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VIRTUAL FIELD OF VIEW FOR PATIENT MONITORING

Abstract

A system for remotely monitoring a patient in a patient environment. The system receives an environment view and determines one or more objects for monitoring in the environment view. The system receives video data of the one or more objects. The video data is captured by a camera positioned inside the patient environment. The system generates a virtual field of view using the video data of the one or more objects. The virtual field of view provides the environment view and detailed views of the one or more objects within the environment view.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 63/555,560, filed Feb. 20, 2024, the entire disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] Video surveillance is increasingly being used for monitoring patients within healthcare environments such as hospitals in view of caregiver shortages. To encapsulate necessary details for effective remote monitoring of a patient, it is desirable to be able to focus on one or more regions of interest. However, it is also desirable to preserve an overall view of the patient's surroundings for context. Obtaining high-resolution video while maintaining environmental context awareness with limited equipment is challenging.

SUMMARY

[0003] In general terms, the present disclosure relates to remote patient monitoring. In one possible configuration, a virtual field of view is generated that provides an environment view and detailed views of one or more regions of interest within the environment view. Various aspects are described in this disclosure, which include, but are not limited to, the following aspects.

[0004] One aspect relates to a system for remotely monitoring a patient in a patient environment, the system comprising: at least one processing device; and at least one computer readable data storage device storing software instructions that, when executed by the at least one processing device, cause the at least one processing device to: receive an environment view; determine one or more objects for monitoring in the environment view; receive video data of the one or more objects, the video data captured by a camera positioned inside the patient environment; and generate a virtual field of view using the video data of the one or more objects, the virtual field of view providing the environment view and detailed views of the one or more objects within the environment view.

[0005] Another aspect relates to a method of remotely monitoring a patient in a patient environment, the method comprising: receiving an environment view of the patient environment; determining one or more objects for monitoring in the environment view; receiving video data of the one or more objects, the video data captured by a camera positioned inside the patient environment; and generating a virtual field of view using the video data of the one or more objects, the virtual field of view providing the environment view and detailed views of the one or more objects within the environment view.

[0006] Another aspect relates to a non-transitory computer readable storage media including computer readable instructions which, when read and executed by a computing device, cause the computing device to: receive an environment view; determine one or more objects for monitoring in the environment view; receive video data of the one or more objects, the video data captured by a camera positioned inside the patient environment; and generate a virtual field of view using the video data of the one or more objects, the virtual field of view providing the environment view and detailed views of the one or more objects within the environment view.

[0007] A variety of additional aspects will be set forth in the description that follows. The aspects can relate to individual features and to combination of features. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the broad inventive concepts upon which the embodiments disclosed herein are based.

Description

DESCRIPTION OF THE FIGURES

[0008] The following drawing figures, which form a part of this application, are illustrative of the described technology and are not meant to limit the scope of the disclosure in any manner.

[0009] FIG. **1** illustrates an example of a system for monitoring a patient in a patient environment by generating a virtual field of view.

[0010] FIG. **2** schematically illustrates an example of a camera that can be implemented in the patient environment of FIG. **1**.

[0011] FIG. **3** schematically illustrates an example of a method of capturing video data that can be used for generating the virtual field of view of the patient environment of FIG. **1**.

[0012] FIG. **4** schematically illustrates an example of a method of generating the virtual field of view of the patient environment of FIG. **1**.

[0013] FIG. **5** illustrates an example of the virtual field of view that can be generated by the method of FIG. **4**.

[0014] FIG. **6** schematically illustrates an example of a method of operating the virtual field of view of FIG. **5**.

DETAILED DESCRIPTION

[0015] FIG. **1** illustrates an example of a system **10** for monitoring a patient P in a patient environment **100** by generating a virtual field of view. The patient P is shown resting on a patient support apparatus **102** inside the patient environment **100**. The patient environment **100** can be an area within a medical facility such as a patient room in a hospital. The patient environment **100** includes medical equipment such as the patient support apparatus **102**, and other medical equipment such as a patient monitoring device **104**, and an ambulation device **106**.

[0016] As shown in FIG. **1**, the patient P is supported on the patient support apparatus **102** inside the patient environment **100**. The patient support apparatus **102** can be a hospital bed, a stretcher, operating room table, or similar type of apparatus on which the patient P can rest. The patient support apparatus **102** can include one or more sensors that measure one or more physiological parameters of the patient P such as heart rate, non-invasive blood pressure (NIBP), motion, and weight. Additionally, the patient support apparatus **102** can include sensors that detect patient exit, incontinence, deterioration, and other metrics.

[0017] The patient monitoring device **104** can be used to measure and monitor physiological parameters of the patient P, and to display representations of the measured physiological parameters on a display **105**. The display **105** can include a touchscreen that operates to receive tactile inputs from a user such as a caregiver such that the display **105** is both a display device and a user input device. In some examples, the display **105** is a liquid-crystal display (LCD), an organic light-emitting diode (OLED, a plasma panel, a quantum-dot light-emitting diode (QLED), or other type or combination of display screen technology.

[0018] The patient monitoring device **104** includes one or more sensor modules that can be used to measure one or more physiological parameters of the patient P. For example, the patient monitoring device **104** can include a temperature sensor module for measuring the patient P's temperature, a pulse oximetry sensor module for measuring the patient P's blood oxygen saturation (SpO2), and a non-invasive blood pressure (NIBP) sensor measurement module for measuring the patient P's blood pressure. As used herein, a “module” is a combination of physical structure which resides in the patient monitoring device **104** and peripheral components that attach to and reside outside of the patient monitoring device **104**. The patient monitoring device **104** can include additional sensor modules for receiving additional physiological parameter measurements, including heart rate, pulse, and ECG/EKG.

[0019] In the illustrative example shown in FIG. **1**, the patient monitoring device **104** is mounted on a mobile cart **107** such that the patient monitoring device **104** is portable and can be brought into and out of the patient environment **100**. In alternative examples, the patient monitoring device

104 can be stationary such that it can include a wall mounted unit.

[0020] Also, in the example shown in FIG. **1**, the ambulation device **106** is illustrated as a walker. Additional types of ambulation devices are contemplated.

[0021] As shown in FIG. **1**, the system **10** includes a camera **200** that is mounted to a wall of the patient environment **100**. The camera **200** can be mounted at different locations within the patient environment **100**. In alternative examples, the system **10** can include a plurality of cameras mounted onto the walls or elsewhere within the patient environment **100**.

[0022] The camera **200** is configured to pan, tilt, and zoom for adjusting a view of the patient environment **100** as well as views of individual objects within the patient environment **100** such as the patient P, the patient support apparatus **102**, the patient monitoring device **104**, and the ambulation device **106**. The camera **200** can include a gimbal or similar structure that is actuated by an electric motor **218** (see FIG. **2**) to pan the camera **200** between left and right and to tilt the camera **200** up and down. Also, the camera **200** can zoom in and out by adjusting a focal length of a lens whether by mechanically (e.g., mechanical zoom) or digitally (e.g., digital zoom).

[0023] The camera **200** operates to capture a wide field of view of the patient environment **100** that can range across 180 degrees, or more. Also, the camera **200** operates to zoom-in on one or more regions of interest within the patient environment **100** such as a region of interest on the patient P, a region of interest on the patient support apparatus **102**, a region of interest on the patient monitoring device **104**, or a region of interest on the ambulation device **106**. As will be described in more detail, the camera **200** is controlled to switch between the wide field of view and the views of the regions of interest based on a timed interval or a detected trigger event.

[0024] Video data captured by the camera **200** can be used to extract one or more parameters relevant to remote monitoring of the patient P. For example, physiological parameters of the patient P such as heart rate, respiration rate, patient movement, and the like can be extracted from the video data captured by the camera **200**. Several techniques can be used to determine the respiration rate of the patient P from the video data captured by the camera **200**, such as those described in U.S. Provisional Patent Application No. 63/489,901, filed Mar. 13, 2023, entitled Respiration Monitoring, which is incorporated herein by reference in its entirety.

[0025] Additional parameters can be extracted from the video data captured by the camera **200** such as a state of operation or functioning of the patient support apparatus **102**, the patient monitoring device **104**, and/or the ambulation device **106**. For example, the camera **200** can zoom-in on the patient support apparatus **102** to determine one or more settings or states of operation of the patient support apparatus **102** such as a bed angle displayed on a display of the patient support apparatus **102**. As another example, the camera **200** can zoom-in on the patient monitoring device **104** to determine a state of operation such as whether one or more alarms are triggered on the display **105** of the patient monitoring device **104**, or one or more vital sign measurements that are displayed on the display **105** of the patient monitoring device **104**.

[0026] As shown in FIG. **1**, the camera **200** is connected to a network **108**. In some examples, the network **108** connects and exchanges data between the camera **200** and other equipment inside the patient environment **100**, as well as between the camera and other systems and devices outside of the patient environment **100**. The network **108** can include any type of wired or wireless connections, or any combinations thereof. In some examples, the wireless connections can be accomplished using Wi-Fi, ultra-wideband (UWB), Bluetooth, and the like. In some examples, the network **108** is an Internet of things (IoT) network.

[0027] As shown in FIG. **1**, the network **108** transfers the data captured by the camera **200** to a patient monitoring system **500** for display on a workstation monitor **502**. The network **108** provides two-way communications between the patient monitoring system **500** and the camera **200**. In some examples, the patient monitoring system **500** is part of a nurse call system. As will be described in more detail, the patient monitoring system **500** displays a virtual field of view on the workstation monitor **502** based on the video data captured by the camera **200**.

[0028] In some examples, the patient monitoring system **500** is communicatively connected to the workstation monitor **502** via the network **108**. Alternatively, the patient monitoring system **500** can be connected directly to the workstation monitor **502** via wired and/or wireless connections without using the network **108** to communicate with the workstation monitor **502**.

[0029] As further shown in FIG. **1**, video data captured by the camera **200** including parameters that are determined from analysis of the video data can be transferred over the network **108** to an EHR system **700** for storage in an electronic health record (EHR) **702**. As described herein, the terms electronic medical records (EMRs) and electronic patient record (EPRs) can be used interchangeably with EHRs. The EHR system **700** collects patient electronically stored health information in a digital format (e.g., EHRs **702**). As such, the EHR system **700** maintains a plurality of EHRs **702** for a plurality of patients. Each EHR **702** can be shared across different health care settings. For example, the EHRs **702** are shared through network-connected, enterprise-wide information systems or other information networks and exchanges. The EHRs **702** may include a range of data, including demographics, medical history, medication and allergies, immunization status, laboratory test results, radiology images, vital signs, personal statistics like age and weight, and billing information.

[0030] FIG. **2** schematically illustrates an example of the camera **200** that can be implemented in the patient environment **100** of FIG. **1**. The camera **200** includes one or more types of imaging modalities **202**. For example, the imaging modalities **202** include an RGB imaging modality **206** that can be used to capture a color video of the patient environment **100** and of regions of interest on the objects located inside the patient environment **100**.

[0031] The imaging modalities **202** of the camera **200** can further include an infrared imaging modality **208** that can be used to capture an infrared video of the patient environment **100** and of the objects that are located inside the patient environment **100**. The imaging modalities **202** of the camera **200** can also include a depth imaging modality **210** that can be used to capture depth (D) data of the objects that are located inside the patient environment **100**. The imaging modalities **202** can also include a thermal imaging modality **212** that can be used to capture a thermal imaging video of the patient environment **100** and of the objects that are located inside the patient environment **100**. The foregoing examples of the imaging modalities **202** are not exhaustive, and it is contemplated that the camera **200** can include additional types of imaging modalities **202** for capturing video data of the patient environment **100** and of the objects that are located inside the patient environment **100**.

[0032] As further shown in FIG. **2**, the camera **200** can also include a millimeter wave antenna **204** that can be used to detect movements within the patient environment **100** such as motion by the patient P and/or other persons such as caregivers inside the patient environment **100**. The millimeter wave antenna **204** can also detect movements of equipment inside the patient environment **100** such as movements of the patient support apparatus **102**, the patient monitoring device **104**, and the ambulation device **106**. Additionally, the millimeter wave antenna **204** can also detect motion such as chest movements for calculating a non-contact vital sign measurement based on the reflected millimeter wave signals of the patient P. The millimeter wave antenna **204** can include aspects described in U.S. Pat. No. 11,653,848 B2, granted on May 23, 2023, which is incorporated herein by reference in its entirety. In some examples, an imaging modality **202** of the camera **200** and the millimeter wave measurements by the millimeter wave antenna **204** can occur simultaneously on the camera **200**.

[0033] The camera **200** can further include a microphone **214** that can detect audio inside the patient environment **100**. For example, the microphone **214** can detect noises due to movement of the patient P, or movement of one or more pieces of equipment inside the patient environment **100** such as by the patient support apparatus **102**, the patient monitoring device **104**, or the ambulation device **106**. While FIG. **2** shows the microphone **214** integrated with the camera **200**, in alternative examples, the microphone **214** can be a separate device that is located outside of the camera **200**, and positioned elsewhere in the patient environment **100**. In some examples, the microphone **214** can be integrated with other pieces of equipment inside the patient environment **100** that are communicatively coupled to the patient monitoring system **500** such as the patient support apparatus **102**, the patient monitoring device **104**, or the ambulation device **106**.

[0034] In some examples, the camera **200** includes a speaker **216** that can be controlled by the patient monitoring system **500** to provide audio for interaction with the patient P inside the patient environment **100**. For example, when the patient P is under a blanket such that a view of the patient P's chest is obstructed, the patient monitoring system **500** can emit an audio command through the speaker **216** to communicate to the patient P the need to remove the blanket so that the camera **200** can obtain an unobstructed view of the patient P's chest. As another illustrative example, when the patient P is moving inside the patient environment **100**, the patient monitoring system **500** can emit an audio command through the speaker **216** to communicate to the patient P the need to remain still such that a non-contact vital sign measurement can be calculated based on the video data captured by the camera **200** or based on the reflected millimeter wave signals captured by the millimeter wave antenna **204**.

[0035] While FIG. **2** shows the speaker **216** integrated with the camera **200**, in alternative examples, the speaker **216** can be a separate device that is located outside of the camera **200**, and positioned elsewhere in the patient environment **100**. In some further examples, the speaker **216** can be integrated with other pieces of equipment inside the patient environment that are communicatively coupled to the patient monitoring system **500** such as the patient support apparatus **102**, the patient monitoring device **104**, or the ambulation device **106**.

[0036] As further shown in FIG. **2**, the camera **200** includes a computing device **220** having at least one processing device **222** and a memory device **224**. The at least one processing device **222** is an example of a processing unit such as a central processing unit (CPU). The at least one processing device **222** can include one or more central processing units (CPUs). In some examples, the at least one processing device **222** includes one or more digital signal processors, field-programmable gate arrays, and/or other types of electronic circuits.

[0037] The memory device **224** operates to store data and instructions for execution by the at least one processing device **222**. In the example illustrated in FIG. **2**, the memory device **224** stores a virtual field of view monitoring application **226**, which will be described in more detail. The memory device **224** includes computer-readable media, which may include any media that can be accessed by the camera **200**. By way of example, computer-readable media include computer readable storage media and computer readable communication media. As such, the memory device **224** is an example of a computer readable data storage device storing software instructions for execution by the at least one processing device **222**.

[0038] Computer readable storage media includes volatile and nonvolatile, removable and non-removable media implemented in any device configured to store information such as computer readable instructions, data structures, program modules, or other data. Computer readable storage media can include, but is not limited to, random access memory, read only memory, electrically erasable programmable read only memory, flash memory, and other memory technology, including any medium that can be used to store information that can be accessed by the camera. The computer readable storage media is non-transitory.

[0039] Computer readable communication media embodies computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. The term “modulated data signal” refers to a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, computer readable communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency, infrared, and other wireless media. Combinations of any of the above are within the scope of computer readable media.

[0040] The camera **200** further includes a communications interface **228** that allows the camera **200** to connect to the network **108**. The communications interface **228** can include wired interfaces and/or wireless interfaces. For example, the communications interface **228** can wirelessly connect to the network **108** through Wi-Fi, or other wireless connections. Alternatively, the communications interface **228** can connect to the network **108** using wired connections such as through an Ethernet or Universal Serial Bus (USB) cable.
[0041] As further shown in FIG. **2**, the camera **200** includes one or more electric motors **218**. The one or more electric motors are controlled to pan the camera **200** between left and right and to tilt the camera **200** up and down. Also, the one or more electric motors **218** can be used to adjust a focal length of a lens of the camera **200** to provide mechanical zoom adjustment.
[0042] The camera **200** further includes a light source **230** that is controlled to illuminate a region of interest in the patient environment **100**. For example, the light source **230** can generate a spotlight to illuminate with white light a region of interest for capturing a color video of the region. In further examples, the light source **230** can emit a referential dot, shape, or pattern that can be tracked in the videos captured by the camera **200** to measure one or more parameters such as respiration rate that is determined based on movement of the patient P's chest.
[0043] FIG. **3** schematically illustrates an example of a method **300** of capturing video data that can be used for generating a virtual field of view of the patient environment **100**. The method **300** can be performed by the camera **200**. The method **300** includes an operation **302** of obtaining an environment view of the patient environment **100**. The environment view is a wide field of view of the patient environment **100**. For example, the environment view can span across a range of 180 degrees or more such that the patient P and all other objects and pieces of equipment inside the patient environment **100** are included in the environment view.
[0044] The method **300** includes an operation **304** of receiving monitoring parameters that are determined based on the environment view captured in operation **302**. In some examples, the monitoring parameters are determined by the patient monitoring system **500**, and are received by the camera **200** from the patient monitoring system **500** over the network **108**. In alternative examples, the camera **200** can determine the monitoring parameters based on the environment view captured in operation **302**. The monitoring parameters will be described in more detail further below with reference to the method **400** of FIG. **4**.
[0045] The method **300** includes an operation **306** of capturing video feeds of one or more regions of interest based on the monitoring parameters received in operation **304**. The video feeds can include color videos using the RGB imaging modality **206**, infrared videos using the infrared imaging modality **208**, depth videos using the depth imaging modality **210**, and/or thermal videos using the thermal imaging modality **212**.
[0046] Operation **306** can include capturing the video feeds based on a predetermine sequence such as a first video feed of a first region of interest, followed by a second video feed of a second region of interest, and so on. Also, the video feed of each region of interest can be captured by the camera **200** using a different imaging modality **202** based on the monitoring parameters received in operation **304**. This can mitigate computational burdens on the camera **200** and the patient monitoring system **500** because certain imaging modalities may have higher data processing and data transfer bandwidth burdens than other imaging modalities. For example, the depth imaging modality **310** typically has a higher data processing and transfer bandwidth burden than other imaging modalities. By capturing the video feeds in a predetermined sequence such that the depth imaging modality **310** is used periodically by the camera **200** (instead of continuously), the data processing and data transfer bandwidth burdens on the camera **200** are mitigated, thereby improving the functional performance of the camera **200**.
[0047] As an illustrative example, operation **306** can include capturing a video feed of the patient P's chest that can be used to measure the patient P's respiration rate. As another example, operation **306** can further include capturing a video feed of a display on the patient support apparatus **102** that

can be used to view one or more settings or states of operation of the patient support apparatus **102** such as a bed angle. As another example, operation **306** can include capturing a video feed of the display **105** on the patient monitoring device **104** to view the physiological variable measurements captured by the patient monitoring device **104**, or whether one or more alarms are triggered on the patient monitoring device **104**.

[0048] In some examples, when a region of interest cannot be viewed by the camera **200** such as due to an obstruction, operation **306** can include issuing an audible command through the speaker **216** to instruct the patient P or another person such as a caregiver inside the patient environment **100** to remove the obstruction. For example, when a region of interest includes the patient P's chest which is obscured by a blanket, operation **306** can include issuing an audible command through the speaker **216** to instruct the patient P or another person to remove the blanket from the patient P's chest to allow the camera **200** to capture a video feed of the chest.

[0049] The method **300** includes an operation **308** of determining whether a predetermined time period has elapsed or a trigger event has occurred. When operation **308** determines that the predetermined time period has not elapsed and one or more trigger events have not occurred (i.e., “No” in operation **308**), the method **300** continues the operation **306** of capturing the one or more video feeds. When operation **308** determines that the predetermined time period has elapsed or one or more trigger events have occurred (i.e., “Yes” in operation **308**), the method **300** returns to operation **302** to obtain an environment view of the patient environment **100**.

[0050] As an illustrative example, a trigger event can include an event or measurement detected based on a video feed captured in operation **306**. For example, a video feed of a region of interest on the patient P can be analyzed in operation **308** to detect an event, which causes the method **300** to return to operation **302** such that the camera **200** zooms out to capture the environment view of the patient environment **100**. This can provide context to explain a potential cause of the event detected in the video feed of the region of interest on the patient P.

[0051] As an illustrative example, operation **308** can include analyzing a video feed of a region of interest on the patient P's chest that detects a decrease in respiration rate by the patient P. This causes the method **300** to return to operation **302** such that the camera **200** zooms out to capture the environment view of the patient environment **100**, which shows the patient P is talking with another person who has entered the patient environment **100**. This provides context to explain the decrease in respiration rate by the patient P such that an alarm that would otherwise be triggered by the patient monitoring system **500** is suppressed.

[0052] As another illustrative example, a trigger event can include a sound detected by the microphone **214** that indicates movement of the patient P within the patient environment **100** such as when the patient P exists the patient support apparatus **102**. As another example, a trigger event can include a sound detected by the microphone **214** that indicates an event such as a patient fall. A trigger event can also include a sound detected by the microphone **214** that indicates movement of an object within the patient environment **100**. As another example, a trigger event can include a sound detected by the microphone **214** that indicates an audible alarm triggered on one or more pieces of equipment inside the patient environment **100** such as an alarm triggered on the patient support apparatus **102** or the patient monitoring device **104**.

[0053] In this manner, the method **300** updates the environment view of the patient environment **100** to maintain overall surveillance and awareness of the patient environment **100**, while also obtaining video feeds of particular regions of interest within the patient environment **100**. This can be accomplished by using a single camera, instead of requiring use of a plurality of cameras, and can thereby improve efficiencies within the medical facility where the patient environment **100** is located by reducing the need to employ additional cameras. The method **300** can improve the functioning of the camera **200** by allowing the camera **200** to capture detailed images or videos of one or more regions of interest on objects within the patient environment **100** without sacrificing a broader contextual view of the patient environment **100**.

[0054] FIG. **4** schematically illustrates an example of a method **400** of generating a virtual field of view of the patient environment **100**. The method **400** can be performed by the patient monitoring system **500**. In some examples, aspects of the method **400** can be performed on the camera **200**. The method **400** includes an operation **402** of receiving the environment view from the camera **200**. The environment view can be received over the network **108**.

[0055] The method **400** includes an operation **404** of identifying objects in the environment view. The objects identified in operation **404** depend on the persons and equipment located inside the patient environment **100** at the time the environment view is captured by the camera **200**. For example, in view of the patient environment **100** shown in FIG. **1**, operation **404** can include identifying the patient P, the patient support apparatus **102**, the patient monitoring device **104**, and the ambulation device **106**. Operation **404** includes identifying the objects using one or more algorithms such as artificial intelligence and machine learning algorithms.

[0056] The method **400** includes an operation **406** of determining which objects to monitor from the objects identified in operation **404**. In some examples, operation **406** can include determining which objects to monitor based on whether an object is stationary, or is non-stationary such that it is portable or movable within the patient environment **100**. Stationary objects like walls and doors remain unchanged and do not require periodic updates. Conversely, portable or movable objects including the patient P and items that can be manipulated by the patient P or caregivers (e.g., the patient support apparatus **102**, the patient monitoring device **104**, the ambulation device **106**, intravenous (IV) pumps, and the like) are dynamic such that they should be periodically monitored by adjusting the viewpoint of the camera **200**.

[0057] In some examples, operation **406** can include applying one or more flags to the objects identified in operation **404**. For example, operation **406** can include applying a dynamic flag on the patient monitoring device **104** when mounted on the mobile cart **107** because the patient monitoring device **104** is portable. In examples where the patient monitoring device **104** is wall mounted such that it is not portable, operation **406** can include applying a static flag to the patient monitoring device **104**. The dynamic/static flags can be used to determine whether to select an object for periodic monitoring or not. For example, static objects are not selected for periodic monitoring since they are stationary and their position does not change within the patient environment **100**. In contrast, portable objects can be selected for periodic monitoring since the position of these objects can change within the patient environment **100**.

[0058] In some examples, operation **406** can include determining which objects to monitor is based on a condition identified in the environment view received in operation **402**. As an illustrative example, operation **406** can include selecting the ambulation device **106** as an object to monitor when the environment view shows the patient P as being within a predetermined distance of the ambulation device **106** such that patient P is within reach of using the device.

[0059] In some examples, operation **406** includes determining which objects to monitor based on information acquired from the EHR system **700**. For example, operation **406** can include determining which objects to monitor based on one or more diseases, conditions, and/or diagnoses of the patient P stored in the EHR **702**. As an illustrative example, operation **406** can include selecting the patient P as an object to monitor when the EHR **702** identifies the patient P as having a fall risk, or as having a health condition such that it is recommended to measure physiological variables such as respiration rate through non-contact means. As another illustrative example, operation **406** can include selecting an infusion pump as an object to monitor when the EHR **702** identifies the patient P is undergoing an infusion therapy.

[0060] The method **400** includes an operation **408** of determining one or more monitoring parameters for the objects determined in operation **406**. The monitoring parameters can define, without limitation, a region of interest on the object, a minimum resolution, a minimum field of view, a movement tolerance, a minimum illumination, and a monitoring frequency. The monitoring parameters control the movement and positioning of the camera **200** when targeting an object during the periodic monitoring of the object performed in the method **300** of FIG. **3**.

[0061] As an illustrative example, when operation **406** selects the patient P as an object for monitoring the respiration rate of the patient P, operation **408** can include defining the chest as the region of interest, a minimum resolution of 200×200 pixels/inch, a minimum field of view that includes the patient P's full body with a minimum allowed obstruction of 20%, a movement tolerance of 0 meters/second, a lighting requirement of 0.01 Lux, and a monitoring frequency of 3 minutes when respiration rate measurements are within a normal range.

[0062] As another example, when operation **406** selects the patient monitoring device **104** as an object for monitoring in the patient environment **100**, operation **408** can include defining the display **105** as the region of interest, and can further select a minimum resolution and a minimum frequency for capturing a video of the display **105** on the patient monitoring device **104**.

[0063] The method **400** includes an operation **410** of sending to the camera **200** the objects determined in operation **406** and the monitoring parameters determined in operation **408**. Operation **410** can be performing using the network **108** which communicatively connects the patient monitoring system **500** to the camera **200**.

[0064] The method **400** includes an operation **412** of receiving the video feeds from the camera **200**. The video feeds are captured by the camera **200** based on the objects determined in operation **406** and the monitoring parameters determined for objects in operation **408**. The video feeds can be received from the camera **200** over the network **108**.

[0065] The method **400** can include an operation **414** of determining one or more physiological parameters based on the video feeds received in operation **412**. For example, operation **414** can include determining the respiration rate of the patient P based on the up and down chest movements observed in a video feed of the patient P's chest.

[0066] The method **400** includes an operation **416** of generating a virtual field of view using the video feeds received from the camera **200** in operation **412**. The virtual field of view allows a caregiver who is remotely located with respect to the patient environment **100** to simultaneously view a wide field of view of the patient environment **100** (e.g., the environment view) and also detailed views of one or more regions of interest on objects in the patient environment such as a detailed view of the patient P or a detail view of the display **105** on the patient monitoring device **104** without interrupting the monitoring of the patient environment **100** by a single camera.

[0067] FIG. **5** illustrates an example of a virtual field of view **504** that can be generated in operation **416** of the method **400**. In FIG. **5**, the virtual field of view **504** is shown as being displayed on the workstation monitor **502**. The virtual field of view **504** includes an environment view **506** that is a wide field of view of the patient environment **100**. The environment view **506** is captured by the camera **200** in operation **302** of the method **300**.

[0068] In some examples, the environment view **506** is a simulation based on the video data captured by the camera **200**. For example, the actual video of the patient P can be replaced by an avatar that represents the positioning and movements of the patient P. The avatar conceals the patient P's identity, which can mitigate unauthorized access to protected health information.

[0069] One or more areas are selectable within the environment view **506** to view a detailed view of a region of interest in the patient environment **100**. In the example shown in FIG. **5**, a region of interest on the patient P such as the patient P's face is selectable in the environment view **506** to view a detailed view **508** of the patient P within the virtual field of view **504**.

[0070] The detailed view **508** is a high-resolution image or video that captures details of the patient P, such as facial characteristics and skin tone, which are not visible in the environment view **506**. The detailed view **508** can include physiological parameters **510** that are determined from the video feeds captured by the camera **200** in accordance with operation **414** of the method **400**. In the illustrative example shown in FIG. **5**, the physiological parameters **510** include blood oxygen saturation (SpO_2), respiration rate, and heart rate.

[0071] In the example shown in FIG. **5**, the detailed view **508** indicates that remote photoplethysmography (rPPG) monitoring is in progress. rPPG measures the variance of red, green, and blue light reflection changes from the skin of a region of interest on the patient P where a high density of blood vessels are concentrated such as on the patient P's face. The heart rate and heart rate variability of the patient P are estimated by measuring inter-beat intervals between peaks of the light reflection changes over time.

[0072] As another illustrative example, the blood oxygen saturation of the patient P can be calculated based on blood perfusion detected from changes in skin tone in the video feed of the patient P's face. As another illustrative example, the respiration rate and/or heart rate of the patient P can be calculated from measuring chest movements either in a video feed of the patient P's chest, or based on reflected millimeter wave signals captured by the millimeter wave antenna **204**. In alternative examples, the physiological parameters **510** can be measured by one or more sensors on the medical equipment located inside the patient environment **100** such as by one or more sensors on the patient support apparatus **102** and/or the patient monitoring device **104**.

[0073] As another illustrative example, a region of interest on the patient support apparatus **102** is selectable in the environment view **506** to view a detailed view **512** of a display of the patient support apparatus **102**. The detailed view **512** is a high-resolution image or video that captures details displayed on the display of the patient support apparatus **102** such as one or more settings of the patient support apparatus **102** such as bed angle, and the like. Such details are not visible in the environment view **506**. The detailed view **512** can further include an area **514** that identifies one or more settings of the patient support apparatus **102**.

[0074] In some examples, the detailed views **508**, **512** are simulations based on the video data captured by the camera **200**. For example, the actual video of the regions of interest can be replaced by simulations of the regions of interest that are representative of the regions of interest based on the video data captured by the camera **200**. The simulations can further conceal the protected health information that is captured by the camera **200**.

[0075] When a region of interest is selected in the environment view **506** to display a detailed view **508**, **512**, the operation of the camera **200** is not interrupted because the high-resolution image or video displayed in the detailed view **508**, **512** is not necessarily a live image or video feed. Instead, the detailed view **508**, **512** can include a display of a previously captured image or video that is captured in accordance with the operations of the method **300**.

[0076] The image or video displayed in the environment view **506** is current even when it is not a live feed based on the operations of the method **300**. For example, when operation **308** includes determining that a predetermined time period has elapsed or a trigger event has occurred, the method **300** returns to operation **302** of recapturing the environment view **506**.

[0077] Similarly, the images or videos displayed in the detailed views **508**, **512** are current even when they are not based on live feed because the method **300** repeats the operation **304** of receiving updated monitoring parameters based on recapturing the environment view **506**, and thereafter, the method **300** repeats the operation **306** of recapturing one or more video feeds for display in the detailed views **508**, **512** based on the updated monitoring parameters.

[0078] The virtual field of view **504** does not continuously monitor all of the regions of interest simultaneously within the patient environment **100**. Instead, the detailed views **508**, **512** of the regions of interest are updated periodically at predetermined intervals or when a trigger event is detected. Thus, the detailed views **508**, **512** do not display real-time video feeds.

[0079] Instead, the virtual field of view **504** includes the detailed views **508**, **512** as a patchwork of video feeds and/or images captured by the camera **200**. In some examples, the video feeds and/or images are captured at different time points. In this manner, the virtual field of view **504** provides dynamic resolution on one or more objects or areas relevant to the healthcare of the patient P inside the patient environment **100**. The one or more objects or areas can be highlighted inside the environment view **506** to indicate their relevance to a user of the patient monitoring system **500**. The user can select the one or more objects or areas in the environment view **506** to view in the detailed views **508**, **512** detailed information such as detailed videos, images, and other data. In this manner, the virtual field of view **504** provides a 3-dimentional space in the environment view **506** where a user of the patient monitoring system **500** can navigate to view specific information, and when desirable, can zoom in on an object or area to display detailed information (as a live or stored feed) in a detailed view **508**, **512** such as 3D images or videos, 2D images or videos, infrared images or videos, thermal images or videos, audio information, or textual information relevant to the healthcare provided to the patient P.

[0080] In some examples, the detailed views in the patchwork of video feeds include a time stamp to indicate when the image, video, or other data displayed in the detailed view was last updated. A user of the virtual field of view **504** can select the regions of interest in the environment view **506** to zoom in and out, while the camera **200** continues to capture the video feeds (see operation **306** of the method **300**) according to a predetermined scheduled which is based on the objects selected for monitoring (see operation **406** of the method **400**) and the monitoring parameters selected for each object (see operation **408** of the method **400**).

[0081] The detailed views in the patchwork of video feeds in the virtual field of view **504** can further include search and playback. For example, each of the detailed views **508**, **512** within the environment view **506** can be rewound to a specific time stamp to view a trigger event. The virtual field of view **504** can also zoom out to playback a whole view of the patient room in the environment view **506** at the time stamp of the trigger event in the detailed view to show what else was happening in the room during the trigger event. In such examples, the virtual field of view **504** includes a multi-dimensional video. Metadata is created based on detected trigger events and associated time stamps. The metadata can be searched for playback of one or more detailed views and/or the environment view **506** within the virtual field of view **504**. The metadata allows a user to view the environment view **506** and the one or more detailed views at a common point in time. The metadata can be retrieved to put together a whole picture of a trigger event that includes playback of the environment view **506** and playback of one or more detailed views during occurrence of the trigger event detected within the patient environment **100**.

[0082] The virtual field of view **504** can further include an input **516** (e.g., “Update Now”). The input **516** is selectable to update the image or video captured by the camera **200** for display inside the detailed view **512**. For example, when the input **516** is selected, the patient monitoring system **500** controls the camera **200** such as by panning the camera from left to right or from right to left, and/or tilting the camera **200** up or tilting the camera **200** down, and/or adjusting a zoom of the camera **200** to obtain an updated image or video for display in the detailed view **512**.

[0083] The virtual field of view **504** improves the functioning of the workstation monitor **502** by providing focus on specific regions of interest within the patient environment **100** while at the same time maintaining an overall view of the patient environment **100** to provide context and overall awareness. As noted above, this is accomplished by using a single camera instead of a plurality of cameras in the patient environment **100**, and thereby improves efficiencies.

[0084] FIG. **6** schematically illustrates an example of a method **600** of operating the virtual field of view **504** shown in FIG. **5**. The method **600** can be performed by the patient monitoring system **500** and/or can be performed on the workstation monitor **502**. The method **600** includes an operation **602** of receiving an input on the virtual field of view **504**. Operation **602** can include receiving a selection of a region of interest in the environment view **506**.

[0085] The method **600** includes an operation **604** of adjusting the virtual field of view **504** by displaying the region of interest inside a detailed view. Operation **604** is performed without altering the operation of the camera **200** because the region of interest displayed in the detailed view is based on an image or video that is previously captured by the camera **200** and that is considered current or up-to-date based on the operations of the method **300**.

[0086] The method **600** can include an operation **606** of displaying one or more parameters that are calculated based on the image or video previously captured by the camera **200**. For example, operation **606** can include displaying respiration rate, heart rate, and/or SpO2 based on the image or video previously captured by the camera **200**. Operation **606** can include displaying the one or more parameters next to the detailed view of the region of interest.

[0087] Operation **606** can further include displaying controls to rewind the detailed view of the region of interest to view a trigger event. Further, operation **606** can include zooming out to playback a video stream of the environment view during the occurrence of the trigger event.

[0088] Additionally, the benefits of the methods and systems described above can extend to settings that include multiple cameras. As an illustrative example, the patient environment **100** can include a plurality of cameras in which a first camera is configured to focus on a particular object to capture a continuous video feed of the object, while another camera is configured to capture updates of other areas in the patient environment **100**. In further examples, the plurality of cameras can include cameras with varying features and operational characteristics such as a wide-angle camera and one or more cameras having a high optical zoom that are independently controllable to pan left and right, tilt up and down, and zoom in and out.

[0089] The various embodiments described above are provided by way of illustration only and should not be construed to be limiting in any way. Various modifications can be made to the embodiments described above without departing from the true spirit and scope of the disclosure.

Claims

1. A system for remotely monitoring a patient in a patient environment, the system comprising: at least one processing device; and at least one computer readable data storage device storing software instructions that, when executed by the at least one processing device, cause the at least one processing device to: receive an environment view; determine one or more objects for monitoring in the environment view; receive video data of the one or more objects, the video data captured by a camera positioned inside the patient environment; and generate a virtual field of view using the video data of the one or more objects, the virtual field of view providing the environment view and detailed views of the one or more objects within the environment view.

2. The system of claim 1, wherein determine the one or more objects for monitoring in the environment view is based on whether the objects are movable within the patient environment.

3. The system of claim 1, wherein determine the one or more objects for monitoring in the environment view is based on a condition identified in the environment view.

4. The system of claim 1, wherein determine the one or more objects for monitoring in the environment view is based on data acquired from an electronic health record system.

5. The system of claim 1, wherein the instructions, when executed by the at least one processing device, further cause the at least one processing device to: determine monitoring parameters for the one or more objects, the monitoring parameters including one or more of a region of interest, a minimum resolution, a minimum field of view, a movement tolerance, a minimum illumination, and a monitoring frequency.

6. The system of claim 1, wherein the instructions, when executed by the at least one processing device, further cause the at least one processing device to: determine a physiological parameter measurement based on the video data; and display the physiological parameter measurement in the virtual field of view.

7. The system of claim 1, wherein the instructions, when executed by the at least one processing device, further cause the at least one processing device to: display controls to rewind one or more of the detailed views of the one or more objects within the environment view for viewing a trigger event.

8. The system of claim 1, wherein the virtual field of view includes an avatar representing positioning and movements of the patient in the patient environment.

9. A method of remotely monitoring a patient in a patient environment, the method comprising:

receiving an environment view of the patient environment; determining one or more objects for monitoring in the environment view; receiving video data of the one or more objects, the video data captured by a camera positioned inside the patient environment; and generating a virtual field of view using the video data of the one or more objects, the virtual field of view providing the environment view and detailed views of the one or more objects within the environment view.

10. The method of claim 9, wherein determining the one or more objects for monitoring in the environment view is based on whether the objects are movable within the patient environment.

11. The method of claim 9, wherein determining the one or more objects for monitoring in the environment view is based on a condition identified in the environment view.

12. The method of claim 9, wherein determining the one or more objects for monitoring in the environment view is based on data from an electronic health record system.

13. The method of claim 9, further comprising: determining monitoring parameters for the one or more objects, the monitoring parameters including one or more of a region of interest, a minimum resolution, a minimum field of view, a movement tolerance, a minimum illumination, and a monitoring frequency.

14. The method of claim 9, further comprising: determining a physiological parameter measurement based on the video data; and displaying the physiological parameter measurement in the virtual field of view.

15. The method of claim 9, further comprising: displaying controls to rewind one or more of the detailed views of the one or more objects within the environment view for viewing a trigger event.

16. The method of claim 9, wherein the virtual field of view includes an avatar representing positioning and movements of the patient in the patient environment.

17. A non-transitory computer readable storage media including computer readable instructions which, when read and executed by a computing device, cause the computing device to: receive an environment view; determine one or more objects for monitoring in the environment view; receive video data of the one or more objects, the video data captured by a camera positioned inside the patient environment; and generate a virtual field of view using the video data of the one or more objects, the virtual field of view providing the environment view and detailed views of the one or more objects within the environment view.

18. The non-transitory computer readable storage media of claim 17, wherein determine the one or more objects for monitoring in the environment view is based on whether the objects are identified as being movable within the patient environment.

19. The non-transitory computer readable storage media of claim 17, wherein determine the one or more objects for monitoring in the environment view is based on a condition identified in the environment view.

20. The non-transitory computer readable storage media of claim 17, wherein determine the one or more objects for monitoring in the environment view is based on data acquired from an electronic health record system.