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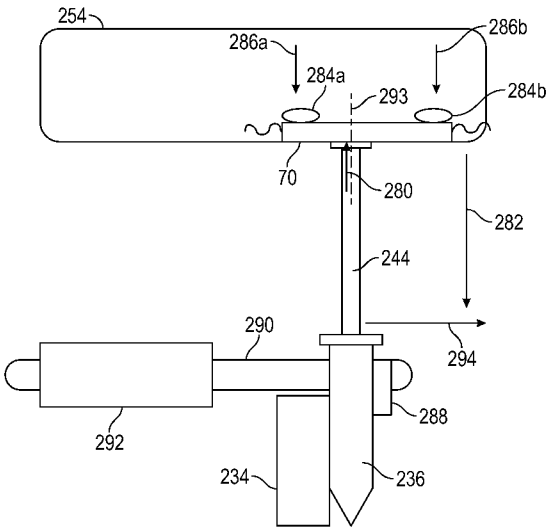

FIG. 4

(57) Abstract: A system for detecting alignment of a syringe in a syringe pump based on force centering detection. A syringe is received into a receptacle of a syringe pump. One or more sensors are positioned on the drive head of the pump and configured to monitor at least a portion of the plunger and to, based on the monitoring, generate sensor measurements pertaining to an alignment of the plunger with respect to the drive head. The system obtains the sensor measurements and determines whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements, and provides an indication of the alignment on a display device and terminate the advancing of the plunger when the alignment deviates from the acceptable alignment.

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SYRINGE PUMP WITH FORCE CENTERING DETECTION

TECHNICAL FIELD

[0001] The present disclosure is related generally to drive mechanisms for medical infusion pumps, and more particularly, to systems and methods for driving the plunger of a syringe in a syringe pump.

BACKGROUND

[0002] The infusion of medical fluids, such as parenteral fluids, into the human body is accomplished in many cases by means of a syringe pump in which a syringe containing the parenteral fluid is mounted. Syringe pumps typically secure the barrel in a fixed position and utilize a drive head to push or "drive" the plunger into the barrel at a controlled rate to expel the fluid. A guide device maintains steady and even administration of the fluid by centering the drive head of the pump against a top of the plunger. If the syringe is not loaded properly then pressure from the drive head on the plunger will be uneven and may result in incorrect amount of fluid being administered. In some cases, an incorrectly positioned drive head may lead to damage to the syringe or the pump itself.

SUMMARY

[0003] The subject technology detects proper loading and alignment of a syringe within a syringe pump using multiple sensors mounted on the drive head.

[0004] The subject technology provides an infusion system comprising: a receptacle for receiving a syringe, the syringe comprising a barrel and a plunger; a drive head for advancing the plunger within the barrel; two or more sensors positioned on the drive head and configured to generate sensor measurements pertaining to an alignment of the plunger with respect to the drive head; and a processor configured to: receive an indication that the syringe was loaded into the receptacle; obtain, from the two or more sensors, the sensor measurements pertaining to the alignment of the plunger with respect to the drive head; determine whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements; and provide an indication of the alignment on a display device and terminate the advancing of the plunger when the alignment deviates from the acceptable alignment.

[0005] A machine-implemented method comprises receiving an indication that a syringe was loaded into a receptacle of a syringe pump, the syringe pump comprising a drive head configured to advance a plunger of the syringe into a barrel of the syringe to infuse a fluid; obtaining, from two or more sensors of the drive head, sensor measurements pertaining to the alignment of the plunger, within the receptacle, with respect to the drive head; determining whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements; and providing an indication of the alignment on a display device and terminate the advancing of the plunger when the alignment deviates from the acceptable alignment. Other aspects include corresponding systems, apparatus, and computer program products for implementation of the corresponding method and its features.

[0006] While the methods and systems disclosed herein are described with regard to syringe pumps, the subject technology is applicable to all infusion pumps. For example, the methods are capable of detecting whether a container volume supplying an infusion fluid (e.g., the medication) is empty. It is understood that other configurations of the subject technology will become readily apparent to those skilled in the art from the following detailed description, wherein various configurations of the subject technology are shown and described by way of illustration. As will be realized, the subject technology is capable of other and different configurations and its several details are capable of modification in various other respects, all without departing from the scope of the subject technology. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a better understanding of the various described implementations, reference should be made to the Description of Implementations below, in conjunction with the following drawings. Like reference numerals refer to corresponding parts throughout the figures and description.

[0008] FIG. 1A depicts an example patient care system that includes an infusion device.

[0009] FIG. 1B depicts a closer view of a portion of the patient care system shown in FIG. 1A.

[0010] FIG. 1C depicts an example of an institutional patient care system of a healthcare organization, according to aspects of the subject technology.

[0011] FIG. 2A depicts an example syringe pump infusion system including a syringe pump, according to various aspects of the subject technology.

[0012] FIG. 2B depicts a partial cross-sectional side view of the drive head of the syringe pump, according to various aspects of the subject technology.

[0013] FIG. 3 shows a block diagram showing a controller of the syringe pump, according to various aspects of the subject technology.

[0014] FIG. 4 depicts the example syringe pump infusion system including sensors for determining an alignment of the plunger with respect to the drive head, according to various aspects of the subject technology.

[0015] FIG. 5 depicts an example process for detecting alignment of a syringe in a syringe pump based on force centering detection, according to aspects of the subject technology.

[0016] FIG. 6 is a conceptual diagram illustrating an example electronic system for detecting alignment of a syringe in a syringe pump based on force centering detection, according to aspects of the subject technology.

DESCRIPTION

[0017] Reference will now be made to implementations, examples of which are illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide an understanding of the various described implementations. However, it will be apparent to one of ordinary skill in the art that the various described implementations may be practiced without these specific details. In other instances, well-known methods, procedures, components, circuits, and networks have not been described in detail so as not to unnecessarily obscure aspects of the implementations.

[0018] When a syringe is loaded into a syringe pump it is important to know that it is loaded correctly and centered. Current methods use a barrel position indicator to visually identify the position of a syringe barrel within the pump. The subject technology provides a system for detecting alignment of a syringe in a syringe pump based on force centering detection. The system uses multiple force sensors on a drive head of a syringe pump to determine whether a syringe loaded into the pump is centered by way of pressure distribution on the drive head by

the plunger. If forces are equal then you know that the syringe is centered. If the forces are unequal then the syringe pump is uncentered and not loaded correctly.

[0019] FIG. 1A is an example patient care system, according to various aspects of the subject technology. The patient care system 20 shown in FIG. 1A includes four fluid infusion pumps 22, 24, 26, and 28 each of which is in operative engagement with a respective fluid administration set 30, 32, 34, and 36. Fluid supplies 38, 40, 42, and 44, which may take various forms but in this case are shown as bottles, are inverted and suspended above the pumps. Fluid supplies may also take the form of bags or other types of containers. Both the patient care system 20 and the fluid supplies 38, 40, 42, and 44 are mounted to a roller stand or pole 46. The specific fluid supplies as well as their orientation (e.g., mount location, mount height, mounting type, etc.) within the care area may generate one or more interaction records. The interaction record for a set for example may be generated in part by detecting a scannable code associated with the set or detecting a physical structure on the set that encodes identifying information for the set prior to use.

[0020] As shown in the example implementation of FIG. 1A, each administration set 30, 32, 34, and 36 is connected between a respective fluid supply 38, 40, 42, and 44 and the same patient 48 so that the patient may receive the fluids in all the fluid supplies. The administration set may be identified either actively by, for example, scanning by a clinician or passively by, for example, wireless or optical detection of the administration set.

[0021] A separate infusion pump 22, 24, 26, and 28 is used to infuse each of the fluids of the fluid supplies into the patient. The infusion pumps are flow control devices that will act on the respective tube or fluid conduit of the fluid administration set to move the fluid from the fluid supply through the conduit to the patient 48. Because individual pumps are used, each can be individually set to the pumping or operating parameters required for infusing the particular medical fluid from the respective fluid supply into the patient at the particular rate prescribed for that fluid by the clinician.

[0022] Typically, medical fluid administration sets have more parts than are shown in FIG. 1. Many have check valves, drip chambers, valved ports, connectors, and other devices well known to those skilled in the art. These other devices have not been included in the drawings so as to preserve clarity of illustration.

[0023] FIG. 1B is a closer view of a portion of the example patient care system shown in FIG. 1A, according to various aspects of the subject technology. FIG. 1B shows two of the fluid infusion pumps mounted at either side of a programming module, and the displays and control keys of each, with the programming module being capable of programming both infusion pumps. The pump 22 includes a door 50 and a handle 52 that operates to lock the door in a closed position for operation and to unlock and open the door for access to the internal pumping and sensing mechanisms and to load administration sets for the pump. When the door 50 is open, the tube can be connected with the pump 22. When the door 50 is closed, the tube is brought into operating engagement with the pumping mechanism, the upstream and downstream pressure sensors, and the other equipment of the pump. A display 54, such as an LED display, is located in plain view on the door in this embodiment and may be used to visually communicate various information relevant to the pump 22, such as alert indications (e.g., alarm messages). Control keys 56 exist for programming and controlling operations of the infusion pump as desired. In some implementations, the control keys may be omitted and be presented as interactive elements on the display 54 (e.g., touchscreen display). The infusion pump may also include an audio alert equipment in the form of a speaker (not shown).

[0024] In some implementations, a programming module 60 is attached to a side of the infusion pump modules 22, 26. In such a system, each attached pump represents a pump channel of the overall patient care system 20. In one embodiment, the programming module 60 is used to provide an interface between the infusion pump(s) and external devices as well as to provide most of the operator interface for the infusion pump(s). In some implementations, the programming module 60 includes a display 62 for visually communicating various information, such as the operating parameters of the pump(s) and alert indications and alert messages. The programming module 60 may also include a speaker to provide audible alerts. In some implementations, the display 62 may be implemented as a touchscreen display. In such implementations, the control keys 64 may be omitted or reduced in number by providing corresponding interactive elements via a graphical user interface presented via the display 62.

[0025] The programming module 60 may include a communications system (not shown) with which the programming module 60 may communicate with external equipment such as a medical facility server or other computer and with a portable processor, such as a handheld communication device or a laptop-type of computer, or other information device that a clinician may have to transfer information as well as to download drug libraries to a programming

module 60 or pump. The communication module may be used to transfer access and interaction information for clinicians encountering the programming module or device coupled therewith (e.g., pump or bar code scanner). The communications system may include one or more of a radio frequency (RF) system, an optical system such as infrared, a BLUETOOTH™ system, or other wired or wireless system. The bar code scanner and communications system may alternatively be included integrally with the infusion pump(s), such as in cases where a programming module is not used, or in addition to one with the programming module 60. Further, information input devices need not be hard-wired to medical instruments, information may be transferred through a wireless connection as well.

[0026] The embodiment shown in FIG. 1B includes a second syringe pump module 26 connected to the programming module 60. As shown in FIG. 1A, more pump modules may be connected. Additionally, other types of modules may be connected to the pump modules or to the programming module such as patient controlled analgesic module, End Tidal CO_2 monitoring module, oximeter monitoring module, or the like.

[0027] In some embodiments, the pressure measurements from the upstream and/or downstream pressure sensors are transmitted to a server or other coordination device, and the methods disclosed herein are implemented on the server or other coordination device. For example, more sophisticated and computationally intensive approaches like machine-learning can be implemented on the server (or on a PCU with a larger memory and/or CPU resources). In some embodiments, machine learning is used to identify syringe pump empty conditions based on pressure signals received from the pump.

[0028] FIG. 1C depicts an example of an institutional patient care system 100 of a healthcare organization, according to aspects of the subject technology. In FIG. 1C, a patient care device (or "medical device" generally) 20 is connected to a hospital network 110. The term patient care device (or "PCD") may be used interchangeably with the term patient care unit (or "PCU"), either which may include various ancillary medical devices such as an infusion pump, a vital signs monitor, a medication dispensing device (e.g., cabinet, tote), a medication preparation device, an automated dispensing device, a module coupled with one of the aforementioned (e.g., a syringe pump module configured to attach to an infusion pump), or other similar devices. Each device may be connected to an internal healthcare network 110 by a transmission channel 131. Transmission channel 131 is any wired or wireless transmission channel, for example an 802.11 wireless local area network (LAN). In some implementations,

network 110 also includes computer systems located in various departments throughout a hospital. For example, network 110 of FIG. 1C optionally includes computer systems associated with an admissions department, a billing department, a biomedical engineering department, a clinical laboratory, a central supply department, one or more unit station computers and/or a medical decision support system. As described further below, network 10 may include discrete subnetworks. In the depicted example, network 110 includes a device network 140 by which patient care devices 20 (and other devices) communicate in accordance with normal operations.

[0029] Additionally, institutional patient care system 100 may incorporate a separate information system server 130, the function of which will be described in more detail below. Moreover, although the information system server 130 is shown as a separate server, the functions and programming of the information system server 130 may be incorporated into another computer, if such is desired by engineers designing the institution's information system. Institutional patient care system 100 may further include one or multiple device terminals 132 for connecting and communicating with information system server 130. Device terminals 132 may include personal computers, personal data assistances, mobile devices such as laptops, tablet computers, augmented reality devices, or smartphones, configured with software for communications with information system server 130 via network 110.

[0030] Patient care device 20 comprises a system for providing patient care, such as that described in U.S. Pat. No. 5,713,856 to Eggers et al., and U.S. Pat. No. 10,732,798 to Langan et al, which are each incorporated herein by reference for this purpose. Patient care device 20 may include or incorporate pumps, physiological monitors (e.g., heart rate, blood pressure, ECG, EEG, pulse oximeter, and other patient monitors), therapy devices, and other drug delivery devices may be utilized according to the teachings set forth herein. In the depicted example, patient care device 20 comprises a control module 60, also referred to as interface unit 60, connected to one or more functional modules 22, 24, 26, 28. Interface unit 60 includes a central processing unit (CPU) 150 connected to a memory, for example, random access memory (RAM) 158, and one or more interface devices such as user interface device 154, a coded data input device 160, a network connection 152, and an auxiliary interface 162 for communicating with additional modules or devices. Interface unit 60 also, although not necessarily, includes a main non-volatile storage unit 156, such as a hard disk drive or non-

volatile flash memory, for storing software and data and one or more internal buses 164 for interconnecting the aforementioned elements.

[0031] In various implementations, user interface device 154 is a touch screen for displaying information to a user and allowing a user to input information by touching defined areas of the screen. Additionally or in the alternative, user interface device 154 could include any means for displaying and inputting information, such as a monitor, a printer, a keyboard, softkeys, a mouse, a track ball and/or a light pen. Data input device 160 may be a bar code reader capable of scanning and interpreting data printed in bar coded format. Additionally or in the alternative, data input device 160 can be any device for entering coded data into a computer, such as a device(s) for reading a magnetic strips, radio-frequency identification (RFID) devices whereby digital data encoded in RFID tags or smart labels (defined below) are captured by the reader 60 via radio waves, PCMCIA smart cards, radio frequency cards, memory sticks, CDs, DVDs, or any other analog or digital storage media. Other examples of data input device 160 include a voice activation or recognition device or a portable personal data assistant (PDA). Depending upon the types of interface devices used, user interface device 154 and data input device 60 may be the same device. Although data input device 160 is shown in FIG. 1C to be disposed within interface unit 14, it is recognized that data input device 160 may be integral within terminal 132 or other external remote interface such as in a mobile device, and which is configured to communicate with the controller 60 by any appropriate wired or wireless communication means. Auxiliary interface 162 may be an RS-232 communications interface, however any other means for communicating with a peripheral device such as a printer, patient monitor, infusion pump or other medical device may be used without departing from the subject technology. Additionally, data input device 60 may be a separate functional module, such as modules 22, 24, 26, and/or 28, and configured to communicate with controller 60, or any other system on the network, using suitable programming and communication protocols.

[0032] Network connection 152 may be a wired or wireless connection, such as by Ethernet, WiFi, BLUETOOTH, an integrated services digital network (ISDN) connection, a digital subscriber line (DSL) modem or a cable modem. Any direct or indirect network connection may be used, including, but not limited to a telephone modem, an MIB system, an RS232 interface, an auxiliary interface, an optical link, an infrared link, a radio frequency link, a microwave link or a WLANS connection or other wireless connection.

[0033] Functional modules 22, 24, 26, 28 are any devices for providing care to a patient or for monitoring patient condition. As shown in FIG. 1C, at least one of functional modules 22, 24, 26, 28 may be an infusion pump module such as an intravenous infusion pump for delivering medication or other fluid to a patient. For the purposes of this discussion, functional module 26 is a syringe pump module. Each of functional modules 22, 24, 26, 28 may be any patient treatment or monitoring device including, but not limited to, an infusion pump, a syringe pump, a PCA pump, an epidural pump, an enteral pump, a blood pressure monitor, a pulse oximeter, an EKG monitor, an EEG monitor, a heart rate monitor, an intracranial pressure monitor, or the like. Functional module 22, 24 and/or 28 may be a printer, scanner, bar code reader, near-field communication reader, RFID reader, or any other peripheral input, output or input/output device.

[0034] Each functional module 22, 24, 26, 28 communicates directly or indirectly with interface unit 60 providing overall monitoring and control of patient care device 20. Functional modules 22, 24, 26, 28 may be connected physically and electronically in serial fashion to one or both ends of interface unit 60 as shown in FIG. 1C. However, it is recognized that there are other means for connecting functional modules with the interface unit that may be utilized without departing from the subject technology. It will also be appreciated that devices such as pumps or patient monitoring devices that provide sufficient programmability and connectivity may be capable of operating as stand-alone devices and may communicate directly with the network without connected through a separate interface unit or control unit 60. As described above, additional medical devices or peripheral devices may be connected to patient care device 20 through one or more auxiliary interfaces 162.

[0035] Each functional module 22, 24, 26, 28 may include module-specific components 176, a microprocessor 170, a volatile memory 172 and a nonvolatile memory 174 for storing information. It should be noted that while four functional modules are shown in FIG. 1C, any number of devices may be connected directly or indirectly to central controller 60. The number and type of functional modules described herein are intended to be illustrative, and in no way limit the scope of the subject technology. Module-specific components 176 include any components necessary for operation of a particular module, such as a pumping mechanism for an infusion pump module (e.g., syringe pump 26).

[0036] While each functional module may be capable of a least some level of independent operation, interface unit 14 monitors and controls overall operation of device 112. For

example, as will be described in more detail below, interface unit 60 provides programming instructions to the functional modules 22, 24, 26, 28 and monitors the status of each module.

[0037] Patient care device 20 (or interface unit 60) is capable of operating in several different modes, or personalities, with each personality defined by a configuration database. The configuration database may be a database 137 internal to patient care device, or an external database 137. A particular configuration database is selected based, at least in part, by patient-specific information such as patient location, age, physical characteristics, or medical characteristics. Medical characteristics include, but are not limited to, patient diagnosis, treatment prescription, medical history, medical records, patient care provider identification, physiological characteristics or psychological characteristics. As used herein, patient-specific information also includes care provider information (e.g., physician identification) or a patient care device's 112 location in the hospital or hospital computer network. Patient care information may be entered through interface device 152, 154, 160 or 162, and may originate from anywhere in network 10, such as, for example, from a pharmacy server, admissions server, laboratory server, and the like.

[0038] Medical devices incorporating aspects of the subject technology may be equipped with a Network Interface Module (NIM), allowing the medical device to participate as a node in a network. While for purposes of clarity the subject technology will be described as operating in an Ethernet network environment using the Internet Protocol (IP), it is understood that concepts of the subject technology are equally applicable in other network environments, and such environments are intended to be within the scope of the subject technology.

[0039] Data to and from the various data sources can be converted into network-compatible data with existing technology, and movement of the information between the medical device and network can be accomplished by a variety of means. For example, patient care device 12 and network 10 may communicate via automated interaction, manual interaction or a combination of both automated and manual interaction. Automated interaction may be continuous or intermittent and may occur through direct network connection 54 (as shown in FIG. 1C), or through RS232 links, MIB systems, RF links such as BLUETOOTH, IR links, WLANS, digital cable systems, telephone modems or other wired or wireless communication means. Manual interaction between patient care device 112 and network 110 involves physically transferring, intermittently or periodically, data between systems using, for example, user interface device 154, coded data input device 160, bar codes, computer disks, portable

data assistants, memory cards, or any other media for storing data. The communication means in various aspects is bidirectional with access to data from as many points of the distributed data sources as possible. Decision-making can occur at a variety of places within network 110. For example, and not by way of limitation, decisions can be made in health information system (HIS) server 130, decision support , remote data server , hospital department or unit stations 46, or within patient care device 112 itself.

[0040] All direct communications with medical devices operating on a network in accordance with the subject technology may be performed through information system server 30, known as the remote data server (RDS). In accordance with aspects of the subject technology, network interface modules incorporated into medical devices such as, for example, infusion pumps or vital signs measurement devices, ignore all network traffic that does not originate from an authenticated RDS. The primary responsibilities of the RDS of the subject technology are to track the location and status of all networked medical devices that have NIMs, and maintain open communication.

[0041] FIG. 2A depicts an example syringe pump 200 infusion system including a syringe pump 26, according to various aspects of the subject technology. Syringe pumps can be used for the infusion of medical fluids, such as parenteral fluids, into the human body. In many cases, smooth delivery of medical fluids is desired. For example, where the medical fluid includes a medication, delivery at a consistent or predicable flow rate allows a medical professional to properly plan and execute a treatment. Mechanical interactions between parts of an infusion system can produce resistance to smooth delivery. Aspects of the embodiments discloses herein address these concerns to provide more consistent and predictable flow during driver operation.

[0042] Prompt, continuous, and smooth delivery is also desirable so that treatment can be administered without any unintended delay. For example, medications can be subject to a biological or terminal half-life, in which a span of time is defined for half of the dose to be eliminated from the bloodstream. Accordingly, ensuring that the medication is delivered within an expected time span allows a healthcare provider to deliver an effective dosage. Additionally, low flow rates may be needed for some patients, such as infants. Where a low flow rate is achieved with slow drive head motion, any delay in initial delivery can be amplified by the programmed slow movement of the drive head.

[0043] The present disclosure presents multiple aspects that, individually or in combination, can improve systems that include a pump driver and syringe to deliver medication smoothly and promptly at low flow rates.

[0044] According to various implementations, the infusion system 200 may include a syringe pump 26 having a drivetrain subsystem. A syringe 232 is shown next to the pump rather than mounted in the pump, for clarity of illustration. The syringe pump 26 includes a cradle 234 in which a barrel 236 can rest when mounted in the syringe pump 26. The cradle 234 can include a clamp 238 to securely hold the barrel 236 in a fixed position in the cradle 234 so that axial and lateral movement is resisted. The clamp 238 can be pivoted so that it may be moved into an open position to permit loading or removal of the syringe 232 and a closed position in which it extends over the cradle 234 to hold a mounted barrel 236. A barrel flange 240 of the syringe 232 can be located in a barrel flange groove 242 in the syringe pump 30 to immobilize the barrel 236 from axial movement during movement of the plunger 244 within the barrel 236.

[0045] The syringe 232 can include the barrel 236 and the plunger 244. The plunger 244 can include a push-button 246 having an inner side 248 and being interconnected with a stopper 262 of the plunger 244 by a piston 250. The plunger 244 can include the stopper 262 to sealingly engage an inner wall of the barrel 236 to prevent fluid from leaking past the stopper 262. When mounted in the syringe pump 26, the push-button 246 can be held by a drive head 254 with a plunger retainer comprising a pair of pivotally mounted claws, first retainer claw 256 and second retainer claw 258, shown in the closed position in FIG. 2A. The retainer claws 256 and 258 can curve inwardly toward each other to grasp the push-button 246 when mounted in the syringe pump 26. A rotation knob 264 can be used to control the positions of the first and second retainer claws 256 and 258 to allow removal and insertion of the push-button 246 and to release the split-nut from the driveshaft to permit axial positioning of the drive head 254. Syringes can be provided for use with a syringe pump with different quantities of fluid, and the plunger can be located at different positions in relation to the barrel.

[0046] The drive head 254 may allow manual adjustment to accommodate syringes with different beginning plunger positions. A syringe inserted in the cradle 234 can align with the drive head 254 within a particular axial range. The points where the axial center lines of the syringes intersect the driver can change according to the size of the syringe but only in one direction along the drive head 254. A guide device 265 can extend from the drive head 254 to a point within a body of the syringe pump 26.

[0047] The syringe pump 26 can include a control panel 76 providing multiple buttons 78 for control of the pump 26 as well as a display 80 used to present pump-specific information to the operator. The buttons 78 can allow the operator to program the pump 26 for the flow rate, the volume to be infused, and other pump parameters. The display 80 can present the programmed flow rate, the amount of fluid remaining to be infused, as well as alarms and other information.

[0048] FIG. 2B depicts a partial cross-sectional side view of the drive head of the syringe pump, according to various aspects of the subject technology. In the depicted example, the drive head 254 includes a contact plate 70 that has a pushing surface 71 that contacts the outer side 72 of the push-button 246 of the syringe 232 as the drive head 254 moves forward toward the barrel 236, pushing the plunger 244 into the barrel 236 of the syringe to expel the syringe contents through a fluid administration set tubing 74 to the patient 48. The contact plate 70 can be interconnected to a force sensor system. When the contact plate 70 exerts force against the push-button 246, one or more force sensors report the detected force, as discussed further herein. A recess 88 can be formed in the drive head 254 to accommodate the contact plate 70. The contact plate 70 can be attached to the drive head 254 inside recess 88. The contact plate 70 can be forced to protrude slightly outward in the vertical direction from the surface of the drive head 54 toward a mounted push-button due to a bias exerted against the push-button contact plate 70. As the contact plate 70 exerts a force against the push-button, one or more force sensors detect the force and transmit the sensed force to a processor for monitoring, as described further herein in relation to FIG. 3.

[0049] According to some implementations, the system 200 can include components for controlling advancement of the plunger 244 within the barrel 36 of the syringe 232. The drive head 254, which engages the push-button 246 of the syringe 232, can be moved by a drivetrain (not shown). For example, the pump 26 can include a motor 112 that operates to rotate a lead screw engaged by a screw drive mechanism, such as a split nut, that translates the rotational motion of the lead screw into linear motion. The drive head 254 is connected to the screw drive mechanism and drives plunger 244 into the barrel 236 in accordance with the movement of the lead screw to expel fluid from the barrel 236.

[0050] According to some embodiments, the motor may include a stepper motor, a brushed DC electric motor, a brushless DC electric motor, a servo motor, an AC motor, or another type of motor. The drivetrain may include appropriate gears, axles, shafts, chains, hydraulics, and/or

any other components for translating rotational motion of the motor into linear motion of the drive head 254. According to some embodiments, the drivetrain, including the motor, can include linear actuating components, such as a linear stepper motor. For example, a linear motor can act directly on the drive head, or a component attached thereto, to control linear motion thereof.

[0051] As depicted in FIGS. 1A, 1B, and 1C, the syringe pump 26 can be mounted to a programming module 60, together forming a modular patient care system 20. The programming module may perform various functions for the pump such as programming and communications. Control elements and functions can be included with and performed, at least in part, by the programming module 152. In addition to the syringe pump 30 mounted to the programming module 152, other modules, such as those providing patient monitoring or therapies, can also form part of the patient care system. The programming module 152 can provide a centralized interface for the various attached modules. One or more syringe pumps can be mounted to the programming module 152 and/or each other.

[0052] The drive head 54 can interact with the syringe 32 in a manner that facilitates prompt, consistent, and predicable infusion of a fluid from the syringe 32 to the patient. The features described herein can be used individually or in combination to improve the ability of the system 200 to deliver medication promptly and smoothly at low flow rates.

[0053] FIG. 3 shows a block diagram showing a controller of the syringe pump, according to various aspects of the subject technology. According to various implementations, the syringe pump 26 may include a processor 110 that controls various aspects of operation. The processor 110 can be connected either directly or indirectly to a friction sensor 94, one or more force sensors 284, and to a flow sensor system 85.

[0054] The flow sensor system 85 can include one or more sensors 97, such as a force sensor, a displacement sensor, a pressure sensor, and/or a flow sensor. Force sensors may be used and pressure extrapolated from the measured force based on a known area. In this regard, the terms “pressure” and “force”, and “pressure sensor(s)” and “force sensor(s)”, are used herein interchangeably. Based on the signals received from these devices and/or other signals, the processor 110 can control the movement of the drive head 254. Conversion equipment, such as analog-to-digital converters, can be provided between the processor 110 and the flow

sensor system 85 and/or the force sensor system 75. The processor 110 can connect to a user interface (not shown).

[0055] The friction sensor 94 may detect a general force 280 at the contact plate (e.g., exerted by the plunger and fluid pressure within the barrel of the syringe) and output a force signal to the processor 110. As the drive head 54 acts on the plunger 44, the friction sensor 94 can detect the force between the drive head 54 and the plunger 44. Where friction is detected by the system (e.g., by the force sensor 94 and/or a flow sensor), the processor may adjust the motor speed of motor 112. When friction between the stopper 62 and the barrel 36 increases, the force required from the drive head 54 to move the plunger 44 can correspondingly increase. Processor may increase the power/speed of the motor to increase the force of the drive head. For example, friction sensor 94 may be used to detect when the end of an infusion is near based on an increase in force, thereby increasing speed of the motor 112 to finish the infusion. If too much force is detected by sensor 94, the processor 110 may stop motor 112 to terminate the infusion and display an error on display 111.

[0056] As will be described further, force sensors 284 may generate sensor measurements pertaining to an alignment of the plunger with respect to the drive head. Force sensors 284 may be in addition to, or alternative to, force sensor 94. For example, force sensor 94 may be used to control general motor activation and power during an infusion, while force sensors 284 may be used to detect alignment of the plunger and/or syringe (e.g., proper loading) within the syringe pump. In some implementations, friction sensor 94 may be omitted and force sensors 284 may provide motor control as well as alignment detection.

[0057] FIG. 4 depicts the example syringe pump 200 infusion system including sensors for determining an alignment of the plunger with respect to the drive head, according to various aspects of the subject technology. In the depicted example, a syringe 232 is loaded into the syringe pump 26, with the barrel 236 of the syringe 232 loaded in a fixed cradle 234. The drive head 254 is positioned over the push button end 246 of the syringe plunger 244 and held steady by the guide device 265 (FIG. 2A and 2B). In this manner, a back pressure of the fluid within the barrel of the syringe may cause a opposing force 280 on the drive head 254 as the drive head 254 moves in a direction 282 toward the barrel 236 of the syringe to push the plunger 244 into the barrel of the syringe and expel the fluid into the downstream infusion line 74.

[0058] Multiple force sensors 284 are positioned on the drive head 254 and configured to monitor at least a portion of the plunger 244 and generate sensor measurements pertaining to an alignment of the plunger with respect to the drive head. In the depicted example, the sensors 284a and 284b are positioned behind the contact plate 70. The force on the contact plate 70 causes a distribution of force across the contact plate 70. In this regard, each sensor 284 detects a portion 286 of the distributed force. With reference to FIG. 3, the processor 110 is configured to receive the sensor measurements from force sensors 284 and to determine whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on the sensor measurements. An indication of the alignment may be displayed on a display device 111. Based in part on the comparison of sensor measurements, the indication may identify a binary condition for alignment (e.g., syringe centered, syringe not centered). In some implementations, the indication may identify how the syringe may be misaligned. For example, in a two-sensor arrangement, if a sensor at the nine o'clock position detects a higher force than a sensor at the three o'clock position, the alignment indicator may suggest tilting from left to right.

[0059] In some implementations, the processor may stop motor 112 to terminate the advancing 282 of the plunger 244 when the alignment deviates from the acceptable alignment (e.g., when the forces 286 are unequal). For example, as the plunger is moved into the barrel by the drive head, the processor 110 may monitor the pressures and terminate the movement and infusion delivery when a deviation in pressure readings satisfies (e.g., is greater than) a threshold deviation (e.g., the pressure measured at 284a is more than 10% greater than the pressure measured at sensor 284b).

[0060] In some implementations, the infusion system 200 includes a barrel sizer 288. In some implementations, the barrel sizer is an arm 290 that extends around the barrel of the syringe, positioning the barrel within the cradle, as shown. The arm 290 may be connected to a barrel sizing potentiometer 292. The potentiometer 292 may be motorized to extend and retract the barrel sizer 282 on command, for example, issued by way of user input at the control panel 76 of the syringe pump 26, or by way of input via network connection 152 (e.g., a terminal 132) or user I/O 154.

[0061] In some implementations, the processor 110 receives a type of the syringe and determines whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on the measured distribution and the type of the syringe. The

type of the syringe may be determined by way of measuring the syringe barrel 236 with the barrel sizer 288. The potentiometer 292 may determine the diameter of the barrel based on an amount that the arm 290 is extended when the barrel is locked in place by the sizer 288. The processor 110 may perform a lookup (e.g., in a remote database 137) of the syringe type based on the measured size. Adjustment parameters for calculating the proper distribution of pressures sensed by sensors 286 may then be determined based on the syringe type and used in the calculation. As depicted in FIG. 4, as the size of the syringe barrel 236 increases, the center of the plunger 244, and its center of mass, will shift outward 294 (or inward), shifting the distribution of force between sensors 286a and 286b. The adjustment parameters change and are applied based on syringe size/type so that the processor 110 may accurately determine when the plunger 244 is properly aligned between the sensors, and thus properly aligned within the syringe pump.

[0062] FIG. 5 depicts an example process 300 for detecting alignment of a syringe in a syringe pump based on force centering detection, according to aspects of the subject technology. For explanatory purposes, the various blocks of example process 300 are described herein with reference to FIGS. 1-4, and the components and/or processes described herein. The one or more of the blocks of process 300 may be implemented, for example, by one or more computing devices including, for example, controller 60 and/or processor 110. In some implementations, one or more of the blocks may be implemented based on one or more machine learning algorithms. In some implementations, one or more of the blocks may be implemented apart from other blocks, and by one or more different processors or devices. Further for explanatory purposes, the blocks of example process 300 are described as occurring in serial, or linearly. However, multiple blocks of example process 300 may occur in parallel. In addition, the blocks of example process 300 need not be performed in the order shown and/or one or more of the blocks of example process 300 need not be performed.

[0063] In the depicted example, a syringe 232 is loaded/received into a receptacle 234 of a syringe pump 26 and an indication is received by the processor 110 that the syringe was loaded (302). According to various implementations, the plunger 244 of syringe 232 is configured to be driven into the barrel 236 of the syringe 232 by way of force on a push button end 246 of the plunger. In some implementations, the type of syringe is detected by the syringe pump responsive to being loaded into the receptacle. Type of syringe may be received via user input or may be detected automatically by way of a barrel sizer 288.

[0064] As described previously, the syringe pump 26 includes a drive head 254 that advances the plunger 244 according to a programmed therapy when an infusion is initiated. One or more sensors 284 are positioned on the drive head 254 and configured to monitor at least a portion of the plunger, and to generate sensor measurements pertaining to an alignment of the plunger with respect to the drive head. In some implementations, two sensors 284a and 284b are positioned on the drive head between the drive head and the push button end.

[0065] The syringe pump may include a retainer The syringe pump may include a retainer to immobilize or otherwise prevent the push button end 246 of the plunger 244 from moving while the plunger is driven into the barrel 236. In some implementations, the retainer is a retainer claw, as depicted in FIG. 2A. Other mechanisms for immobilizing the plunger are known and may be alternatively used. As shown in FIGS. 2B and 4, a contact plate 70 may be positioned between the sensors 284 and the push button end 246. The contact plate 70 may be in contact with the push button end of the plunger when the push button end is immobilized; for example, gripped by the retainer claw. According to various implementations, the contact plate distributes, between the sensors, an opposing force 280 of the plunger being driven into the barrel when the plunger is loaded and/or when advanced within the barrel by the drive head.

[0066] The processor 110 is configured to detect the alignment of the plunger based on determining whether the push button end is centered on a location on the drive head between the plurality of sensors. For example, depending on the type of syringe being aligned, the processor determines a center location 293 between the sensors 284. While only two sensors is depicted, the system 200 may use any number of sensors. For example, three, four, five, six, or seven sensors may be used, with the multiple sensors surrounding an area designated for receiving a force pressure from the push button end 246 of the plunger 244 (and possible locations of center location 293). In some implementations, the detection of the alignment may be achieved with a single sensor (e.g., a gyroscope). In this regard, the sensor may move to the center location based on the type of syringe detected by the system, measure the amount of force applied at the center location and determines whether the alignment is incorrect based on whether the amount of force is expected for the location of the center location.

[0067] The processor 110 obtains/receives, from the sensor(s) 284, the sensor measurements pertaining to the alignment of the plunger with respect to the drive head (304). In some implementations, the measurements may be obtained automatically responsive to the syringe 232 being loaded in the receptacle 234. In some implementations, sensor

measurements may be continuously (e.g., periodically) obtained as the drive head 254 advances to push 282 the plunger 244 into the syringe barrel 236.

[0068] In the depicted example, the processor 110 determines whether the alignment of the drive head 254 with respect to the plunger deviates from an acceptable alignment based on the sensor measurements (306). In this regard, the processor 110 obtains a pressure or force measurement from each sensor 284. The processor may determine the alignment based on comparing pressure readings from the pressure sensors 284 and, for example, determine whether the push button end is centered on a location on the drive head between the plurality of sensors. For example, if the pressure is greater than an expected pressure at one sensor (e.g., sensor 284b) then the processor may presume that the plunger is misaligned too far in a direction toward the sensor measuring the greater pressure value.

[0069] As described previously, the type of syringe may be automatically determined by a barrel sizer 288, or based on user input. The type of syringe may be used to determine a center location 293 of the push button end of the plunger. In this regard, the pressure expected to be measured at each sensor may be adjusted based on the determined center location 293. In some implementations, pressure sensors are measured and then a ratio is determined, with the processor expecting a predetermined ration based on the center location. The type of syringe may be used to adjust/bias the ratio to account for the location of the center position when determining whether the plunger is misaligned. The amount of adjustment/bias may be selected from a table of biases indexed by syringe type or syringe identifier. In some implementations, the bias coefficient may be determined according to:

$$b_s\left(\frac{f(j)}{f(i)}\right) - e_s$$

where b is the syringe bias coefficient; f(x) is the force reading of sensor x; i and j are sensors; and e is the expected syringe ratio for a centered syringe.

[0070] In some implementations, a tilt of the plunger with respect to the receptacle may be determined based on the syringe type and a difference between the measurements and/or a comparison between the measured ratio and an expected ratio.

[0071] The processor provides an indication of the alignment on a display device (308). For example, the processor may display a representation of the plunger's tilt, an indication that

the plunger/syringe is moved too far in a direction, and/or that the plunger/syringe is misloaded and an adjustment is required before an infusion is initiated. In some implementations, the alignment may be displayed responsive to loading the syringe. If the syringe is misaligned, a prompt may be provided to realign the syringe. In some implementations, the processor 110 may detect how the syringe has been misloaded and provide guidance and animation on a display of device 60 indicating how to correct loading of the syringe. For example, if sensor 286a (adjusted by the adjustment parameters) measures a pressure greater than sensor 286b then the processor 110 may determine that the syringe should be moved in a direction toward sensor 286b, and an instruction pertaining to readjusting the syringe in the direction may be displayed on the display screen. In some implementations, the indication of the alignment may be continuously (e.g., periodically) updated on the display device as the drive head moves 282 to advance the plunger within the barrel.

[0072] Additionally or in the alternative, the processor may terminate the advancing of the plunger when the alignment deviates from the acceptable alignment (310). For example, the processor 110 may prevent the syringe pump from activating to infusion a fluid until the processor 110 determines (by way of the sensor measurements) that the syringe is properly aligned. In another example, the processor 110 may stop the motor 112 from advancing the drive head (and plunger) on detecting a misalignment after an infusion has begun.

[0073] The foregoing process provides multiple benefits including, but not limited to, ensuring the patient receives all of the prescribed medicine. Moreover, early detection of a syringe being fully emptied reduces strain on the pump thereby conserving the resources needed to deliver the fluid such as power, pumping motor cycles, and pumping finger wear. Indeed, many infusion pumps are battery powered and power limited. In such power constrained systems, the life of a battery may be extended by preventing an infusion from running needlessly when no fluid is being pumped. The system detects the threshold trigger condition and initiates rapid emptying of the syringe or other remedial remedies (such as reducing an end of delivery threshold) to ensure the infusion is timely completed.

[0074] Many of the above-described example process 600, and related features and applications, may also be implemented as software processes that are specified as a set of instructions recorded on a computer readable storage medium (also referred to as computer readable medium), and may be executed automatically (e.g., without user intervention). When these instructions are executed by one or more processing unit(s) (e.g., one or more processors,

cores of processors, or other processing units), they cause the processing unit(s) to perform the actions indicated in the instructions. Examples of computer readable media include, but are not limited to, CD-ROMs, flash drives, RAM chips, hard drives, EPROMs, etc. The computer readable media does not include carrier waves and electronic signals passing wirelessly or over wired connections.

[0075] The term "software" is meant to include, where appropriate, firmware residing in read-only memory or applications stored in magnetic storage, which can be read into memory for processing by a processor. Also, in some implementations, multiple software aspects of the subject disclosure can be implemented as sub-parts of a larger program while remaining distinct software aspects of the subject disclosure. In some implementations, multiple software aspects can also be implemented as separate programs. Finally, any combination of separate programs that together implement a software aspect described here is within the scope of the subject disclosure. In some implementations, the software programs, when installed to operate on one or more electronic systems, define one or more specific machine implementations that execute and perform the operations of the software programs.

[0076] A computer program (also known as a program, software, software application, script, or code) can be written in any form of programming language, including compiled or interpreted languages, declarative or procedural languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, object, or other unit suitable for use in a computing environment. A computer program may, but need not, correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub programs, or portions of code). A computer program can be deployed to be executed on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communication network.

[0077] FIG. 6 is a conceptual diagram illustrating an example electronic system 600 for detecting alignment of a syringe in a syringe pump based on force centering detection, according to aspects of the subject technology. Electronic system 600 may be a computing device for execution of software associated with one or more portions or steps of method 600, or components and methods provided by FIGS. 1-5, including but not limited to computing hardware within patient care device 12, or syringe pump 26, and/or any computing devices or

associated terminals disclosed herein. In this regard, electronic system 600 may be a personal computer or a mobile device such as a smartphone, tablet computer, laptop, PDA, an augmented reality device, a wearable such as a watch or band or glasses, or combination thereof, or other touch screen or television with one or more processors embedded therein or coupled thereto, or any other sort of computer-related electronic device having network connectivity.

[0078] Electronic system 600 may include various types of computer readable media and interfaces for various other types of computer readable media. In the depicted example, electronic system 600 includes a bus 608, processing unit(s) 612, a system memory 604, a read-only memory (ROM) 610, a permanent storage device 602, an input device interface 614, an output device interface 606, and one or more network interfaces 616. In some implementations, electronic system 600 may include or be integrated with other computing devices or circuitry for operation of the various components and methods previously described.

[0079] Bus 608 collectively represents all system, peripheral, and chipset buses that communicatively connect the numerous internal devices of electronic system 600. For instance, bus 408 communicatively connects processing unit(s) 612 with ROM 610, system memory 604, and permanent storage device 602.

[0080] From these various memory units, processing unit(s) 612 retrieves instructions to execute and data to process in order to execute the processes of the subject disclosure. The processing unit(s) can be a single processor or a multi-core processor in different implementations.

[0081] ROM 610 stores static data and instructions that are needed by processing unit(s) 612 and other modules of the electronic system. Permanent storage device 602, on the other hand, is a read-and-write memory device. This device is a non-volatile memory unit that stores instructions and data even when electronic system 600 is off. Some implementations of the subject disclosure use a mass-storage device (such as a magnetic or optical disk and its corresponding disk drive) as permanent storage device 602.

[0082] Other implementations use a removable storage device (such as a floppy disk, flash drive, and its corresponding disk drive) as permanent storage device 602. Like permanent storage device 602, system memory 604 is a read-and-write memory device. However, unlike storage device 602, system memory 604 is a volatile read-and-write memory, such a random

access memory. System memory 604 stores some of the instructions and data that the processor needs at runtime. In some implementations, the processes of the subject disclosure are stored in system memory 604, permanent storage device 602, and/or ROM 610. From these various memory units, processing unit(s) 612 retrieves instructions to execute and data to process in order to execute the processes of some implementations.

[0083] Bus 608 also connects to input and output device interfaces 614 and 606. Input device interface 614 enables the user to communicate information and select commands to the electronic system. Input devices used with input device interface 614 include, e.g., alphanumeric keyboards and pointing devices (also called "cursor control devices"). Output device interfaces 606 enables, e.g., the display of images generated by the electronic system 600. Output devices used with output device interface 606 include, e.g., printers and display devices, such as cathode ray tubes (CRT) or liquid crystal displays (LCD). Some implementations include devices such as a touchscreen that functions as both input and output devices.

[0084] Also, as shown in FIG. 6, bus 608 also couples electronic system 600 to a network (not shown) through network interfaces 616. Network interfaces 616 may include, e.g., a wireless access point (e.g., Bluetooth or WiFi) or radio circuitry for connecting to a wireless access point. Network interfaces 616 may also include hardware (e.g., Ethernet hardware) for connecting the computer to a part of a network of computers such as a local area network ("LAN"), a wide area network ("WAN"), wireless LAN, or an Intranet, or a network of networks, such as the Internet. Any or all components of electronic system 600 can be used in conjunction with the subject disclosure.

[0085] These functions described above can be implemented in computer software, firmware or hardware. The techniques can be implemented using one or more computer program products. Programmable processors and computers can be included in or packaged as mobile devices. The processes and logic flows can be performed by one or more programmable processors and by one or more programmable logic circuitry. General and special purpose computing devices and storage devices can be interconnected through communication networks.

[0086] Some implementations include electronic components, such as microprocessors, storage and memory that store computer program instructions in a machine-readable or

computer-readable medium (also referred to as computer-readable storage media, machine-readable media, or machine-readable storage media). Some examples of such computer-readable media include RAM, ROM, read-only compact discs (CD-ROM), recordable compact discs (CD-R), rewritable compact discs (CD-RW), read-only digital versatile discs (e.g., DVD-ROM, dual-layer DVD-ROM), a variety of recordable/rewritable DVDs (e.g., DVD-RAM, DVD-RW, DVD+RW, etc.), flash memory (e.g., SD cards, mini-SD cards, micro-SD cards, etc.), magnetic and/or solid state hard drives, read-only and recordable Blu-Ray® discs, ultra density optical discs, any other optical or magnetic media, and floppy disks. The computer-readable media can store a computer program that is executable by at least one processing unit and includes sets of instructions for performing various operations. Examples of computer programs or computer code include machine code, such as is produced by a compiler, and files including higher-level code that are executed by a computer, an electronic component, or a microprocessor using an interpreter.

[0087] While the above discussion primarily refers to microprocessor or multi-core processors that execute software, some implementations are performed by one or more integrated circuits, such as application specific integrated circuits (ASICs) or field programmable gate arrays (FPGAs). In some implementations, such integrated circuits execute instructions that are stored on the circuit itself.

[0088] As used in this specification and any claims of this application, the terms "computer", "server", "processor", and "memory" all refer to electronic or other technological devices. These terms exclude people or groups of people. For the purposes of the specification, the terms display or displaying means displaying on an electronic device. As used in this specification and any claims of this application, the terms "computer readable medium" and "computer readable media" are entirely restricted to tangible, physical objects that store information in a form that is readable by a computer. These terms exclude any wireless signals, wired download signals, and any other ephemeral signals.

[0089] To provide for interaction with a user, implementations of the subject matter described in this specification can be implemented on a computer having a display device, e.g., a CRT (cathode ray tube) or LCD (liquid crystal display) monitor, for displaying information to the user and a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; e.g., feedback provided to the user can be any form of sensory feedback,

e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input. In addition, a computer can interact with a user by sending documents to and receiving documents from a device that is used by the user; e.g., by sending web pages to a web browser on a user's client device in response to requests received from the web browser.

[0090] Embodiments of the subject matter described in this specification can be implemented in a computing system that includes a back end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the subject matter described in this specification, or any combination of one or more such back end, middleware, or front end components. The components of the system can be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network ("LAN") and a wide area network ("WAN"), an inter-network (e.g., the Internet), and peer-to-peer networks (e.g., ad hoc peer-to-peer networks).

[0091] The computing system can include clients and servers. A client and server are generally remote from each other and may interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other. In some embodiments, a server transmits data (e.g., an HTML page) to a client device (e.g., for purposes of displaying data to and receiving user input from a user interacting with the client device). Data generated at the client device (e.g., a result of the user interaction) can be received from the client device at the server.

[0092] Those of skill in the art would appreciate that the various illustrative blocks, modules, elements, components, methods, and algorithms described herein may be implemented as electronic hardware, computer software, or combinations of both. To illustrate this interchangeability of hardware and software, various illustrative blocks, modules, elements, components, methods, and algorithms have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. The described functionality may be implemented in varying ways for each particular application. Various components and blocks may be arranged differently (e.g., arranged in a

different order, or partitioned in a different way) all without departing from the scope of the subject technology.

[0093] It is understood that the specific order or hierarchy of steps in the processes disclosed is an illustration of example approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged. Some of the steps may be performed simultaneously. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0094] Illustration of Subject Technology as Clauses:

[0095] Various examples of aspects of the disclosure are described as numbered clauses (1, 2, 3, etc.) for convenience. These are provided as examples, and do not limit the subject technology. Identifications of the figures and reference numbers are provided below merely as examples and for illustrative purposes, and the clauses are not limited by those identification

[0096] Clause 1. An infusion system comprising: a receptacle for receiving a syringe, the syringe comprising a barrel and a plunger; a drive head for advancing the plunger within the barrel; two or more sensors positioned on the drive head and configured to generate sensor measurements pertaining to an alignment of the plunger with respect to the drive head; and a processor configured to: receive an indication that the syringe was loaded into the receptacle; obtain, from the two or more sensors, the sensor measurements pertaining to the alignment of the plunger with respect to the drive head; determine whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements; and provide an indication of the alignment on a display device and terminate the advancing of the plunger when the alignment deviates from the acceptable alignment.

[0097] Clause 2. The infusion system of Clause 1, wherein the plunger is configured to be driven into the barrel of the syringe by way of force on a push button end of the plunger, wherein the infusion system further comprises: the two or more sensors being positioned on the drive head between the drive head and the push button end, wherein the processor is further configured to determine the alignment based on comparing pressure readings from the two or more sensors.

[0098] Clause 3. The infusion system of Clause 2, wherein the drive head comprises: a retainer for preventing movement of the push button end of the plunger while the plunger is driven into the barrel; and a contact plate positioned between the sensors and the push button end, the contact plate in contact with the push button end of the plunger when the push button end is prevented from moving by the retainer, the contact plate distributing, between the sensors, an opposing force of the plunger being driven into the barrel when the plunger is advanced within the barrel by the drive head, wherein the processor is further configured to determine whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on a measured distribution or ratio between the sensors of the opposing force on the contact plate.

[0099] Clause 4. The infusion system of Clause 2 or Clause 3, wherein the processor is further configured to: receive a type of the syringe; and determine whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on the measured distribution and the type of the syringe.

[0100] Clause 5. The infusion system of Clause 4, wherein the processor is further configured to: determine a center location associated with the push button end, between the two or more sensors on the drive head, based on the type of the syringe; and detect the alignment based on determining whether the push button end is centered on a location on the drive head between the two or more sensors.

[0101] Clause 6. The infusion system any one of Clauses 2 through 5, wherein the two or more sensors comprises only two pressure sensors.

[0102] Clause 7. The infusion system of any one of Clauses 1 through 6, wherein the processor is further configured to: cause the drive head to advance the plunger within the barrel; and as the drive head advances the plunger within the barrel, periodically obtain sensor measurements pertaining to the alignment of the plunger with respect to the drive head.

[0103] Clause 8. The infusion system of Clause 7, wherein the processor is further configured to: as the drive head advances the plunger within the barrel, periodically update the indication of the alignment on the display device.

[0104] Clause 9. A machine-implemented method, comprising: receiving an indication that a syringe was loaded into a receptacle of a syringe pump, the syringe pump comprising a

drive head configured to advance a plunger of the syringe into a barrel of the syringe to infuse a fluid; obtaining, from one or more sensors of the drive head, sensor measurements pertaining to the alignment of the plunger, within the receptacle, with respect to the drive head; determining whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements; and providing an indication of the alignment on a display device and terminate the advancing of the plunger when the alignment deviates from the acceptable alignment.

[0105] Clause 10. The machine-implemented method of Clause 9, further comprising: determining the alignment based on comparing pressure readings from two or more sensors positioned on the drive head between the drive head and a push button end of the plunger.

[0106] Clause 11. The machine-implemented method of Clause 10, further comprising: receiving a type of the syringe; and determining whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on the sensor measurements and the type of the syringe.

[0107] Clause 12. The machine-implemented method of Clause 11, further comprising: determining a center location associated with the push button end, between the two or more sensors on the drive head, based on the type of the syringe; and detecting the alignment based on determining whether the push button end is centered on a location on the drive head between the two or more sensors

[0108] Clause 13. The machine-implemented method of any one of Clauses 9 through 12, further comprising: causing the drive head to advance the plunger within the barrel; and as the drive head advances the plunger within the barrel, periodically obtaining sensor measurements pertaining to the alignment of the plunger with respect to the drive head.

[0109] Clause 14. The machine-implemented method of Clause 13, further comprising: as the drive head advances the plunger within the barrel, periodically updating the indication of the alignment on the display device.

[0110] Clause 15. A non-transitory machine-readable storage medium embodying instructions that when executed by a machine, facilitate the machine to perform the method of any one of Clauses 9-14.

[0111] Further Consideration:

[0112] It is understood that the specific order or hierarchy of steps in the processes disclosed is an illustration of example approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged. Some of the steps may be performed simultaneously. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0113] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. The previous description provides various examples of the subject technology, and the subject technology is not limited to these examples. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. Pronouns in the masculine (e.g., his) include the feminine and neuter gender (e.g., her and its) and vice versa. Headings and subheadings, if any, are used for convenience only and do not limit the invention described herein.

[0114] The predicate words "configured to", "operable to", and "programmed to" do not imply any particular tangible or intangible modification of a subject, but, rather, are intended to be used interchangeably. For example, a processor configured to monitor and control an operation or a component may also mean the processor being programmed to monitor and control the operation or the processor being operable to monitor and control the operation. Likewise, a processor configured to execute code can be construed as a processor programmed to execute code or operable to execute code.

[0115] The term automatic, as used herein, may include performance by a computer or machine without user intervention; for example, by instructions responsive to a predicate action by the computer or machine or other initiation mechanism. The word "example" is used herein to mean "serving as an example or illustration." Any aspect or design described herein as

"example" is not necessarily to be construed as preferred or advantageous over other aspects or designs.

[0116] A phrase such as an "aspect" does not imply that such aspect is essential to the subject technology or that such aspect applies to all configurations of the subject technology. A disclosure relating to an aspect may apply to all configurations, or one or more configurations. An aspect may provide one or more examples. A phrase such as an aspect may refer to one or more aspects and vice versa. A phrase such as an "embodiment" does not imply that such embodiment is essential to the subject technology or that such embodiment applies to all configurations of the subject technology. A disclosure relating to an embodiment may apply to all embodiments, or one or more embodiments. An embodiment may provide one or more examples. A phrase such as an "embodiment" may refer to one or more embodiments and vice versa. A phrase such as a "configuration" does not imply that such configuration is essential to the subject technology or that such configuration applies to all configurations of the subject technology. A disclosure relating to a configuration may apply to all configurations, or one or more configurations. A configuration may provide one or more examples. A phrase such as a "configuration" may refer to one or more configurations and vice versa.

[0117] As used herein a "user interface" (also referred to as an interactive user interface, a graphical user interface or a UI) may refer to a network based interface including data fields and/or other control elements for receiving input signals or providing electronic information and/or for providing information to the user in response to any received input signals. Control elements may include dials, buttons, icons, selectable areas, or other perceivable indicia presented via the UI that, when interacted with (e.g., clicked, touched, selected, etc.), initiates an exchange of data for the device presenting the UI. A UI may be implemented in whole or in part using technologies such as hyper-text mark-up language (HTML), FLASH™, JAVA™, .NET™, C, C++, web services, or rich site summary (RSS). In some embodiments, a UI may be included in a stand-alone client (for example, thick client, fat client) configured to communicate (e.g., send or receive data) in accordance with one or more of the aspects described. The communication may be to or from a medical device or server in communication therewith.

[0118] As used herein, the terms "determine" or "determining" encompass a wide variety of actions. For example, "determining" may include calculating, computing, processing, deriving, generating, obtaining, looking up (e.g., looking up in a table, a database or another

data structure), ascertaining and the like via a hardware element without user intervention. Also, "determining" may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like via a hardware element without user intervention. "Determining" may include resolving, selecting, choosing, establishing, and the like via a hardware element without user intervention.

[0119] As used herein, the terms "provide" or "providing" encompass a wide variety of actions. For example, "providing" may include storing a value in a location of a storage device for subsequent retrieval, transmitting a value directly to the recipient via at least one wired or wireless communication medium, transmitting or storing a reference to a value, and the like. "Providing" may also include encoding, decoding, encrypting, decrypting, validating, verifying, and the like via a hardware element.

[0120] As used herein, the term "message" encompasses a wide variety of formats for communicating (e.g., transmitting or receiving) information. A message may include a machine readable aggregation of information such as an XML document, fixed field message, comma separated message, JSON, a custom protocol, or the like. A message may, in some implementations, include a signal utilized to transmit one or more representations of the information. While recited in the singular, it will be understood that a message may be composed, transmitted, stored, received, etc. in multiple parts.

[0121] As used herein, the term "selectively" or "selective" may encompass a wide variety of actions. For example, a "selective" process may include determining one option from multiple options. A "selective" process may include one or more of: dynamically determined inputs, preconfigured inputs, or user-initiated inputs for making the determination. In some implementations, an n-input switch may be included to provide selective functionality where n is the number of inputs used to make the selection.

[0122] As user herein, the terms "correspond" or "corresponding" encompasses a structural, functional, quantitative and/or qualitative correlation or relationship between two or more objects, data sets, information and/or the like, preferably where the correspondence or relationship may be used to translate one or more of the two or more objects, data sets, information and/or the like so to appear to be the same or equal. Correspondence may be assessed using one or more of a threshold, a value range, fuzzy logic, pattern matching, a machine learning assessment model, or combinations thereof.

[0123] In any embodiment, data generated or detected can be forwarded to a "remote" device or location, where "remote," means a location or device other than the location or device at which the program is executed. For example, a remote location could be another location (e.g., office, lab, etc.) in the same city, another location in a different city, another location in a different state, another location in a different country, etc. As such, when one item is indicated as being "remote" from another, what is meant is that the two items can be in the same room but separated, or at least in different rooms or different buildings, and can be at least one mile, ten miles, or at least one hundred miles apart. "Communicating" information references transmitting the data representing that information as electrical signals over a suitable communication channel (e.g., a private or public network). "Forwarding" an item refers to any means of getting that item from one location to the next, whether by physically transporting that item or otherwise (where that is possible) and includes, at least in the case of data, physically transporting a medium carrying the data or communicating the data. Examples of communicating media include radio or infra-red transmission channels as well as a network connection to another computer or networked device, and the internet or including email transmissions and information recorded on websites and the like.

What is claimed is:

1. An infusion system comprising:

a receptacle for receiving a syringe, the syringe comprising a barrel and a plunger;

a drive head for advancing the plunger within the barrel;

two or more sensors positioned on the drive head and configured to generate sensor measurements pertaining to an alignment of the plunger with respect to the drive head; and

a processor configured to:

receive an indication that the syringe was loaded into the receptacle;

obtain, from the two or more sensors, the sensor measurements pertaining to the alignment of the plunger with respect to the drive head;

determine whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements; and

provide an indication of the alignment on a display device and terminate the advancing of the plunger when the alignment deviates from the acceptable alignment.

2. The infusion system of Claim 1, wherein the plunger is configured to be driven into the barrel of the syringe by way of force on a push button end of the plunger, wherein the infusion system further comprises:

the two or more sensors being positioned on the drive head between the drive head and the push button end, wherein the processor is further configured to determine the alignment based on comparing pressure readings from the two or more sensors.

3. The infusion system of Claim 2, wherein the drive head comprises:

a retainer for preventing movement of the push button end of the plunger while the plunger is driven into the barrel; and

a contact plate positioned between the sensors and the push button end, the contact plate in contact with the push button end of the plunger when the push button end is prevented from moving by the retainer, the contact plate distributing, between the sensors, an opposing force of the plunger being driven into the barrel when the plunger is advanced within the barrel by the drive head,

wherein the processor is further configured to determine whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on a measured distribution or ratio between the sensors of the opposing force on the contact plate.

4. The infusion system of Claim 2 or Claim 3, wherein the processor is further configured to:

receive a type of the syringe; and

determine whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on the measured distribution and the type of the syringe.

5. The infusion system of Claim 4, wherein the processor is further configured to:

determine a center location associated with the push button end, between the two or more sensors on the drive head, based on the type of the syringe; and

detect the alignment based on determining whether the push button end is centered on a location on the drive head between the two or more sensors.

6. The infusion system any one of Claims 2 through 5, wherein the two or more sensors comprises only two pressure sensors.

7. The infusion system of any one of Claims 1 through 6, wherein the processor is further configured to:

cause the drive head to advance the plunger within the barrel; and

as the drive head advances the plunger within the barrel, periodically obtain sensor measurements pertaining to the alignment of the plunger with respect to the drive head.

8. The infusion system of Claim 7, wherein the processor is further configured to:

as the drive head advances the plunger within the barrel, periodically update the indication of the alignment on the display device.

9. A machine-implemented method, comprising:

receiving an indication that a syringe was loaded into a receptacle of a syringe pump, the syringe pump comprising a drive head configured to advance a plunger of the syringe into a barrel of the syringe to infuse a fluid;

obtaining, from one or more sensors of the drive head, sensor measurements pertaining to the alignment of the plunger, within the receptacle, with respect to the drive head;

determining whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements; and

providing an indication of the alignment on a display device and terminate the advancing of the plunger when the alignment deviates from the acceptable alignment.

10. The machine-implemented method of Claim 9, further comprising:

determining the alignment based on comparing pressure readings from two or more sensors positioned on the drive head between the drive head and a push button end of the plunger.

11. The machine-implemented method of Claim 10, further comprising:

receiving a type of the syringe; and

determining whether the alignment of the drive head with respect to the plunger deviates from an acceptable alignment based on the sensor measurements and the type of the syringe.

12. The machine-implemented method of Claim 11, further comprising:

determining a center location associated with the push button end, between the two or more sensors on the drive head, based on the type of the syringe; and

detecting the alignment based on determining whether the push button end is centered on a location on the drive head between the two or more sensors

13. The machine-implemented method of any one of Claims 9 through 12, wherein the processor is further configured to:

causing the drive head to advance the plunger within the barrel; and

as the drive head advances the plunger within the barrel, periodically obtaining sensor measurements pertaining to the alignment of the plunger with respect to the drive head.

14. The machine-implemented method of Claim 13, further comprising:

as the drive head advances the plunger within the barrel, periodically updating the indication of the alignment on the display device.

15. A non-transitory machine-readable storage medium embodying instructions that when executed by a machine, facilitate the machine to perform the method of any one of Claims 9-14.

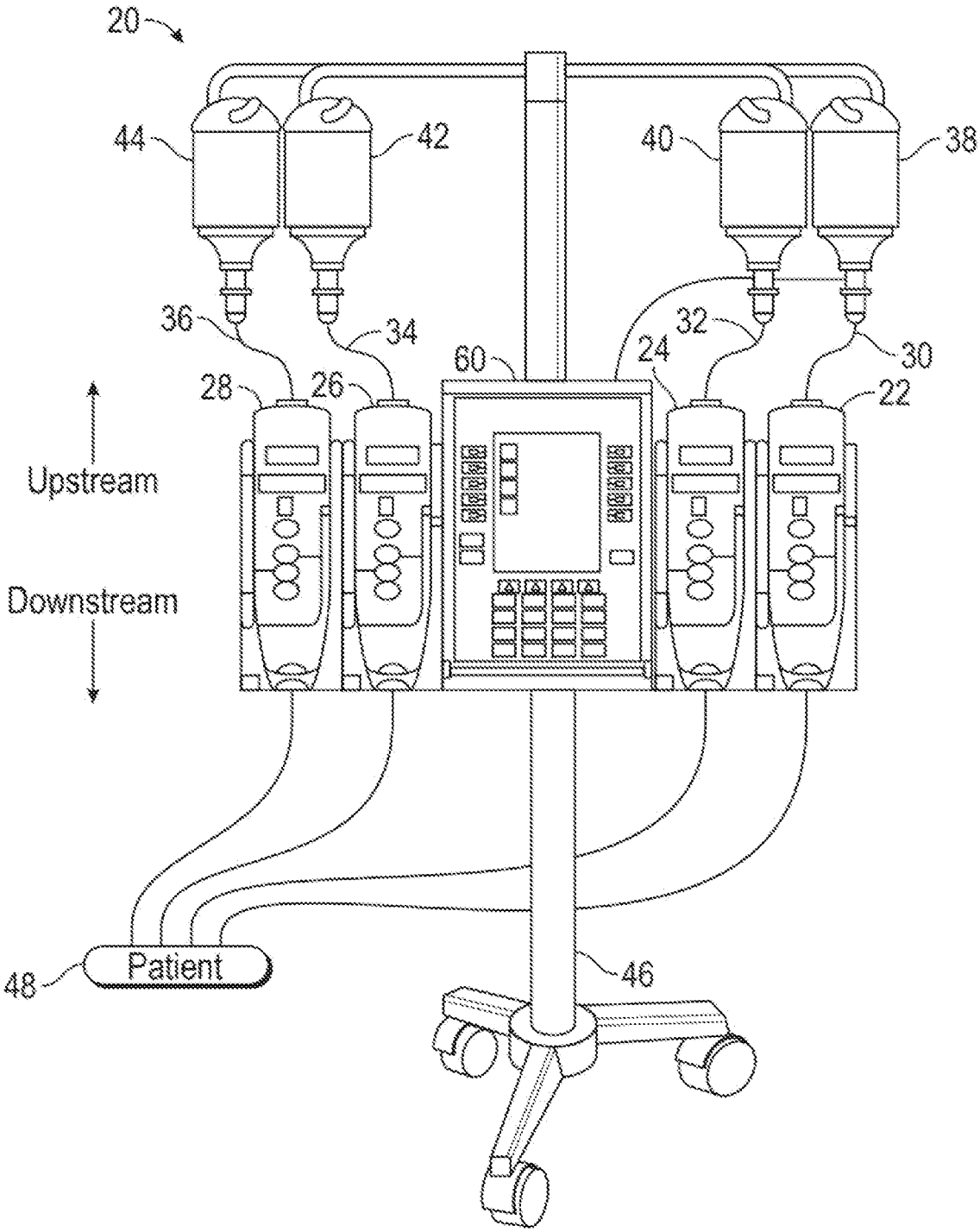
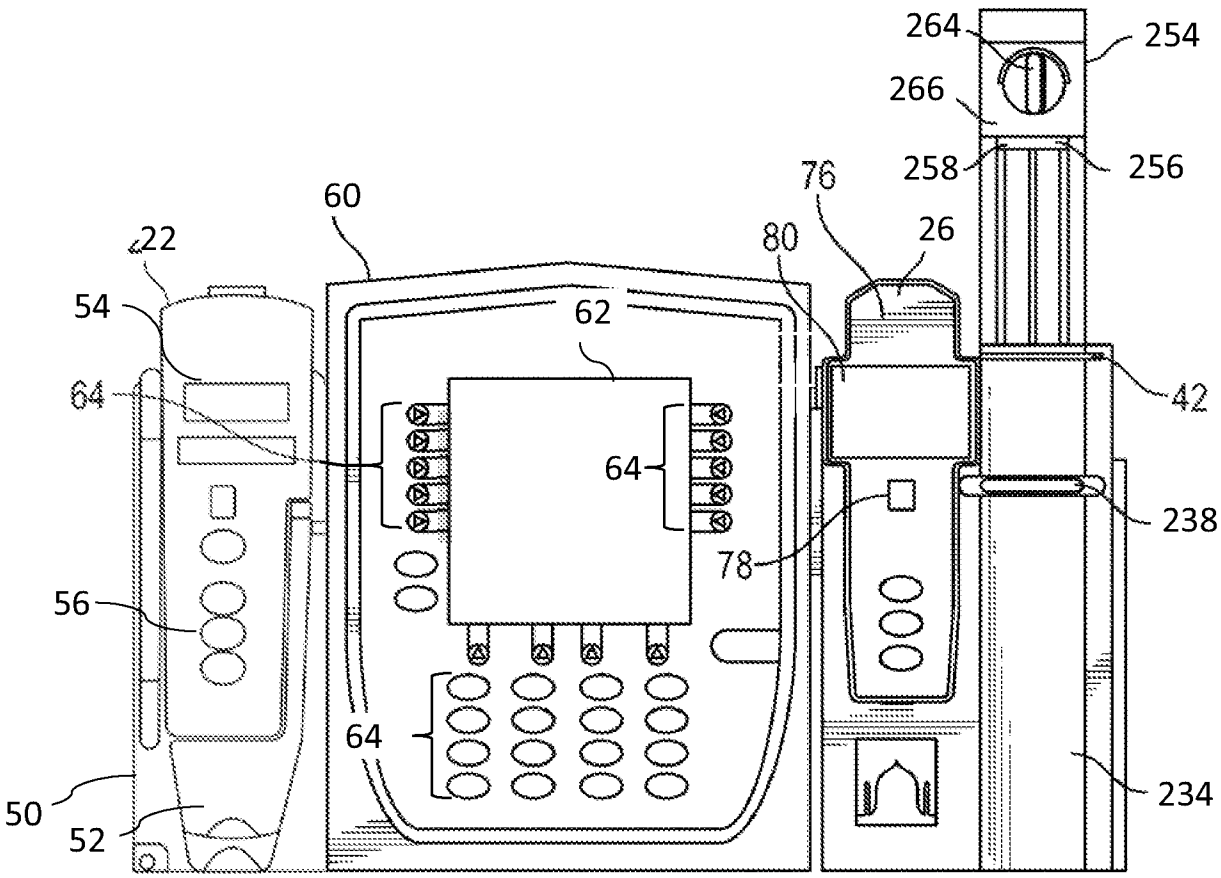

20
44
42
40
38
36
34
60
32
24
30
28
26
22
Upstream
Downstream
48
Patient
46

FIG. 1A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76
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80
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22
54
62
64
42
64
238
78
56
64
50
234
52

FIG. 1B

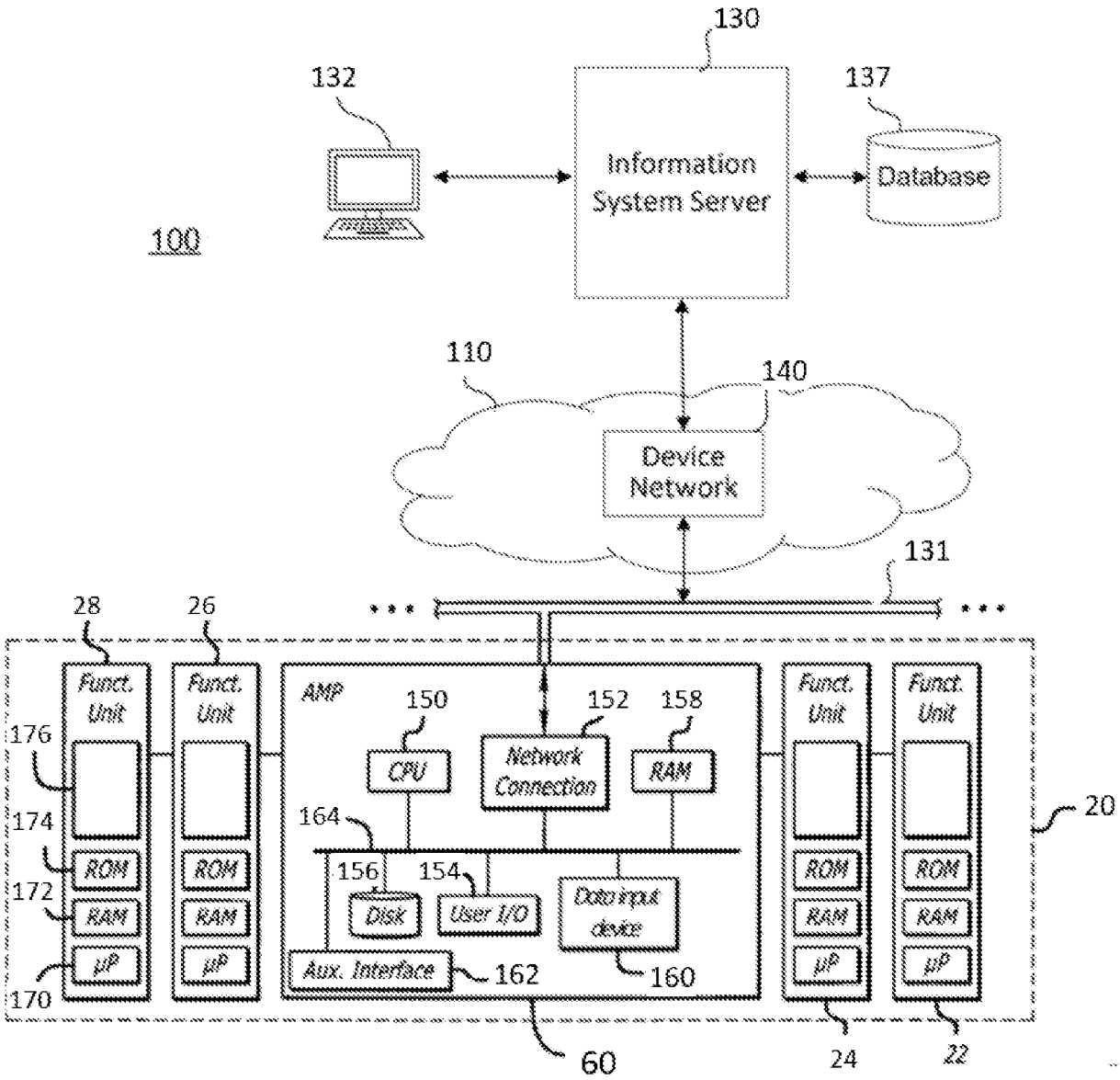
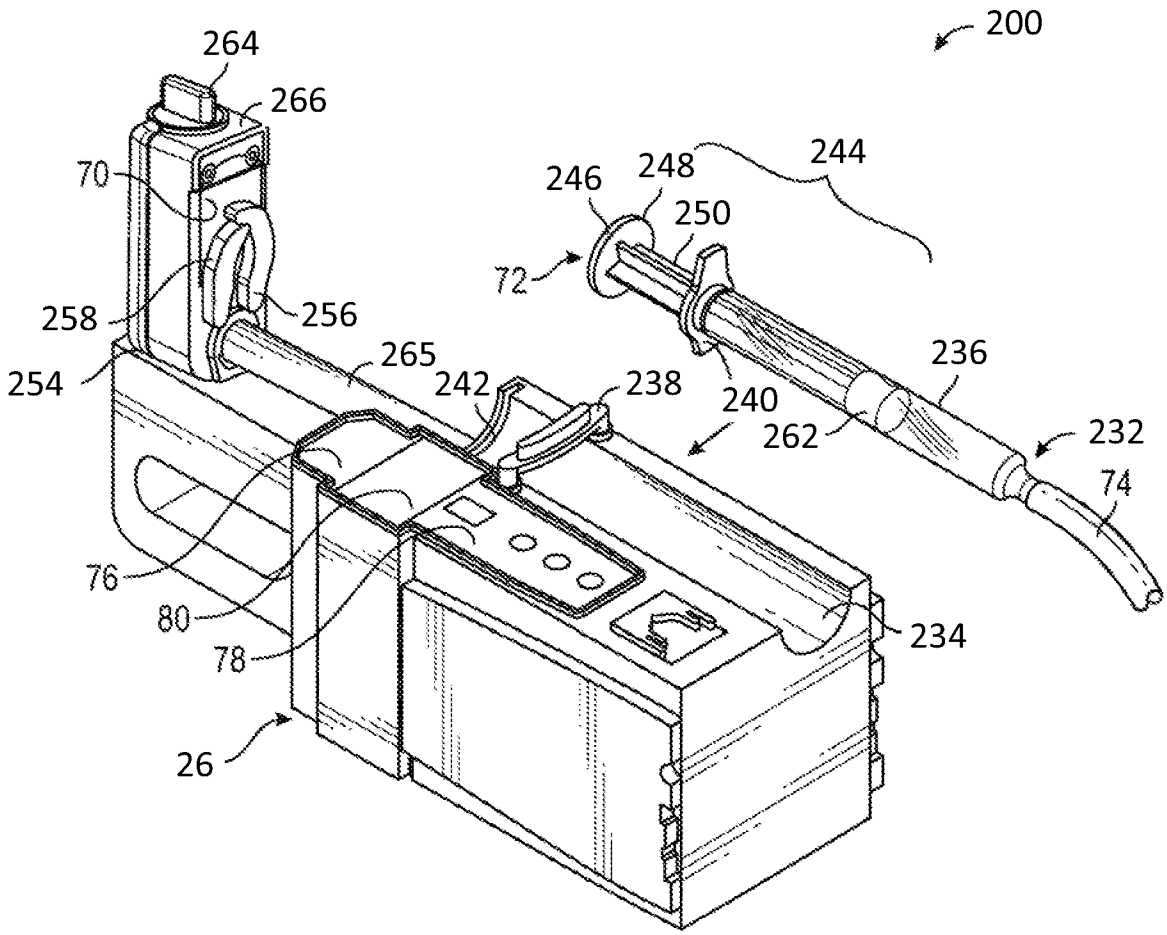

130
132
137
Information System Server
Database
100
110
140
Device Network
131
28
26
Funct. Unit
Funct. Unit
AMP
150
152
158
CPU
Network Connection
RAM
176
174
164
ROM
156
154
172
RAM
Disk
User I/O
Data input device
μP
Aux. Interface
162
160
170
20
60
24
22

FIG. 1C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246
248
244
250
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265
254
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232
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78
234
26

FIG. 2A

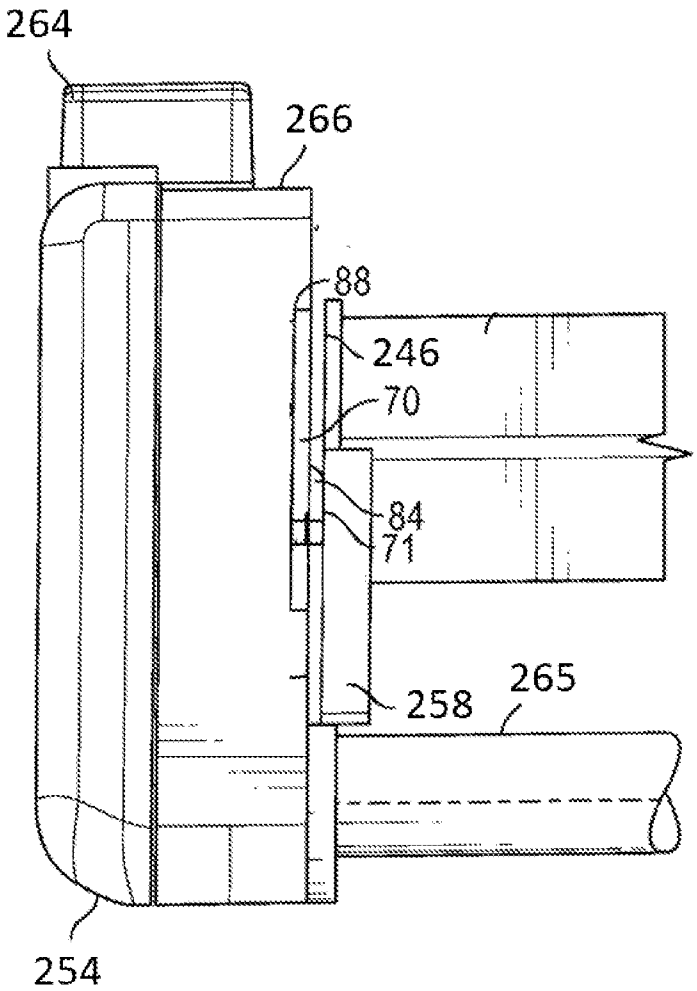


FIG. 2B

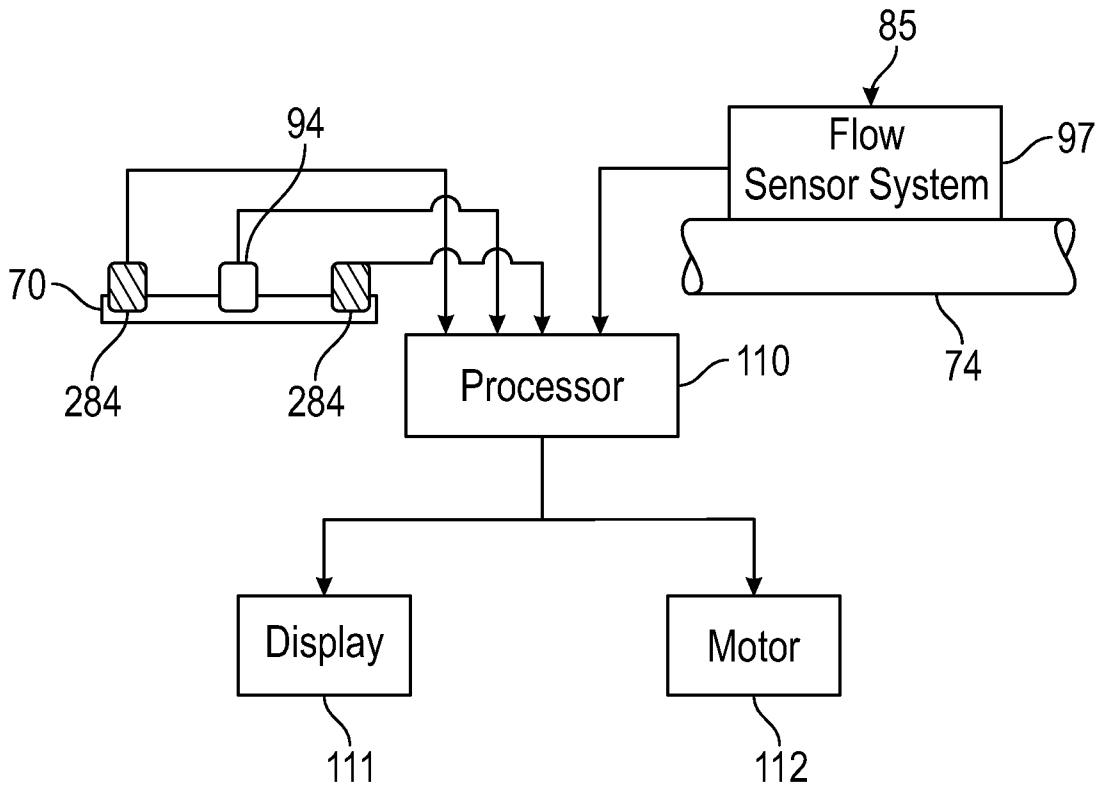
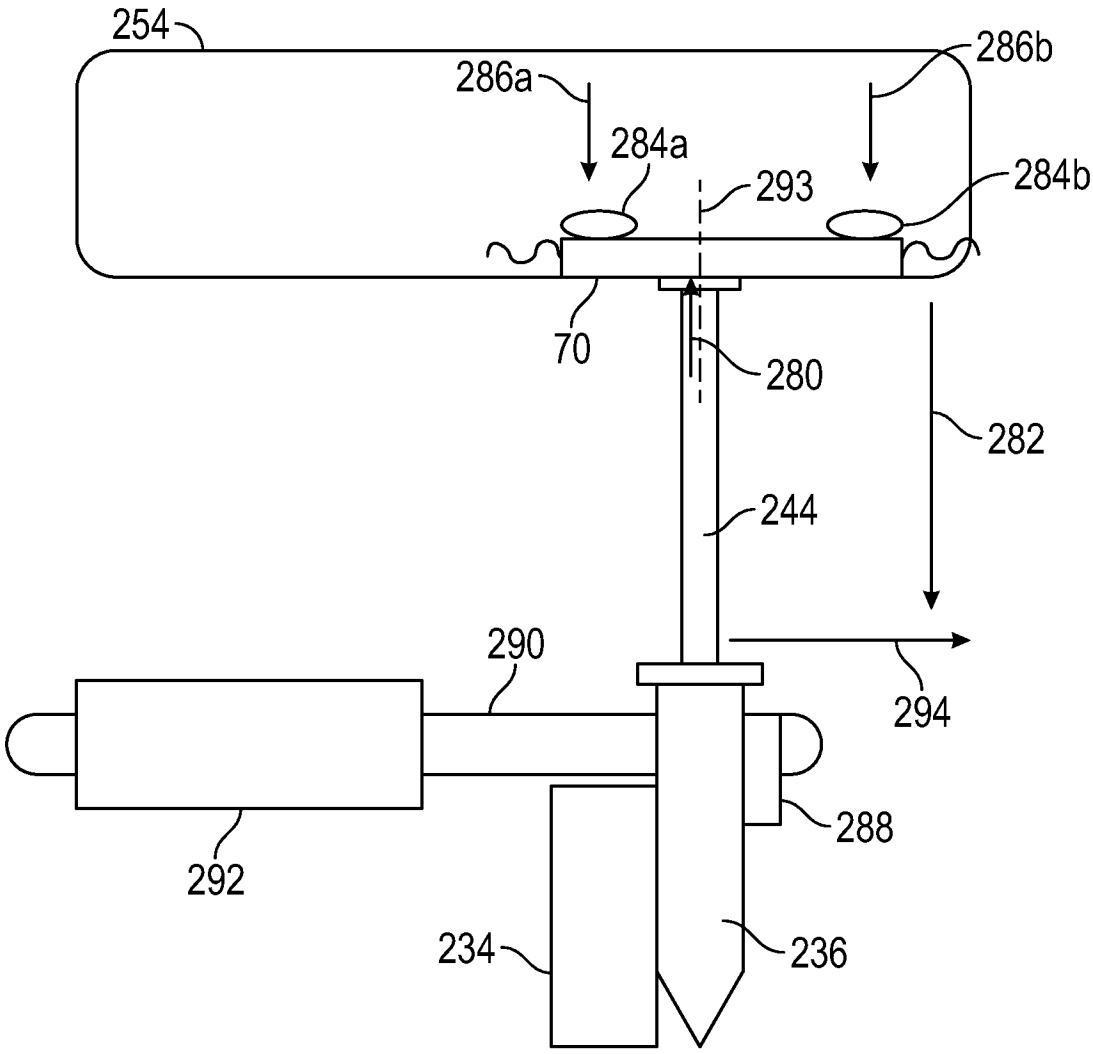

85
94
Flow
Sensor System
97
70
284
284
Processor
110
74
Display
Motor
111
112

FIG. 3


254
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286b
284a
293
284b
70
280
282
244
290
294
288
292
234
236

FIG. 4

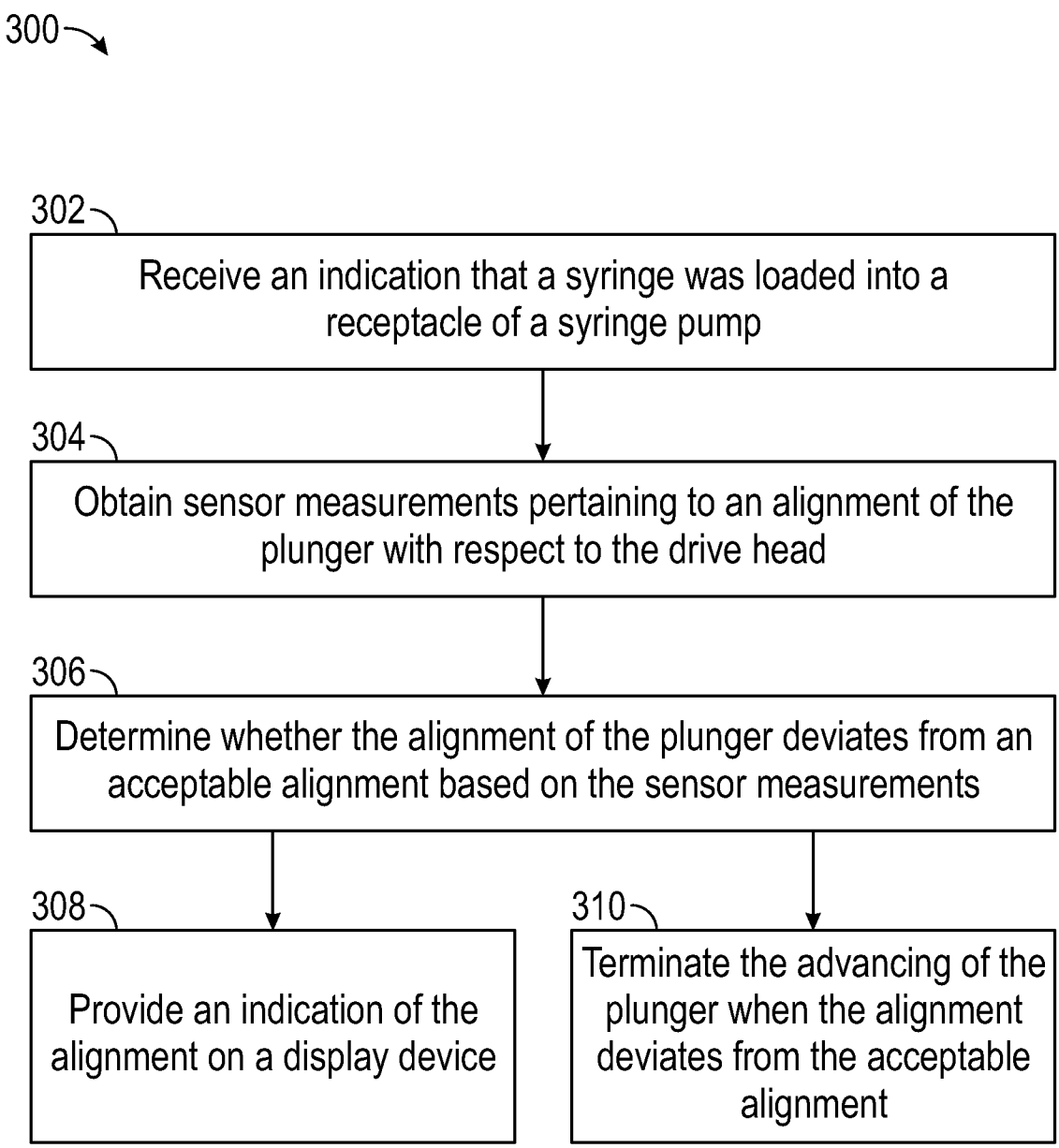
300
302
Receive an indication that a syringe was loaded into a receptacle of a syringe pump
304
Obtain sensor measurements pertaining to an alignment of the plunger with respect to the drive head
306
Determine whether the alignment of the plunger deviates from an acceptable alignment based on the sensor measurements
308
Provide an indication of the alignment on a display device
310
Terminate the advancing of the plunger when the alignment deviates from the acceptable alignment

FIG. 5

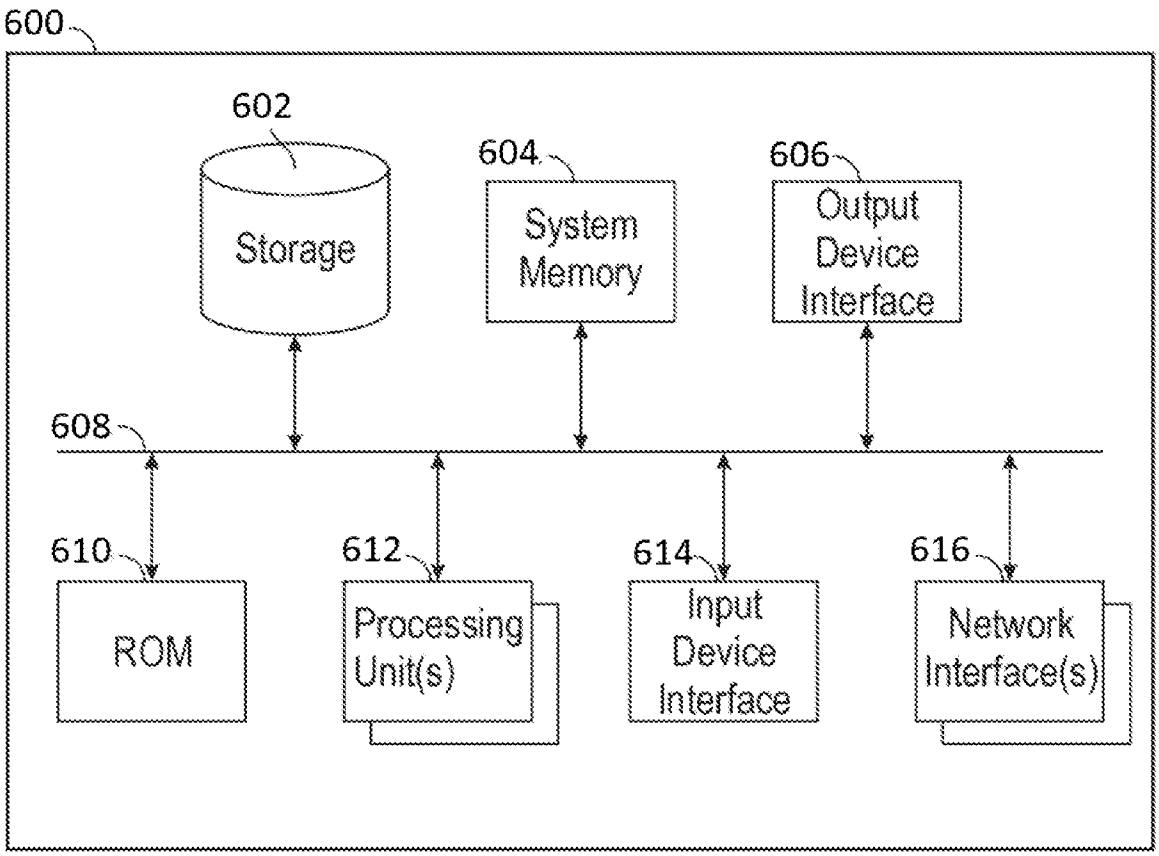
600
602
Storage
604
System Memory
606
Output Device Interface
608
610
ROM
612
Processing Unit(s)
614
Input Device Interface
616
Network Interface(s)

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/013729

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61M5/145 A61M5/168 A61M5/172 A61M5/142
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 3 622 983 A1 (DEKA PRODUCTS LP [US]) 18 March 2020 (2020-03-18) figures 1, 2, 14, 15, 16, 59B-J, 60, 61, 62, 83-148 paragraphs [0174] - [0204], [0348] - [0376], [0473] - [0601], [0602] - [0639], [0640] - [0671] -----	1-8
A	US 2019/351131 A1 (BUTTERFIELD ROBERT DWAINE [US] ET AL) 21 November 2019 (2019-11-21) the whole document -----	1-8
A	EP 0 589 328 A2 (BECTON DICKINSON CO [US]) 30 March 1994 (1994-03-30) the whole document -----	1-8

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

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 August 2023	23/08/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Benes, Václav

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2023/013729

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

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

1. [X] Claims Nos.: 9-15
because they relate to subject matter not required to be searched by this Authority, namely:
see FURTHER INFORMATION sheet PCT/ISA/210

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.1

Claims Nos.: 9-15

The subject-matter of independent method claim 9 explicitly comprises the step of "termination of the advancing of the plunger", therefore the method directly affects the therapy, i.e. the infusion of the medicament into the patient. Claim 9 and its dependent claims 10-15 are therefore not allowable under Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2023/013729

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3622983 A1	18-03-2020	EP 3107601 A1	28-12-2016
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		EP 0589328 A2	30-03-1994
		JP 2610385 B2	14-05-1997
		JP H06190037 A	12-07-1994
		US 5254096 A	19-10-1993