, and a distortion feature extractor (not shown). Audio feature extraction may utilize one or more models commonly used in NLP (Natural Language Processing) or ASR (Automatic Speech Recognition) such as Artificial Neural Network (ANN), Gaussian Mixture Modelling (GMM), or Support Vector Model (SVM). The mentioned models and similar models may be used for audio signal processing and other feature extractions to determine key audio information such as MFCC (Mel-Frequency Cepstral Coefficients), filter banks, sampling frequencies, amplitude, Fourier transform, and more for the purpose of classifying audio signals.

The use of publicly available tools and datasets, such as Librosa, may be used to conduct an in-depth audio analysis and digital signal pre-processing.

In one variation, the sound class feature extractor can apply one or more algorithms or models to the audio signals **405** to determine one or more sound classes present in one or more of the audio signals **405**. The sound classes can include a specific sound type, such as speech, music, laughter, sounds made by particular objections (e.g., toilets flushing or other exemplary sounds set out in Figure 4a), etc., or other types of sounds. In addition, the sound class feature extractor can determine whether the audio signals include multiple sound classes or whether the sound classes vary or change over time.

The sound class feature extractor itself can include one or more machine learning models or other (semi-)supervised learning or statistical models that are trained or calibrated to determine the different sound classes, respectively, based on the audio signal **405** as its input. For example, a data corpus, including various ground truth-labeled sounds of different sound classes, is collected. The data corpus can then be partitioned or otherwise separated into training sets and testing sets. The machine learning model is trained or calibrated to determine the sound class or sound classes using the training set. The accuracy of the machine learning may then be determined using the testing set, e.g., to determine whether the machine learning model assigns classes to signals of the testing set at a threshold rate or level of accuracy.

Further, in one variation, a plurality of feature extractors **410** can include a directional feature extractor (not shown). The directional feature extractor can perform signal processing on one or more of the audio signals **410** to determine spatial signatures or characteristics, e.g., there is a dynamic sound source vs. a static sound source recorded in the audio signals **410**. For example, an audio signal that contains a recording of a sound emitted from a stationary device (e.g., toilet, sink water faucet, shower, bathtub, or ceiling fan) may have stationary or static spatial characteristics, but an audio signal from a sound of a person talking or yelling may have dynamic spatial characteristics due to the person turning their head or walking around (while talking). The directional feature extractor can process the audio signal to determine directional characteristics of the sound, such as a specific direction, time of arrival, angle, etc. For example,

sounds emitted from such stationary devices will generally be received from the same position and will have the same or similar directional characteristics reflected in the audio signal. Still further, the plurality of feature extractors **410** can include a distortional feature extractor and other types of feature extractors (while still remaining within the scope of the present disclosure).

The ARM may include a classifier **350**, employing a neural network or other suitable machine learning model **355**, whose output may be a sound classification that classifies the sound as an audio trigger vs. audio non-trigger. The classifier **350** receives the plurality of features and previously stored sound metadata in sound storage **360**. For example, these features and historical data can be used as inputs to the neural network, deciding whether the sound is a recognized trigger audio event. In some cases, the decision made by the classifier **350** (to determine whether the audio signal is from a trigger sound vs. non-trigger sound) can be based on just the historical data without relying upon an output of the neural network (e.g., if the current audio signal has substantially similar features or the same feature vector as those of a previously classified audio signal.)

As shown in Figure 3b, the system may include a similar arrangement of components arranged for classifying motion/movement signals. Motion signals generally relate to the physical movement of one or more users present in the ambient environment. The outcome from the motion-related Motion Recognition Module (MRM) has a similar goal – to classify what type of motions detected in the ambient environment is related to hand hygiene vs. those motions unrelated to hand hygiene. A plurality of motion feature extractors **425** or one or more feature extraction or detection components or modules that perform specific signal processing on received motion signals **425** to determine specific features, aspects, or characteristics thereof. The plurality of motion feature extractors **425** can apply algorithms or modeling (e.g., machine learning modeling) to the motion signals (e.g., components thereof) to determine their specific features. The plurality of motion feature extractors **425** may include a motion class feature extractor and other types of motion feature extractors (not shown). Feature extraction will require use of ML models such as PCA (Principal Component Analysis), Convolutional Neural Networks (CNN), SVM, K Nearest Neighbor (KNN), Random Forrest, or models like such. The development process of these models within the MRM may include a workflow such as loading

the data, preprocessing the image, defining model parameters, and training/testing network. Point cloud segmentation may take the input form of voxels, point clouds, graphs, 2D view, and other similar networks.

In one variation, the motion class feature extractor can apply one or more algorithms or models to the motion signals **420** to determine one or more motion classes present in one or more of the motion signals **420**. The motion classes can include a specific motion type, such as user exiting washroom, a user walking toward a sink area, user washing his/her hands, a user entering the washroom, user applying soap, user rinsing hands, a user activating sink faucet, user rinsing hands with water, user scrubbing hands, user deactivating sink faucet, user drying hands, etc.

The motion class feature extractor itself can include one or more machine learning models or other supervised learning or statistical models that are trained or calibrated to determine the different motion classes, respectively, based on the motion signal **420** as its input. For example, a data corpus, including various ground truth labeled sounds of different motion classes, is collected. The data corpus can then be partitioned or otherwise separated into training sets and testing sets. The machine learning model is trained or calibrated to determine the motion class or motion classes using the training set. The accuracy of the machine learning may then be determined using the testing set, e.g., to determine whether the machine learning model assigns classes to signals of the testing set at a threshold rate or level of accuracy.

The MRM may include a classifier **365** employing a neural network or other suitable machine learning model **370**, whose output may be a sound classification that classifies the sound as an audio trigger vs. audio non-trigger. The classifier **365** receives the plurality of features and previously stored motion metadata in motion storage **375**. For example, the neural network receives as inputs features and historical data, which can decide whether the motion is a recognized trigger motion event. In some cases, the decision made by the classifier **365** (to determine whether the motion signal is from a trigger motion vs. non-trigger motion) can be based on just the historical data without relying upon an output of the neural network (e.g., if the current motion signal has substantially similar features or the same feature vector as those of a previously classified motion signal.)

Based on the sound classification decision **415** and the motion classification decision **435**, a decision is made whether the sensor data from the monitored ambient environment is non-compliant hand hygiene-related activity. This determination may be based on a plurality of conditions based on sound and/or motion triggers detection. Generally, if a first condition is satisfied and a second condition is satisfied, then a determination is made whether or not it is non-compliant hand hygiene-related activity.

By way of example, let's assume the device has been configured to operate in a washroom. If the sound classification determines that the sound processed is that of a toilet flush, and if the motion classification determines a subsequent motion detected in the ambient environment is that of a user tending to exit the washroom (with a further confirmation that the sound classifier did not detect any sound of water flowing from the sink faucet before the imminent exit), the hand hygiene-related activity decision **440** would conclude that this activity is that of hand hygiene-related activity particularly that of non-compliance to acceptable hand hygiene.

By way of another example, if the sound classification determines that the sound processed is that of a faucet running water into a sink, and if the motion classification and/or sound classification determines soap dispenser use was not detected, the hand hygiene-related activity decision **440** would conclude that this activity is that of hand hygiene-related activity particularly that of non-compliance to acceptable hand hygiene. The device **300** takes output action indicative of remedying the non-compliance.

The device **300** is programmed for this sound-to-motion correlation or mapping for various permutations of trigger sounds and triggers motions to determine whether hand hygiene activity has occurred. Naturally, a multitude of conditions are possible given the exemplary sound and motion triggers described herein. It is naturally within the scope of the present disclosure that the determination could be either that hand hygiene is complied with, or that hand hygiene has not to be complied with. In ambient environments where multiple users are present at any given time, a temporal user identifiable data distinguishes each user present to ensure that the device reacts (or outputs) according to that particular user's hand hygiene compliance.

Figure 3b shows illustrate the PET components **412** and **430**, which removes one or more data artifacts that may be personally identifiable information (PII) of a user. Although shown as a single component, the present disclosure may include instances of the PET **412** component repeated in different stages of processing the user's data information. This equally applies to the components associated with the motion recognition module.

Figures 5a and 4b

Figure 5a illustrates a flow diagram of an example process for addressing a non-compliance to a handwashing-related activity using the system set out in Figures 3a and 3b, according to one embodiment. Figure 5a is intended to disclose algorithms or functional descriptions that may be used as a basis of writing computer programs to implement the functions that are described herein, and which cause a computer to operate in the new manner that is disclosed herein. Further, Figure 5a is provided to communicate such an algorithm at the same level of detail that is normally used, by persons of skill in the art to which this disclosure is directed, to communicate among themselves about plans, designs, specifications and algorithms for other computer programs of a similar level of complexity. The steps of process set out in Figure 5a may be performed in any order, and is not limited to the order shown in Figure 5a. The procedure starts with the device monitoring the ambient environment for user activity **450**. The monitoring step may utilize the process and componentry set out in Figures 3a and 3b. A determination is made whether or not the activity is related to handwashing or hand hygiene **455**. If the activity is related to hand hygiene, the process then presents a recommended handwashing step / hand hygiene step **460**. Again, the process returns to monitoring the user's activity **465**, and a determination is made if the user deviates from acceptable hand hygiene protocol **470**. If there is a deviation detected at step **470**, the process proceeds to present output to the user to further encourage compliance to an acceptable hand hygiene protocol **475**.

Figure 4b lists examples of how the device modifies its output according to one or more embodiments. Depending on the recommended step and the type of deviation, reinforcement may include outputting the importance of the particular step's compliance to ensure good hand hygiene; outputting the deviation in such a manner to "call out" the deviation to the user and to

others in the washroom; repeating the display of the recommended step with additional urgency to comply with the step; or some combination thereof. When the device **300** detects that the user appears to not comply with a recommended hand wash, the device **300** highlights non-compliance to the user by the use of an audio warning, a visual warning, or some combination thereof. The audio warning could be a voice recording, "You are not quite done your handwash!" or some suitable equivalent that may reference the type of non-compliance. If the process determines the user has complied with the recommended step at step **470**, the logical procedure determines whether all hand hygiene steps are complete **480**. If no, the appropriate recommended handwashing step is outputted. If yes, the process returns to monitor the ambient environment for the next user **450**. Before this, a variation of the present disclosure includes recognizing the user's hand hygiene compliance and/or feedback on improving the user's hand hygiene compliance. The device then returns to monitoring the environment to detect the next user. The steps set out in Figure 5a may be performed in any order or simultaneously, and the steps of detecting the user and/or detecting whether the user deviates may be continuous. Although shown sequentially, these steps may be performed in any order or simultaneously, and at least detecting the user may be continuous.

Other remediation is available should the user fail to comply with hand hygiene compliance. For example, the user ignores all recommended steps to comply, a notification is sent to janitorial staff to clean door handles at that bathroom location. This especially useful a work environment where janitorial staff are available for this remedial effort to mitigate the risks associated with non-compliance by users.

Figure 5b

Figure 5b is a flow chart illustrating an example algorithm for encouraging compliance for proper handwashing to be executed on device **300**, as shown in Figures 3a and 3b. At the start **505**, the system monitors the environment. Monitoring may include motion sensing. Upon a user approaching the device, which is preferably installed near the sink, the device will detect the user **510** and activate an output. Although shown sequentially, these steps may be performed in any order or simultaneously, and at least detecting the user may be continuous.

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Upon this activation, the device, in an embodiment, alerts the user of the device's **300** presence by displaying a visual message, an audio message/alert, or a combination thereof to the user. In another embodiment, the message is the statistics of those users doing a proper hand wash at the sink. For example, "Over 100 people followed the recommended handwashing protocol to ensure a healthy tomorrow. You are next!" or "Every employee has washed his/her hands today, you are next!" In this manner, the device **300** acts to influence the user's behavior to comply with better hand hygiene through a real-time reminder to wash his/her hands.

In this embodiment, the device displays the recommended steps for a proper hand wash. Each recommended handwashing step is displayed. In an alternative embodiment, the device also outputs a voice-over to reinforce each step displayed. Regarding Figure 5, the recommended handwashing step of wetting the hands is displayed **515** on the device's display. Next, the recommended step of applying soap is displayed **520** on the device's display. After that the recommended step of lathering/scrubbing the hands with soap is displayed **525** on the device's display. The message includes a countdown for hand lathering/scrubbing for a recommended period **530** is presented to the user.

In different embodiments, the period **530** may vary depending on the current public healthcare guidance. For example, in one embodiment, the period is twenty (20) seconds. In another embodiment, the period is fifteen (15) seconds. The configuration stage sets the recommended period. The algorithm starts the timer **535**, and a series of best practices of proper hand lathering/scrubbing is displayed **540**, and the countdown timer continues **550** until the countdown timer is complete **545**. Once the recommended period of time is complete, the step of rinsing of hands is displayed **555** on the device's display. Next, the step of drying of hands is displayed **560** on the device's display. Next, the step of turning off the water is displayed **565** on the device's display. Finally, the user is congratulated with a successful completion message displayed **570**. The process returns to start **505** by monitoring the arrival of the next user.

Figures 6a & 6b

Figure 6a and its continuation Figure 6b is a flow chart illustrating an example algorithm for encouraging compliance for proper handwashing to be executed on the device **300**, as shown

in Figure 3a. At the start **605**, the system monitors the washroom environment for a user **615**. Upon the device detecting a user **610**, it will activate its handwashing informational protocol. Although shown sequentially, these steps may be performed in any order or simultaneously, and at least detecting the user, environment monitoring, and other deviation conditions (such as non-compliance conditions as discussed below) may be continuous.

Upon this user detection, the device presents a message to encourage proper handwashing, namely wet the hands **615**. Next, the device monitors the environment for running water **617**. The device determines if water from the faucet is detected **620**. In one embodiment, the device listens through its audio input device **310** for the sound of running water. If no water is detected, the device reinforces this step by re-announcing the user to turn on the water tap to wet his/her hands **622**.

Once the device detects water, the algorithm then displays instructions to apply soap to the hands **625**. Next, the device monitors the environment for the use of the soap dispenser **627**. The device determines if the soap is being applied to the hands **630**. In one embodiment, the device listens for the use of the soap dispenser. If no dispenser use is detected, the device announces to the user to use the soap dispenser **632**. Once soap dispenser use is detected by the device, the algorithm then displays instructions to scrub the hands **635**.

The device displays a countdown timer **637** and monitors the user's environment commencing the step of scrubbing **640**. The device determines if the hands are being scrubbed **642**. In one embodiment, the device monitors the environment near the sink to detect the scrubbing hands through sound and/or motion detection. If yes, the device determines if all recommended scrubbing steps are completed in the recommended period **647**. In one embodiment, the period is twenty (20) seconds for the scrubbing steps. In another embodiment, the period is fifteen (15) seconds. Optionally, the process includes the output of a musical composition, tune or song during the time period. The recommended period is previously set during the configuration stage. If not, the device continues to display recommended scrubbing steps **635**. If yes, the rinse of hands step is displayed **650** on the device's display. Next, the device

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monitors the environment for the rinsing step **652**. The device determines if rinsing is detected **655**. If this step is not detected, a reinforcement message of rinsing is displayed **657**.

Next, the step of the drying of hands is displayed **660** on the device's display. The device monitors the environment for the drying of hands **662**. The device determines if the step of drying of the hands occurs at step **665**. In one embodiment, the device listens for the use of an air dryer or paper towel dispenser. If no hand drying is detected, the device announces to the user to dry his/her hands **667**. Once the device detects drying, the algorithm continues to then display instructions to shut the water off **670**.

Finally, the user is congratulated with a successful completion message displayed **672**. Once the user is detected to have moved away from the sink, the device returns to a sleep state whereby the device display conserves battery power by switching off or powering down the display. This detection of the user motion is determined by the sound of water no longer pouring from the faucet; the closing of the faucet to the off position; the user's footsteps moving away from the sink area; the closing of the washroom; or some combination thereof. The process then returns to start **605** by monitoring the arrival of the next user.

Figures 7a-7m

Exemplary instructions for compliance with the recommended handwashing protocol are shown in Figures 7a-7m. These instructions are sample outputs on display **320** on device **300**. Similar outputs may be provided in device **200**. As shown in Figures 7c - 7i, while the instructions are provided on how to scrub the hands correctly, a timer, preferably in the form of a countdown, is outputted to help inform and create accountability user to comply with the recommended scrubbing time duration. The graphical countdown includes a graphical element **755** that either increases or decreases according to the time remaining element **760** in the countdown as illustrated in Figure 7m. The steps illustrated are preferably embodied in an animated or video format with a voice-over and/or music.

Figures 8, 9a-c

With reference to Figure 8, the installation and set-up of device **300** now follow. The device **300** is preferably connected in the general vicinity of the sink area. In one variation, the

display **320** is situated such that it is at a user's viewing angle when the user is washing his/her hands. One example of the installation is shown in Figure 1c. Several other locations of the device may accomplish the same objective, including placing the device on the counter of the wash sink or on an opposing wall facing the sink area.

It is within the scope of the present disclosure to include a plurality of devices **300** working together collecting data that forms the learning training set for the plurality of devices. This technique is referred to as federated learning. This is a machine learning technique to train an algorithm across multiple decentralized edge devices (such as device **300**) or servers holding local data samples, without exchanging them. With the decentralization of servers, the entity managing the devices and system of the present disclosure can also achieve data minimization by reducing the amount of data that must be retained on a centralized server or in cloud storage. In that variation, a first device may house a set of the components described in device **300**, while a second device may have another set of components described in device **300**. For example, the second device may be positioned next to the sink area, primarily acting as an output device with a display driven by the first device positioned in another area of the room through wireless communication between the first and second device.

The configuration process includes the installer inputting the number of washroom elements at step **810**. As shown in Figures 9a-9c, this input may be achieved through a companion mobile app **900** in communication with the device **300**. Elements may generally include any fixture or apparatus that originates sound when in operation. Elements **905** may comprise sink, bathtub, shower, fan, doors, toilet, doors, the sound of footsteps on floor and other elements. The installer then inputs the number of each element at step **820** found in the ambient environment and may add certain characterizations of each element to better distinguish a particular washroom from other washroom environments. For example, the type of hand air dryer or toilet could be inputted. At least one sample audio recording for each element in operation **910** is preferably added at step **830**, and those labeled samples are added to the ML dataset at step **840** to enhance the ML model detection of the user's hand hygiene compliance. The app requests and receives at least one or more of the sounds set out in Figure 4a.

In the same manner, labeled motions may be added to the ML dataset. In one variation of the mobile app, the configurations of various physical layouts of the environment where the device is installed is preloaded into the app. This is likely feasible in commercial settings such as fast-food franchises where washroom configurations tend to be standardized. In this manner, the companion app **900** may assist in the quick configuration of the device **300**. The installer can quickly input ambient environment information through a simplified user interface (UI) as shown in Figures 9a-9c.

Although actual data sampling of the ambient environment is described above, the present disclosure may utilize synthetic data. As the name suggests, this type of data is artificially created rather than being generated by actual events. It is often created with the help of algorithms and is used for a wide range of activities, including as test data for new products and tools, for model validation, and in AI/ML model training. Synthetic data is important because it can be generated to meet specific needs or conditions that are not available in existing (real) data. This can be useful in numerous cases such as:

- when privacy requirements limit data availability or how it can be used

- data is needed for testing a product to be released however such data either does not exist or is not available to the testers

In the present disclosure, in one embodiment, synthetic data enables the entity that manages the device **300** and related systems to use ambient record data while still maintaining user confidentiality. The synthetic data may be combined with other PETs such as data masking and anonymization. The present disclosure includes modifying observed sensor data for purposes of adapting the training dataset towards a deployment environment. In this way, even if the actual captured sensor data is not from that specific ambient environment, the data may be leveraged for the target ambient environment. For instance, sensor data taken from a rest room in a bus station may be adapted for use in a football stadium. When the model training takes place is also a consideration. In one variation, the model may be trained prior to deployment, in another variation it may be trained over time in the deployment environment, or in yet another variation the model may be trained in a hybrid approach whereby you start with a training data set that

mimics the deployment environment and then retrain/update the model after deployment, to adapt it to the specific target environment.

However, it must be noted that audio sounds may vary from restroom-to-restroom such as faucets (pressure of water), environmental noise (football stadium bathroom much louder compared to company office bathroom), etc. That being said, training specific models to adapt to certain environments such as dedicating one model to loud environmental distortion noise (football stadium, bars, airport) is desired.

Figures 10a-10e

The process description below sets forth one analytic approach without the use of ML described earlier to determine the type of element (toilet flush, fan, etc.) that is detected in the audio signal received by the device **300**. It is within the scope of the present disclosure to incorporate some of the process below with the ML process description above. Figures 10a-10c are sample audio signal spectrum observations **1000** associated with flushes from three different toilets. Samples were collected over approximately a thirty second timespan. The vertical axis units are decibels whilst the horizontal axis is the frequency of the audio signal measured in Hertz for an element being monitored for its audio signal. The initialization/learning phase begins with measuring the power of the element. The power, which is the energy in a predetermined frequency band, is measured. A power ratio, for the element, is then established by dividing the power from the first band filter by the power from the second band filter. A ratio range is established for the element and variations thereof. A similar process occurs for a second element. Once the learning phase is established for various elements, when the trained device **300** receives an audio signal, the power ratio of the signal is measured and the type of element originating the audio signal may be determined by the association of the ratio range established for an element.

By way of example, a first bandpass filter is set for 0-600Hz, and a second bandpass filter is set for 3000-5000Hz. The power of the first bandpass is divided by the power of the second bandpass to establish a power ratio. With reference to Figures 10a-10c, the power ratio of the toilet flushes is approximately 3 through 7 (meaning the power in the first bandpass is 3 to 7

times more powerful than the second bandpass). Similarly, Figures 10d and 10e are sample audio signal observations **1000** associated, respectively, with an exemplary bathroom fan and faucet running water into a sink. In contrast to the toilet flush, with reference to Figure 10d, the fan tends to have a power ratio of greater than 7. Hence, if the device **300** determines a ratio of greater than 7, the origination of the audio signal is presumed to be a fan. Likewise, with reference to Figure 10e, the faucet running water into the sink tends to have a power ratio less than 3. The above-described bands were chosen specifically for a specific device configuration (e.g., processor limitations of the testing device); however, various bands may be adopted depending in part with the processor capabilities.

RFID Enabled Device

In one embodiment, the device has a Radio Frequency Identification (RFID) reader means. RFID uses radio waves produced by a reader to detect the presence of (then read the data stored on) an RFID tag. RFID tags may be in small items like cards, buttons, or name tags on uniforms. This particular embodiment is useful for use in the hospitality or healthcare industry where employees are wearing RFID-enabled name tags or employee badges, and where collection of PII as it relates to employees in their role at their work environment is acceptable. Employers are then able to enhance the compliance of the proper handwashing protocol of their employees when the device is in use. If the device detects non-compliance, a notification is sent to the appropriate person or system to inform the particulars of the user's non-compliance.

Gamification

In one variation, information is collected in the aggregate and stored on a datastore for dissemination in a way that illustrates the adherence of certain washroom facilities compared to others. For example, a geographically diverse fast food business can readily identify where problematic users are located by the lack of adherence to the recommended steps. In an alternative variation, users may opt to share their experience (on whatever social media platform of their choice) of compliance with proper handwash. They may do so by scanning a barcode or other unique identifier associated with the device to share stats of how well that particular washroom is doing in having users comply with properly washing their hands. In another

variation, the device displays a statistic to recognize the user's contribution to help fend off the spread of germs and disease by performing a proper handwash - for example: "Congratulations, you are 400th person today to properly handwash. Be clean, be safe and be healthy!".

Voice Recognition and Figure 4c

The present disclosure, in another variation, detects a user's voice as it only relates to issues associated with washroom hygiene-related issues. Some examples of the limited context of the voice it may detect and recognize are set forth in Figure 4c. The intention of limiting the recognition of voice is to reduce the concerns relating to protecting the user's privacy. The issues in Figure 4c may trigger in this variation a new response by the device to modify the recommended handwashing steps and/or seek to remedy the outstanding issue by informing the appropriate janitorial staff.

Thermal Sensing Device

In another variation of the present disclosure, with reference to Figure 3a, an additional input device in the form of a thermal sensing device may be added to device **300**. With adequate adaptation, this will add considerable new functionality in the form of better detecting user deviation from the recommended handwashing protocol. The thermal sensing device will, for example, better distinguish when a user simply walks past the device, perhaps to use the washroom facilities, including the urinal or toilet, versus leaving the washroom without attending to wash his/her hands. The thermal sensing device could combine audio data from the audio input device and/or motion-sensing device to further enhance the positive determination of this deviation. Hence, this deviation detection is directed to determine whether the user intends to use the sink to wash his/her hands. As an alternative to the thermal sensor, an optical video capture device may be substituted. This may raise privacy issues that need to be addressed using PET.

In another aspect, a system to encourage hand hygiene comprises a first device and a second device that cooperates with a toilet. The first device is situated at or near the sink area while the second device is situated in or at the toilet tank area. The second device communicates with the first device when the second device detects the flushing operation of a toilet.

The second device comprising a microprocessor, power source, wireless transmitter, and sensor. The sensor may be an accelerometer, a motion sensor, or an infra-red sensor. The second device may comprise a waterproof or water-resistant housing that may be floatable on the surface of water found in the toilet tank or cistern. Alternatively, the second device sits on the lip of the tank and detects the water displacement. Detection could be sound, vibration, visual, infrared, motion, or some combination thereof.

In one aspect, the second device detects the displacement of water from a first level to a second level in the toilet tank or cistern after a flush operation occurs in the toilet. Upon this detection, the second device wirelessly communicates information through the wireless transmitter to the first device about the flush operation. The first device, upon receiving this information, activates its functionality that hand-hygiene related activity may soon ensue. Such functionality includes visual and/or audio annunciation to wash hands.

It should be noted that while certain steps within procedures may be optional as described above, the steps are shown in Figures 5a, 5b, 6a, 6b, and 8 are merely examples for illustration, and certain other steps may be included or excluded as desired. Further, while a particular order of the steps is shown, this ordering is merely illustrative, and any suitable arrangement of the steps may be utilized without departing from the scope of the embodiments herein. Moreover, while some procedures are described separately, certain steps from each procedure may be incorporated into each other procedure, and the procedures are not meant to be mutually exclusive.

For example, while certain embodiments are described herein with respect to using certain models for purposes of non-compliance detection, the models are not limited as such and may be used for other functions in other embodiments. In addition, while certain recommended handwashing protocols are shown, other suitable protocols may be used accordingly.

The foregoing description has been directed to specific embodiments. It will be apparent, however, that other variations and modifications may be made to the described embodiments, with the attainment of some or all of their advantages. For instance, it is expressly contemplated that the components and/or elements described herein can be implemented as software being

stored on a tangible (non-transitory) computer-readable medium (e.g., disks/CDs/RAM/EEPROM/etc.) having program instructions executing on a computer, hardware, firmware, or a combination thereof. Accordingly, this description to be taken only by way of example and not to otherwise limit the scope of the embodiments herein. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the embodiments herein.

CLAIMS

1. A method comprising:

      obtaining, by a device, sensor data captured by one or more sensors deployed in a washroom, the sensor data comprising audio signals;

      identifying, by the device and using the sensor data as input to one or more machine learning-based classifiers, one or more events associated with a user of the washroom;

      making, by the device, a decision as whether the one or more events comply with a hand hygiene protocol; and

      providing, by the device, data indicative of the decision for presentation to the user.

2. The method as in claim 1, wherein the sensor data further comprises motion signals indicative of movements by the user.

3. The method as in claim 2, wherein the one or more machine learning-based classifiers comprises a motion classifier.

4. The method as in claim 1, wherein providing the data indicative of the decision for presentation to the user comprises:

      customizing the data indicative of the decision based in part on a history of compliance with the hand hygiene protocol by the user.

5. The method as in claim 1, wherein the data indicative of the decision further indicates a comparison between the decision and other decisions made regarding compliance with the hand hygiene protocol by others.

6. The method as in claim 1, further comprising:

      identifying, by the device and based on the sensor data, a maintenance issue associated with the washroom.

7. The method as in claim 6, further comprising:

adjusting, by the device and based on the identified maintenance issue, the hand hygiene protocol, prior to making the decision as to whether the one or more events comply with the hand hygiene protocol.

8. The method as in claim 6, further comprising:

sending, by the device, an alert regarding the identified maintenance issue.

9. The method as in claim 1, wherein the data indicative of the decision comprises an instruction to perform a particular step of the hand hygiene protocol.

10. The method as in claim 1, wherein the one or more sensors deployed to the washroom comprises an audio sensor.

11. The method as in claim 1, wherein the one or more sensors comprises a motion sensor.

12. The method as in claim 1, wherein identifying the one or more events associated with the user comprises:

obfuscating, by the device, personally identifiable information of the user that is present in the sensor data.

13. The method as in claim 1, further comprising:

providing, by the device, data indicative of a step of the hand hygiene protocol for presentation to the user, prior to identifying the one or more events.

14. The method as in claim 1, wherein the audio signals are indicative of running water.

15. The method as in claim 1, wherein the audio signals are indicative of use of soap by the user.

16. The method as in claim 1, wherein the provided data comprises a voice recording.

17. The method as in claim 1, wherein the provided data comprises display data for presentation by an electronic display.

18. The method as in claim 17, wherein the electronic display is a display of a wearable electronic device worn by the user.

19. An apparatus comprising:

one or more interfaces;

a microprocessor coupled to the one or more interfaces; and

a memory storing instructions that, when executed by the microprocessor, are configured to:

obtain sensor data captured by one or more sensors deployed in a washroom, the sensor data comprising audio signals;

identify, using the sensor data as input to one or more machine learning-based classifiers, one or more events associated with a user of the washroom;

make a decision as whether the one or more events comply with a hand hygiene protocol; and

provide data indicative of the decision for presentation to the user.

20. A tangible, non-transitory, computer-readable medium storing program instructions that cause a device to execute a process comprising:

obtaining, by the device, sensor data captured by one or more sensors deployed in a washroom, the sensor data comprising audio signals;

identifying, by the device and using the sensor data as input to one or more machine learning-based classifiers, one or more events associated with a user of the washroom;

making, by the device, a decision as whether the one or more events comply with a hand hygiene protocol; and

providing, by the device, data indicative of the decision for presentation to the user.

ABSTRACT

In one embodiment, a device obtains sensor data captured by one or more sensors deployed in a washroom, the sensor data comprising audio signals. The device identifies, using the sensor data as input to one or more machine learning-based classifiers, one or more events associated with a user of the washroom. The device makes a decision as whether the one or more events comply with a hand hygiene protocol. The device provides data indicative of the decision for presentation to the user.