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### **DYNAMICALLY ADJUSTABLE FRAME RATE FROM MEDICAL DEVICE CONTROLLER**

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#### **Abstract**

A medical device monitoring system and method extract information from screen images from medical device controllers, and intelligently vary rates at which the screen images are fetched from the respective medical device controllers, so as to reduce computer network load, timely report high-priority information, such as alarms, and provide information at intervals requested by users. The rates at which the screen images are fetched are automatically varied based on information available to a server, such as available network bandwidth, level of network congestion, number of medical device controllers co-located at a single medical institution or on a given local area network (LAN), alarm status of a medical device controller and/or historical timing information regarding use of medical devices connected to the medical device controllers.

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## **Background/Summary**

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. application Ser. No. 16/365,293, filed on Mar. 26, 2019, now allowed, the disclosure of which is hereby incorporated herein by reference.

### **TECHNICAL FIELD**

[0002] The present invention relates to remotely monitoring medical devices and, more particularly, to dynamically adjusting a frame rate at which images of screens displayed by medical device controllers are requested for optical character recognition (OCR) processing of the images.

### **BACKGROUND**

[0003] Many medical devices, such as some intravascular blood pumps, for example the Impella® 2.5 heart pump available from Abiomed, Inc., Danvers, MA, are connected to external medical device controllers that collect and display operational data about the medical devices, such as heart signal level, battery temperature, blood flow rate and plumbing integrity. An exemplary medical device controller is available from Abiomed, Inc. under the trade name Automated Impella Controller®. The medical device controllers raise alarms when operational data values fall beyond predetermined values or ranges, for example if a leak or loss of suction is detected. These medical device controllers include video display screens as human interfaces, on which the operational data and/or alarms are displayed.

[0004] To facilitate remote monitoring by medical personnel to ensure efficacy and patient safety, some such medical device controllers may be coupled via computer networks, often including wireless segments, to central servers, which may be accessed by monitoring stations. The monitoring stations may display real-time operational data and/or alarms on display screens for viewing by the medical personnel.

[0005] The servers request and receive images of contents displayed on the screens of the medical device controllers. Some servers use optical character recognition (OCR) technology to parse the images and extract textual information, such as heart pump serial number, blood flow rate, warning message text and the like.

[0006] However, network congestion and intermittent wireless network connectivity make it difficult or impossible for the servers to fetch the images from the medical device controllers in a timely fashion, possibly leading to missed or delayed notifications of alarms and the like. Furthermore, each OCR request issued by the servers incurs a cost. This cost creates a tension between low-cost operation (infrequent image analysis, at the risk of delayed information reporting) and low-latency information reporting (frequent image analysis).

### **SUMMARY**

[0007] An embodiment of the present invention provides a medical device monitoring system. The medical device monitoring system includes a server. The server is configured to automatically request and receive images. The server is configured to request and receive the images via a computer network from each medical device controller of a plurality of medical device controllers. Each image includes contents displayed on a screen of a medical device controller. The server is

also configured to have at least a portion of each image optical-character-recognized. The server is further configured to dynamically adjust a rate at which the server requests the images from each medical device controller.

[0008] In any embodiment, the server may be configured to dynamically adjust the rate based on information about the medical device controller.

[0009] In any embodiment, the information about the medical device controller may be provided by the medical device controller.

[0010] In any embodiment, the information about the medical device controller may include information about an alarm state of the medical device controller.

[0011] In any embodiment, the information about the medical device controller may include information about an operational parameter.

[0012] In any embodiment, the information about the medical device controller may include information about a power source for the medical device controller.

[0013] In any embodiment, the information about the medical device controller may include information about a number of users simultaneously monitoring the medical device controller.

[0014] In any embodiment, the server may be configured to dynamically adjust the rate based on information about the computer network.

[0015] In any embodiment, the information about the computer network may include information about a load on the computer network.

[0016] In any embodiment, the information about the computer network may include historical information about reliability of the computer network.

[0017] In any embodiment, the information about the computer network may include information about signal strength of a wireless network connection available to the medical device controller.

[0018] In any embodiment, the information about the computer network may include information about a number of other medical device controllers co-located with the medical device controller at a facility.

[0019] In any embodiment, the server may be configured to dynamically adjust the rate based on information about workload on the server.

[0020] In any embodiment, the server may be configured to dynamically adjust the rate based on input from a human user.

[0021] In any embodiment, the server may be configured to dynamically adjust the rate based on historical information.

[0022] In any embodiment, the historical information may include historical information about timing of connection of a medical device to the medical device controller.

[0023] In any embodiment, the historical information may include historical information about accuracy of the optical-character-recognition of at least one earlier image.

[0024] In any embodiment, the server may be further configured to dynamically adjust a number of servers that request optical character recognition of the at least the portion of each image.

[0025] Another embodiment of the present invention provides a method of monitoring a medical device. The method includes automatically requesting and receiving images of contents displayed on a screen of a medical device controller. The images are requested and received via a computer network. The images are requested and received from each medical device controller of a plurality of medical device controllers. The method also includes automatically having at least a portion of each image optical-character-recognized, and automatically dynamically adjusting a rate at which the images are requested.

[0026] In any embodiment, information about the medical device controller may be received. Automatically dynamically adjusting the rate at which the images are requested may involve automatically dynamically adjusting the rate based on the information about the medical device controller.

[0027] In any embodiment, information about the computer network may be received.

Automatically dynamically adjusting the rate at which the images are requested may involve automatically dynamically adjusting the rate based on the information about the computer network.

[0028] In any embodiment, information about workload on a server may be received. Automatically dynamically adjusting the rate at which the images are requested may involve automatically dynamically adjusting the rate based on the information about the workload on the server.

[0029] In any embodiment, an input from a human user may be received. Automatically dynamically adjusting the rate at which the images are requested may involve automatically dynamically adjusting the rate based on the input from the human user.

[0030] Yet another embodiment of the present invention provides a non-transitory computer-readable medium. The medium is encoded with instructions. When executed by a processor, the instructions establish processes for performing a computer-implemented method of monitoring a medical device. The processes include a process configured to automatically request and receive images of contents displayed on a screen of a medical device controller. The images are requested and received via a computer network from each medical device controller of a plurality of medical device controllers. A process is configured to automatically have at least a portion of each image optical-character-recognized. A process is configured to automatically dynamically adjust a rate at which the images are requested.

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## **Description**

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0031] The invention will be more fully understood by referring to the following Detailed Description of Specific Embodiments in conjunction with the Drawings, of which:

[0032] FIG. 1 is a perspective view of an exemplary convention medical device controller and an exemplary conventional medical device, in this example a heart pump, coupled to the medical device controller, according to the prior art.

[0033] FIG. 2 shows exemplary hypothetical display screen contents that may be displayed on a screen of the medical device controller of FIG. 1, according to the prior art.

[0034] FIG. 3 is a schematic block diagram of major components of a medical device monitoring system for collecting, storing and retrieving operational data from and about a plurality of medical device controllers, such as the medical device controller of FIGS. 1 and 2, according to an embodiment of the present invention.

[0035] FIG. 4 is a flowchart schematically illustrating a method of monitoring a medical device, such as a method performed by a server of FIG. 3, according to an embodiment of the present invention.

[0036] FIG. 5 is a flowchart schematically illustrating steps involved in automatically dynamically adjust a rate at which images are requested, based on the information about a medical device or controller, which is a sub-process of the method of FIG. 4, according to an embodiment of the present invention.

### **DETAILED DESCRIPTION**

[0037] Embodiments of the present invention provide a medical device monitoring system and method that extract information from screen images from medical device controllers, and intelligently vary rates at which the screen images are fetched from the respective medical device controllers, so as to reduce computer network load, timely report high-priority information, such as alarms, and provide information at intervals requested by users. The rates at which the screen images are fetched are automatically varied based on information available to a server, such as available network bandwidth, level of network congestion, number of medical device controllers co-located at a single medical institution or on a given local area network (LAN), alarm status of a

medical device controller and/or historical timing information regarding use of medical devices connected to the medical device controllers.

[0038] FIG. 1 is a perspective view of an exemplary convention medical device controller **100** and an exemplary conventional medical device **102**, in this example a heart pump, coupled to the medical device controller **100**. In the example shown in FIG. 1, the medical device controller **100** is an Automated Impella Controller® from Abiomed, Inc., Danvers, MA, and the heart pump **102** is an Impella® 2.5 heart pump, also available from Abiomed, Inc., although any suitable medical device controller may be used. In some cases, the medical device and its associated medical device controller are combined. Such a combination is referred to herein simply as a medical device controller.

[0039] The medical device controller **100** includes a display screen **104**, on which the medical device controller **100** displays operational data about the medical device **102**, such as heart signal level, battery temperature, blood flow rate and plumbing integrity. As discussed in more detail herein, the medical device controller **100** may be connected to a computer network and thereby send images of contents displayed on the screen **104** to a remote server (not shown).

[0040] FIG. 2 shows exemplary hypothetical display screen contents **200** that may be displayed on the screen **104** of the medical device controller **100** of FIG. 1. For example, the display screen contents may include a heart pump type (“Impella 5.0”) **202**, a heart pump serial number (“120703”) **204**, a warning/error message **206**, a placement signal **207**, a present heart pump speed (performance) setting (“P-0”) **208**, a heart pump motor current value **210**, a current or average blood flow rate **212** and minimum and maximum blood flow rates **213**. The display screen contents **200** are typically pixelated.

[0041] FIG. 3 is a schematic block diagram of major components of a medical device monitoring system **300** for collecting, storing and retrieving operational data from and about a plurality of medical device controllers **100**. For simplicity, only medical device controllers **100**, and not separate medical devices, are shown in FIG. 3. Although three medical device controllers **100** are shown, other numbers of medical device controllers **100** may be used. Each medical device controller **100** is connectable to a computer network **302**, optionally via a remote link module **304**. Each medical device controller **100** is configured to automatically repeatedly capture status information about the medical device connected thereto and display the status information on a display screen **104** (FIG. 1). As noted, FIG. 2 shows respective hypothetical display screen contents **200** that may be displayed on the screen **104** of any given medical device controller **100**.

[0042] A server **306** is configured to automatically periodically or occasionally request and receive an image of the contents displayed on the screen **104** of each medical device controller **100**, typically about every 20 second. The request and the image are sent via the computer network **302**. The image may be sent in one or more messages encoded as a video frame or a sequence of video frames. The video frame(s) may, for example, contain pixelated copies of images displayed on the display screens **104** of the medical device controllers **100**.

[0043] The server **306** is configured to process the received frames (images). As noted, the server **306** parses the images and extracts textual information, such as heart pump serial number, blood flow rate, warning message text and the like, by optical character recognizing (OCR) portions of the images. The server **306** may also parse the images and extract graphical information, such as a power source icon, and compare this graphical information to predetermined pixel patterns and/or colors. The server **306** may include an OCR engine, or the server **306** may communicate with an external OCR engine **310**, such as via the computer network **302**. The server **306** may then use the recognized text to automatically ascertain serial numbers or other identifiers of the medical device controllers **100**, operating parameters of the medical device controllers **100**, whether an alarm has been raised by one of the medical device controllers **100**, etc.

[0044] A data store **308** is configured to store one or more media files, and in particular frames (images), such as MP4 video or other suitable types of media files, and the server **306** is configured

to automatically store received frames (images) in the data store **308**. The data store **308** records the screen images received by the server **306** for later playback, such as in response to requests from one of several monitoring stations **312**. The monitoring stations **312** may use cloud-based technology to securely and remotely display images of the medical device controller **100** screens **104** to physicians and hospital staff anywhere with Internet connectivity. An exemplary remote monitoring system is available under the trade name Impella Connect® online device management system, available from Abiomed, Inc., Danvers, MA.

[0045] The data store **308** is configured to provide a requested portion of the stored media file in response to a provision request. The data store **308** thereby supports playback of the medical device controller **100** status information. For example, the data store **308** may provide one or more frames (images) of video stored in the media file, for display to a user. The server **306** may also be configured to provide status information about one or more of the medical device controllers **100** to ones of the monitoring stations **312**, based on images received by the server **306** in real time and/or based on historical information held in the data store **308**.

[0046] However, congestion in the computer network **302**, such as congestion in computer networks internal to medical institutions, and unreliable wireless network connections, create a challenging environment for the server **306** to request and timely receive the images from the medical device controllers **100**. Furthermore, each image is separately processed by the OCR engine **310**, and each OCR request issued by the server **306** incurs a cost.

[0047] Embodiments of the present invention solve these problems by automatically dynamically adjusting a rate at which the server **306** requests the images from the medical device controllers **100**. Optionally or alternatively, the server **306** sends a (possibly different) rate to each medical device controller **100**, and in response each medical device controller **100** sends its images to the server **306** at the commanded rate, without an explicit request from the server **306** for each image. For simplicity of explanation, here and in the claims, dynamically adjusting a rate at which the server **306** “requests the images” encompasses both: (a) the server **306** explicitly requesting each image and (b) the server **306** commanding a rate at which a medical device controller **100** should send images, without an explicit request for each image.

[0048] The server **306** may request the images at different rates from different ones of the medical device controllers **100**, and the server **306** may dynamically adjust the rates independently for different ones of the medical device controllers **100**. Exemplary factors used by the server **306** to automatically determine an image rate from a particular medical device controller **100**, or group of medical device controllers **100**, include: level of network congestion, whether a medical device controller **100** is alarming, alarm severity, whether a heart pump **102** or other medical device is connected to a particular medical device controller **100**, patient condition and user command.

[0049] The server **306** may automatically dynamically adjust the rates at which the images are requested, based on information in a variety of categories, such as: (a) information from the medical device controller **100**, (b) information about the computer network **302**, (c) information about the server **306** or other servers, such as the OCR engine **310**, and (d) information from or about a human user of the system **300** or a patient. Some of the information in any of the categories may be historic. Examples from each of these categories are provided below. Different and/or other categories of information may be used as needed to meet or approach operational objectives.

[0050] FIG. 4 is a flowchart schematically illustrating a method of monitoring a medical device **100**. The server **306** (FIG. 3) may perform this method. At operation **400**, the method requests and receives images (“received images”). The received images are requested and received via the computer network **302**. The received images are requested and received from each medical device controller **100** of a plurality of medical device controllers. Each received image includes contents displayed on a screen **104** of the medical device controller **100**.

[0051] At **402**, for each received image, at least a portion of the image is optical-character-recognized via a service call to the OCR engine **310** to produce text results. At **404**, a first text

result is extracted from the text results. The first text result is extracted from a portion of the image that contains information about the medical device controller **100** and/or a medical device, such as a heart pump, connected to the medical device controller **100**. At **406**, information about the medical device controller **100** is automatically ascertained from the first text result.

[0052] Optionally or alternatively, one or more portions of the received image may be analyzed, such as by comparing the portions on a per-pixel basis to a set of predetermined pixel patterns and/or predetermined colors, to automatically determine information about the medical device controller **100** and/or a medical device connected to the medical device controller **100**. For example, a power source icon **222** in the image may be compared to a predetermined pattern to automatically determine whether the medical device controller **100** is currently powered by a battery or by mains.

[0053] At **408**, the rate at which images are requested from the medical device controller **100** is automatically dynamically adjusted, based on the information about the medical device controller **100** or the associated medical device **102**. “Dynamically” means the rate is changed over time, not only once. The rate may be changed as frequently as the server **306** detects reasons to change the rate, or less frequently.

[0054] Examples of the first category of information, i.e., information received from the medical device controller **100**, that may be automatically ascertained from the image, and how this information influences the image request rate, are listed in Table 1. For example, if OCR of the current image from a medical device controller **100** fails, the server **306** may change the interval to zero, so as to immediately request a new image, at least until an image is, or a predetermined number (such as three) of successive images are, successfully OCR processes, after which the interval may be returned to a default value, or a value determined by other information. If, however, a predetermined number of successive images incur OCR failures, the server **306** should increase the interval and raise an error.

[0055] The server **306** receives information from the medical device controllers **100** when significant events occur, such as when a medical device controllers **100** power on and when a heart pump **102** is connected to a medical device controller **100**. The server **306** may be configured to store information, such as time, of these events. The server **306** may be further configured to calculate statistics and store statistical or historical information, such as a calculated average amount of time between when a medical device controller **100** is powered on and when a heart pump **102** or other medical device is connected to the medical device controller **100**. After a statistically significant number of samples have been collected by the server **306**, upon detecting that a medical device controller **100** has powered on, the server **306** can set the image request interval to a relatively high value, such as about 1 minute, for about 70% of the average time until a heart pump **104** is connected, and thereafter automatically switch to the default interval, such as about 20 seconds, or another predetermined value.

[0056] The examples in Table 1 relate to a particular type of medical device controller **100** and a particular type of medical device (a heart pump). Other types of medical device controllers and medical devices may provide different types of information and thus may have different types of triggers and different intervals. Thus, the contents of Table 1 should not be viewed as a limitation on the breadth of this disclosure or the appended claims. The same applies to other tables included herein.

TABLE-US-00001 TABLE 1 Exemplary information about a medical device controller Name Trigger Interval Alarm text 206 “Impella Stopped” 3 sec. Alarm text 206 “Air in Purge System” 10 sec. Alarm text background color Yellow 10 sec. Alarm text background color Red 5 sec.

Placement signal 207 >100 15 sec. Motor current 210 <0.1 OR >5 10 sec. Avg. blood flow rate 212 <1 OR >8 5 sec. Min. blood flow rate 213 <1 3 sec. Max. blood flow rate 213 >8 3 sec.

Connected blood pump 202 (none) 1 min. Connected blood pump 202 (any) 20 sec. Power source icon 222 Battery 1 min. Power source icon 222 Mains 20 sec. OCR failure on current image TRUE

0 sec. Any field validation failure TRUE 5 sec., until valid

[0057] The server **306** is configured to automatically dynamically adjust the rate that images are requested from the medical device controller **100**, based on information about the medical device controller **100**. Each entry in Table 1 includes a name of a piece of information, a trigger condition and an interval. If the server **306** detects a condition in the information that meets the trigger condition of an entry in Table 1, the server **306** may change the interval at which the server **306** requests images from the corresponding medical device controller **100** to the interval value in the table entry. The server **306** may use additional rules to control to what value the image request interval is changed and/or how frequently the image request interval is changed. If multiple conditions are met, the server **306** may change the image request interval to the shortest interval of the met conditions, or to the longest interval of the met conditions, based on additional rules.

[0058] If no condition in the table is met, the server **306** may revert to a default interval, such as about 20 seconds. Some of the conditions may cause a change in the image request interval to a value larger than the default value. For example, if no blood pump is currently connected to a given medical device controller **100**, the image request interval may be made relatively large, because the medical device controller **100** is essentially not currently in use, and it therefore currently provides no particularly useful information. On the other hand, for example, if the alarm text **206** indicates a problem, the image request interval may be made relatively small, to cause displays on the monitoring station(s) **312** to be refreshed more frequently, so personnel observing the monitoring station(s) **312** receive more current information.

[0059] Optionally, the server **306** may perform validation tests on the text results returned by the OCR engine **310**. For example, if a field, such as average blood flow rate **212** (FIG. 2) is expected to be numeric, the returned OCR text may be checked and accepted only if it contains only numeric characters, and an optional decimal point. Numeric fields may be range checked. For example, if it is known a priori that each placement signal **207** value must be in a range 0-100, the returned OCR text may be compared to this range. If a field fails its respective validation test, the interval may be reduced, for example to 5 seconds, until an image is OCR processed to yield a valid value for the field.

[0060] Although the examples in Table 1 are simple conditions, the server **306** may use combinations of conditions to automatically determine the image request interval. For example, if the average blood flow rate **212** is less than 1 or greater than 8, and the minimum blood flow rate **213** is less than 1, the server **306** may change the image request interval to 1 second, i.e., less than the interval for either of the two conditions separately.

[0061] Other examples of the first category of information, i.e., information received from the medical device controller **100**, include any information that is available in the image, such as: pump performance level **208**, any specific alarm **206**, local time **224** and pump serial number **204**. The pump performance level **208** is an indication of an operational parameter, in this case essentially desired pump speed, set by a user of the medical device controller **100**, such as through a user interface implemented using the display screen **104** on the medical device controller **100**.

[0062] FIG. 5 is a flowchart schematically illustrating sub-operations of operation **408** (FIG. 4), i.e., automatically dynamically adjusting a rate at which images are requested, based on information about a medical device or controller **100**. At **500**, a table, such as Table 1, is scanned for entries whose names match the information about the medical device controller **100**. Recall that information was automatically ascertained from the first OCR text result (operation **406** in FIG. 4), and/or one or more portions, such as a power source icon, of the received image were analyzed to determine information about the medical device controller **100**.

[0063] At **502**, if any matching table entry is found, control passes to **504**. In general, entries in Table 1 can be characterized as either increasing the interval above the default or decreasing the interval below the default. In general, table entries that increase the interval value above the default value may be associated with relatively “relaxed” situations, where rapid updates are not needed or



not wanted, such as because no pump is connected to a medical device controller **100**, or network congestion warrants less frequent updates. On the other hand, table entries that decrease the interval value below the default value may be associated with relatively “tense” situations, where rapid updates are needed, such as because a medical device controller **100** is alarming.

[0064] If all the matching table entries increase the interval above the default value, the overall situation may be deemed to be relaxed, and the largest interval value may be selected. In another, more conservative, embodiment, the smallest interval value may be selected.

[0065] If all the matching table entries decrease the interval below the default value, the overall situation may be deemed to be tense, and the smallest interval value may be selected, so as to accommodate the most serious issue represented by the matching table entries.

[0066] If at least one matching table entry increases the interval above the default value, and at least one matching table entry decreases the interval below the default value, one or more additional rules may be used to determine whether to increase or decrease the interval value. In some embodiments, each table entry has a priority value (not shown), and the matching table entry with the highest priority value is selected. In this way, for example, if some information indicates a short image request interval value is appropriate, but no heart pump is connected to the corresponding medical device controller **100**, there is no point in rapidly fetching images from the medical device controller **100**, and a long interval value can be selected. This strategy may be implemented as follows.

[0067] At **504**, of all the matching table entries, the shortest interval value is temporarily stored. Likewise, at **506**, of all the matching table entries, the longest interval value is temporarily stored. At **508**, either the shortest or the longest interval value is selected from the temporary storage, based on one or more additional rules.

[0068] If any matching table entry decreases the interval below the default, then the additional rule may cause the shortest interval value to be selected, or the additional rule may choose a table entry based on priority value or according to other selection criteria. On the other hand, if no matching table entry decreases the interval below the default value, the additional rule may cause the longest interval value to be selected.

[0069] At **510**, the selected interval value is used to set the image request interval for the medical device controller **100**. At **512**, information about the next medical device controller is analyzed.

[0070] Returning to FIG. 4, at **410**, information about the computer network **320** is automatically ascertained. For example, the server **306** may query the computer network **306** or use tools, such as ping, to measure a level of network congestion, utilization and/or available bandwidth. It should be noted that the computer network **320** may include several public and/or private networks, such as wired and/or wireless private networks in a medical institution, public and private wide area networks, such as the Internet, public and private cellular networks, and a private network located within a service provider's facility that houses the server **306**. Each of these networks or segments may have its own set of characteristics, and different medical device controllers **100** may be coupled to the server **306** via different networks and segments. Therefore, for each medical device controller **100**, or groups of co-located medical device controllers **100**, the server **306** may choose to use the characteristics of most restrictive network or segment in a route to that medical device controller **100** or group.

[0071] The server **306** may store information indicating to which wide area network, local network and/or network segment, etc. each medical device controller **100** is connected, and/or through which network components or segments computer network traffic travels. This information may be extracted from header information in network packets received by the server **306** from the medical device controllers **100**, through use of the traceroute tool or other well-known tools and techniques.

[0072] Information about which computer network, segment, etc., to which the various medical device controllers **100** are connected, enables the server **306** to calculate the number of medical device controllers **100** connected to any given computer network, segment, router, etc. This

information, together with information about bandwidths of networks and segments between the server **306** and the medical device controllers **100**, enables the server **306** to calculate intervals that are sustainable over the available infrastructure. In particular, the server **306** may calculate an aggregate interval that is sustainable over the available infrastructure, and then divide that aggregate interval among the medical device controllers **100**, based on information about the individual medical device controllers **100**.

[0073] The server **306** may store historical information about reliability of computer network connections to various medical device controllers **100** and use relatively shorter intervals on historically unreliable networks. Each medical device controller (MDC) **100** may report the medical institution where the medical device controller **100** is installed. This information may have been entered by a human into a memory of the medical device controller **100**, such as through a user interface implemented on the screen **104**. The server **306** may use information about which medical institutions host which medical device controllers **100** to predict information, such as network reliability, of newly connected medical device controllers **100**.

[0074] Examples of the second category of information, i.e., information about the computer network **302**, that may be automatically ascertained by the server **306**, and how this information influences the image request rate, i.e. triggers and corresponding intervals, are listed in Table 2.

TABLE-US-00002	TABLE 2 Exemplary information about a computer network
Name	Trigger Interval
Number of MDCs on same LAN	>10 25 sec.
Number of MDCs at same institution	>50 40 sec.
Number of MDCs at same institution	>100 50 sec.
Available network bandwidth	<50% 1 min.
History of reliable network	Good, ex. >95% 20 sec.
History of reliable network	Poor, ex. <75% 10 sec.
Network or segment utilization	>50% 30 sec.
Wi-Fi signal strength at MDC	Stronger than -30 dBm 20 sec.
Wi-Fi signal strength at MDC	Stronger than -67 dBm 15 sec.
Wi-Fi signal strength at MDC	Stronger than -70 dBm 12 sec.
Wi-Fi signal strength at MDC	Stronger than -80 dBm 7 sec.
Wi-Fi signal strength at MDC	Weaker than -80 dBm 3 sec.

[0075] At **412**, the rate at which images are requested from the medical device controller **100** is automatically dynamically adjusted, based on the information about the computer network **302**, in a manner similar to that discussed with respect to Table 1 and FIG. 5, mutatis mutandis.

[0076] Examples of the third category of information, i.e., information about the server **306** or other servers, such as the OCR engine **310**, that may be automatically ascertained by the server **306**, and how this information influences the image request rate, i.e. triggers and corresponding intervals, are listed in Table 3.

TABLE-US-00003	TABLE 3 Exemplary information about servers and server environments
Name	Trigger Interval
Workload on server 306	<10% CPU busy 10 sec.
Workload on server 306	<50% CPU busy 20 sec.
Workload on server 306	>50% CPU busy 30 sec.
OCR invocations on engine 310	>10 per sec. 30 sec.

[0077] At **414**, the server **306** automatically ascertains information about the server **306** and, optionally, related servers (some not shown), such as the OCR engine **310**. At **416**, the rate at which images are requested from the medical device controller **100** is automatically dynamically adjusted, based on the information about the server(s), including server **306**, in a manner similar to that discussed with respect to Tables 1 and 2 and FIG. 5, mutatis mutandis. Optionally, if a server, such as the server **306** or the OCR engine **310**, is found to be busy beyond a predetermined threshold value, such as about 70%, another copy of the server may be spawned, for example using virtual machine technology, and the workload may be divided among the available servers. Conversely, if a server is found to be less busy than a predetermined threshold value, such as about 40%, the server can be terminated, and the terminated server's workload may be distributed among remaining servers.

[0078] Examples of the fourth category of information, i.e., information from or about a user of the system **300** or a patient, that may be ascertained by the server **306**, and how this information

influences the image request rate, i.e. triggers and corresponding intervals, are listed in Table 4. As noted, each monitoring station (MS) **312** displays information about one or more user-selected medical device controllers (MDC) **100**. It may be assumed that one user accesses each monitoring station **312**. Thus, the number of monitoring stations **312** equals the number of monitoring users.

TABLE-US-00004	TABLE 4	Exemplary user inputs and information about users
Name	Trigger	Interval
Number of MSs monitoring one MDC	>2	15 sec.
Number of MSs monitoring one MDC	>4	10 sec.
Number of MSs monitoring one MDC	>6	5 sec.
User input designated a specific MDC	"Important"	15 sec.
User input designated a specific MDC	"Critical"	10 sec.
User input designated a specific MDC	"Monitor" (user specified)	Patient condition "Critical" 6 sec.

[0079] Returning to FIG. 4, at **418**, an input (command) from a user is received, such as by the server **306**, or by one of the monitoring stations **312** and forwarded to the server **306**. The user input may, for example, designate a particular medical device controller **100** "Important" or "Critical." Similarly, the user input may designate a particular patient "Critical." A user input ("Monitor") may include a user-specified interval. Each monitoring station **312** may monitor one or more medical device controllers **312**. The server **306** may supply information to the monitoring stations **312**, as described herein, so the monitoring stations **312** can display this information to their respective users, or the server **306** may be informed by the monitoring stations **312** or by another server (not shown) which monitoring stations **312** are monitoring which medical device controller(s) **100**. In any case, the server **306** stores information indicating the number of monitoring stations **312** that are monitoring each medical device controller **100**. The server **306** may use this information and/or other information to automatically dynamically adjust the image request rate from individual medical device controllers **100**, as indicated at **420** in FIG. 4, in a manner similar to that discussed with respect to Tables 1-3 and FIG. 5, *mutatis mutandis*.

[0080] While the invention is described through the above-described exemplary embodiments, modifications to, and variations of, the illustrated embodiments may be made without departing from the inventive concepts disclosed herein. For example, although specific parameter values, such as interval times and triggers, may be recited in relation to disclosed embodiments, within the scope of the invention, the values of all parameters may vary over wide ranges to suit different applications. Unless otherwise indicated in context, or would be understood by one of ordinary skill in the art, terms such as "about" mean within  $\pm 20\%$ .

[0081] As used herein, including in the claims, the term "and/or," used in connection with a list of items, means one or more of the items in the list, i.e., at least one of the items in the list, but not necessarily all the items in the list. As used herein, including in the claims, the term "or," used in connection with a list of items, means one or more of the items in the list, i.e., at least one of the items in the list, but not necessarily all the items in the list. "Or" does not mean "exclusive or."

[0082] Although aspects of embodiments may be described with reference to flowcharts and/or block diagrams, functions, operations, decisions, etc. of all or a portion of each block, or a combination of blocks, may be combined, separated into separate operations or performed in other orders. All or a portion of each block, module or combination thereof may be implemented as computer program instructions (such as software), hardware (such as combinatorial logic, Application Specific Integrated Circuits (ASICs), Field-Programmable Gate Arrays (FPGAs), processor or other hardware), firmware or combinations thereof.

[0083] The server **306**, or portions thereof, may be implemented by one or more processors executing, or controlled by, instructions stored in a memory. Each processor may be a general purpose processor, such as a central processing unit (CPU), a graphic processing unit (GPU), digital signal processor (DSP), a special purpose processor, etc., as appropriate, or combination thereof.

[0084] The memory may be random access memory (RAM), read-only memory (ROM), flash memory or any other memory, or combination thereof, suitable for storing control software or other instructions and data. Instructions defining the functions of the present invention may be delivered

to a processor in many forms, including, but not limited to, information permanently stored on tangible non-transitory non-writable storage media (e.g., read-only memory devices within a computer, such as ROM, or devices readable by a computer I/O attachment, such as CD-ROM or DVD disks), information alterably stored on tangible non-transitory writable storage media (e.g., floppy disks, removable flash memory and hard drives) or information conveyed to a computer through a communication medium, including wired or wireless computer networks. Moreover, while embodiments may be described in connection with various illustrative data structures, systems may be embodied using a variety of data structures.

[0085] Disclosed aspects, or portions thereof, may be combined in ways not listed above and/or not explicitly claimed. In addition, embodiments disclosed herein may be suitably practiced, absent any element that is not specifically disclosed herein. Accordingly, the invention should not be viewed as being limited to the disclosed embodiments.

## Claims

**1-24.** (canceled)

**25.** A medical device monitoring system comprising one or more processors configured to: receive, via a computer network, from at least one medical device controller of a plurality of medical device controllers, at least one image of contents displayed on a screen of the at least one medical device controller; analyze the at least one image to determine whether one or more trigger conditions of a plurality of trigger conditions are met; and send, in response to at least two trigger conditions of the plurality of trigger conditions being met, a request to the at least one medical device controller to change a first rate at which the at least one medical device controller sends images to the one or more processors to a second rate, wherein the first and second rates are non-zero, wherein each one of the plurality of trigger conditions is associated with at least one of a plurality of predetermined rates at which the at least one medical device controller sends images to the one or more processors, wherein two or more of the plurality of trigger conditions are associated with different ones of the plurality of predetermined rates, and wherein the second rate is selected by the one or more processors in response to a determination that the second rate is the fastest or the slowest of the predetermined rates associated with one or more of the at least two trigger conditions.

**26.** The medical device monitoring system of claim 25, wherein the second rate is faster than the first rate.

**27.** The medical device monitoring system of claim 25, wherein the second rate is slower than the first rate.

**28.** The medical device monitoring system of claim 25, wherein each one of the plurality of medical device controllers is configured to connect to a heart pump.

**29.** The medical device monitoring system of claim 28, wherein the plurality of trigger conditions comprises: a first trigger condition based on whether the at least one image comprises a placement signal value within a first predetermined range; a second trigger condition based on whether the at least one image comprises a motor current value within a second predetermined range; or a third trigger condition based on whether the at least one image comprises a blood flow rate within a third predetermined range.

**30.** The medical device monitoring system of claim 29, wherein the first trigger condition, the second trigger condition, and the third trigger condition are associated with different ones of the plurality of predetermined rates.

**31.** The medical device monitoring system of claim 28, wherein the plurality of trigger conditions comprises a trigger condition based on whether the at least one medical device controller is connected to a power source.

**32.** A method comprising: receiving, via a computer network, from at least one medical device controller of a plurality of medical device controllers, at least one image of contents displayed on a

screen of the at least one medical device controller; analyzing the at least one image to determine whether one or more trigger conditions of a plurality of trigger conditions are met; and sending, in response to at least two trigger conditions of the plurality of trigger conditions being met, a request to the at least one medical device controller to change a first rate at which the at least one medical device controller sends images to one or more processors to a second rate, wherein the first and second rates are non-zero, wherein each one of the plurality of trigger conditions is associated with at least one of a plurality of predetermined rates at which the at least one medical device controller sends images to the one or more processors, wherein two or more of the plurality of trigger conditions are associated with different ones of the plurality of predetermined rates, and wherein the second rate is selected in response to a determination that the second rate is the fastest or the slowest of the predetermined rates associated with one or more of the at least two trigger conditions.

**33.** The method of claim 32, wherein the second rate is faster than the first rate.

**34.** The method of claim 32, wherein the second rate is slower than the first rate.

**35.** The method of claim 32, wherein each one of the plurality of medical device controllers is configured to connect to a heart pump.

**36.** The method of claim 35, wherein the plurality of trigger conditions comprises: a first trigger condition based on whether the at least one image comprises a placement signal value within a first predetermined range; a second trigger condition based on whether the at least one image comprises a motor current value within a second predetermined range; and a third trigger condition based on whether the at least one image comprises a blood flow rate within a third predetermined range.

**37.** The method of claim 36, wherein the first trigger condition, the second trigger condition, and the third trigger condition are associated with different ones of the plurality of predetermined rates.

**38.** The method of claim 35, wherein the plurality of trigger conditions comprises a trigger condition based on whether the at least one medical device controller is connected to a power source.

**39.** A non-transitory computer-readable storage medium having instructions stored thereon that, when executed by one or more processors, cause the one or more processors to perform the method of claim 32.

**40.** A medical device monitoring system comprising a server having one or more processors configured to: receive, via a computer network, from at least one medical device controller of a plurality of medical device controllers, at least one image of contents displayed on a screen of the at least one medical device controller; send a request to an optical character recognition engine to extract textual information from at least a portion of the at least one image; and send a request to the at least one medical device controller to change a first rate at which the at least one medical device controller sends images to the server to a second rate, wherein the first and second rates are non-zero, and wherein the second rate is selected by the one or more processors based on information about the computer network.

**41.** The medical device monitoring system of claim 40, wherein the information about the computer network comprises information about a load on the computer network or information about a reliability of the computer network.

**42.** The medical device monitoring system of claim 40, wherein the information about the computer network comprises information about a signal strength of a wireless network connection available to the at least one medical device controller.

**43.** The medical device monitoring system of claim 40, wherein the information about the computer network comprises information about a number of other medical device controllers co-located with the at least one medical device controller at a facility.

**44.** The medical device monitoring system of claim 40, wherein the selection of the second rate by the one or more processors is further based on information about a timing of a connection of a medical device to the at least one medical device controller or information about an accuracy of an

optical character recognition of at least one image previously received by the server from the at least one medical device controller.

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