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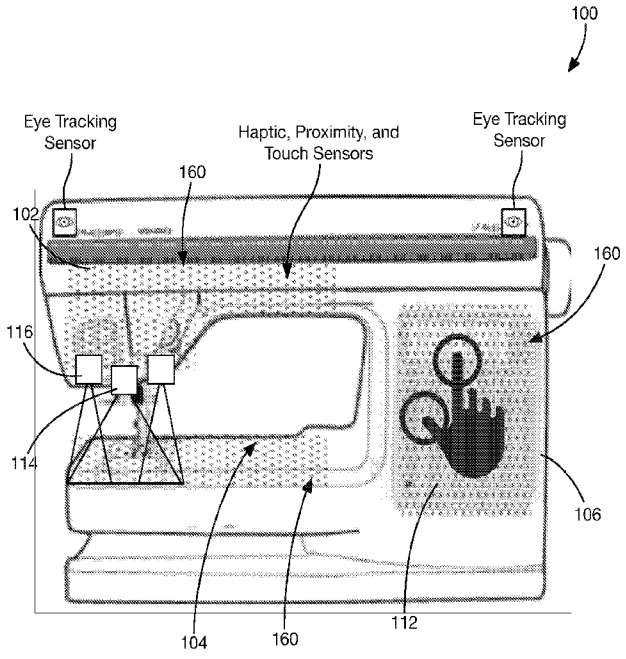
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(54) Title: SEWING MACHINE AND METHODS OF USING THE SAME



(57) Abstract: An exemplary sewing machine includes a sewing head, a needle bar holding a needle, a motor for moving the needle during a sewing operation, a user interface, a data gathering device, a data storage device, and a processor. The data gathering device gathers data related to at least one of the sewing machine, an environment surrounding the sewing machine, a sewing material, the sewing operation performed by the sewing machine, and one or more interactions of a user with the sewing machine. The data storage device stores gathered data and data related to a neural network. The processor processes the gathered data through the neural network to generate processed data. Based on the processed data, the processor controls at least one of the user interface, the data storage device, and the motor.

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SEWING MACHINE AND METHODS OF USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is related to and claims any benefit of U.S. Provisional Application Serial No. 63/041204, filed on June 19, 2020, titled SEWING MACHINE AND METHODS OF USING THE SAME, and U.S. Provisional Application Serial No. 63/175035, filed on April 14, 2021, titled SEWING MACHINE AND METHODS OF USING THE SAME, the disclosures of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

[0002] The present invention relates generally to sewing machines, and in particular to control systems thereof.

BACKGROUND OF THE INVENTION

[0003] Sewing machines can be used to form stitches in a single piece of material and to stitch together various pieces of material. Particular sewing machines can be used to form stitches in workpieces having a certain shape, cut and stitch over the edge of a workpiece, attach decorative elements to a workpiece, and cut and hem an edge of a workpiece, attach decorative sew an embroidery pattern on a workpiece that is mounted in an embroidery frame or to cut the workpiece during the sewing operation. A sewing machine can also cut, fold, roll, or otherwise manipulate the workpiece in addition to or separate from the sewing procedure. The workpiece is moved underneath the needle so that stitches can be formed in the fabric. The user configures the sewing machine for each particular application by adjusting various parameters of the machine and by attaching a variety of different tools or accessories to the machine.

SUMMARY

[0004] Exemplary embodiments of sewing machines, control systems for the same, and methods of using the same are disclosed herein.

[0005] An exemplary sewing machine includes a sewing head attached to an arm suspended above a sewing bed by a pillar, a needle bar extending from the sewing head and toward the sewing bed, a needle held by the needle bar, a motor connected to the needle bar for moving the needle bar in a reciprocating motion to move the needle and a thread through a workpiece during a sewing operation, and a user interface for receiving instructions from the user of the sewing machine and for giving feedback information to the user. The exemplary sewing machine also includes a data gathering device, a data storage device, and a processor. The data gathering device is for gathering data related to at least one of the sewing machine, an environment surrounding the sewing machine, a sewing material, the sewing operation performed by the sewing machine, and one or more interactions of the user with the sewing machine. The data storage device is for storing data gathered by the data gathering device as gathered data and for storing data related to a neural network. The neural network is made up of a plurality of nodes. Each node of the neural network has an input connection for receiving input data, a node parameter, a calculation unit for calculating an activation function based on the input data and a node parameter, and an output connection for transmitting output data. The processor is configured to processes the gathered data through the neural network to generate processed data and to control, based on the processed data, at least one of the user interface to interact with the user, the data storage device to store the processed data, and the motor to alter the sewing operation.

[0006] An exemplary method of controlling a sewing machine includes the steps of: gathering data, storing the gathered data in data storage device, processing the gathered data through a neural network, and controlling a user interface, the data storage device, and the motor based on the processed data. The step of gathering data includes gathering data related to at least one of the sewing

machine, an environment surrounding the sewing machine, a sewing material, a sewing operation performed by the sewing machine, and one or more interactions of a user with the sewing machine. The neural network in the processing step has a plurality of nodes, wherein each node includes an input connection for receiving input data, a node parameter, a calculation unit for calculating an activation function based on the input data and a node parameter, and an output connection for transmitting output data. During the controlling step, the processor controls the user interface to interact with the user, the data storage device to store the processed data, and/or the motor to alter the sewing operation.

[0007] An exemplary control system for a sewing machine includes a data gathering device, a data storage device, and a processor. The data gathering device is for gathering data related to at least one of the sewing machine, an environment surrounding the sewing machine, a sewing material, the sewing operation performed by the sewing machine, and one or more interactions of the user with the sewing machine. The data storage device is for storing data gathered by the data gathering device as gathered data and for storing data related to a neural network. The neural network is made up of a plurality of nodes. Each node of the neural network has an input connection for receiving input data, a node parameter, a calculation unit for calculating an activation function based on the input data and a node parameter, and an output connection for transmitting output data. The processor is configured to processes the gathered data through the neural network to generate processed data, store processed data in the data storage device, and control, based on the processed data, at least one of a user interface to interact with the user and a motor to alter the sewing operation.

[0008] A further understanding of the nature and advantages of the present invention are set forth in the following description and claims, particularly when considered in conjunction with the accompanying drawings in which like parts bear like reference numerals.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] To further clarify various aspects of embodiments of the present disclosure, a more particular description of the certain embodiments will be made by reference to various aspects of the appended drawings. It is appreciated that these drawings depict only typical embodiments of the present disclosure and are therefore not to be considered limiting of the scope of the disclosure. Moreover, while the figures can be drawn to scale for some embodiments, the figures are not necessarily drawn to scale for all embodiments. Embodiments and other features and advantages of the present disclosure will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0010] Figures 1–18 show various views and diagrams relating to an exemplary sewing machine and the systems thereof;

[0011] Figures 19–23 show diagrams and flowcharts related to artificial intelligence and neural networks;

[0012] Figures 24–33 show various views relating to stitch regulation of an exemplary sewing machine;

[0013] Figures 34–39 show diagrams of various machine vision techniques;

[0014] Figures 40–42 show various views relating to an exemplary sewing projection feature of an exemplary sewing machine;

[0015] Figures 43–65 show various views relating to an exemplary fabric and thread compatibility monitoring feature of an exemplary sewing machine;

[0016] Figures 66–70 show various views relating to an exemplary thread quality monitoring feature of an exemplary sewing machine;

[0017] Figures 71–81 show various views relating to an exemplary object recognition feature of an exemplary sewing machine;

[0018] Figures 82–84 show various views relating to an exemplary tactile feedback feature of an exemplary sewing machine; and

[0019] Figures 85–88 show various views relating to an exemplary machine diagnostics feature of an exemplary sewing machine.

[0020] Figure 89 shows a cross-sectional view of an exemplary thread sensor;

[0021] Figure 90 shows a perspective view of an exemplary sewing machine;

[0022] Figure 91 shows a front view of the sewing machine of Figure 90;

[0023] Figure 92 shows a bottom–left–front perspective view of the sewing machine of Figure 90;

[0024] Figure 93 shows a bottom–left–rear perspective view of the sewing machine of Figure 90;

[0025] Figure 94 shows a detail view of the area 92 of Figure 92;

[0026] Figure 95 shows a detail view of the area 93 of Figure 93;

[0027] Figure 96 shows an exemplary process for controlling a sewing machine; and

[0028] Figures 97–109 show flow charts detailing the operation of an exemplary sewing machine.

DETAILED DESCRIPTION

[0029] The following description refers to the accompanying drawings, which illustrate specific embodiments of the present disclosure. Other embodiments having a different structure and operation do not depart from the scope of the present disclosure. Exemplary embodiments of the present disclosure are directed to sewing machines and accessories for use with the same.

[0030] As described herein, when one or more components are described as being connected, joined, affixed, coupled, attached, or otherwise interconnected, such interconnection may be direct as between the components or may be indirect such as through the use of one or more intermediary components. Also as described herein, reference to a "member," "component," or "portion" shall not be limited to a single structural member, component, or element but can include an assembly of components, members, or elements. Also as described herein, the terms "substantially" and "about" are defined as at least close to (and includes) a given value or state (preferably within 10% of, more preferably within 1% of, and most preferably within 0.1% of).

[0031] Referring now to Figures 1–18 and 90–95, various views and diagrams of exemplary sewing machines and portions thereof are shown. An exemplary sewing machine, such as the sewing machine 100 shown in Figure 1, includes a sewing bed or base 104 having a pillar 106 extending upward from one end to support an arm that extends horizontally above the sewing bed. A sewing head 102 is attached to the end of the arm and can include one or more needle bars 108 for moving one or more needles 110 up and down for sewing a workpiece on the sewing bed 104 below the

sewing head 102. The sewing bed includes a needle or stitch plate arranged below the sewing head that has openings for the needle or needles 110 to pass through when making or forming stitches in the workpiece. In some sewing machines, a bobbin arranged beneath the needle plate assists in stitch formation and dispenses a lower thread that is stitched together with an upper thread delivered through the workpiece from above by the needle. In other sewing machines, such as, for example, an overlock or serger machine, lower threads are dispensed by loopers. The user can interact with the sewing machine 100 via a wide variety of buttons, knobs, switches, and other user interface elements. A touch-screen display 112 can also be used to both present a software-based user interface to the user and to receive input from the user. A projector 114 arranged in the sewing head 102 can be used to project one or more user interface elements onto the sewing bed 104 or a workpiece placed thereon. One or more cameras 116 arranged in the sewing head 102 or elsewhere around the sewing machine 100 gather information from the workpiece and environment surrounding the sewing machine 100 that can be used to enhance the performance and user experience of the sewing machine 100.

[0032] As used herein, "sewing machine" means a device that forms one or more stitches in a workpiece with a reciprocating needle and a length of thread. "Sewing machine" as used herein includes, but is not limited to, sewing machines for forming particular stitches (e.g., a sewing machine configured to form a lock-stitch, a chain stitch, a buttonhole stitch), embroidery machines, quilting machines, overlock or serger machines, or the like. It should be noted that various embodiments of sewing machines and accessories are disclosed herein, and any combination of these options can be made unless specifically excluded. In other words, individual components or portions of the disclosed devices can be

combined unless mutually exclusive or otherwise physically impossible.

[0033] A "stitch" means a loop formed with one or more threads, wherein at least one of thread passes through a hole formed in a workpiece. The mechanical components of the sewing machine—e.g., needles, hooks, loopers, thread tensioning devices, feed mechanisms, and the like—cooperate to form stitches in one or more pieces of a workpiece. One repetition of this complex mechanical dance can form one stitch or a pattern of stitches in the workpiece. A "stitch length" of the repetition or pattern refers to a distance that the workpiece is moved as the repetition is performed. The stitch length measurement is different for different types of repetitions and patterns and can encompass one or more stitches in the workpiece.

[0034] A presser bar with a presser foot also extends downward from the sewing head to press the workpiece against the sewing bed and against feed dogs that move from back-to-front and optionally side-to-side to move the workpiece. The feed dogs move the workpiece in coordination with the presser foot and with a speed that can be fixed or can be variably controlled by the user, such as with a foot pedal. A wide variety of presser feet and other types of accessories can be attached to the presser bar to assist in the formation of certain kinds of stitches or features in the workpiece, such as, for example, a buttonhole presser foot. An accessory mount can also extend below the sewing head for holding a special tool or accessory on or above the sewing bed.

[0035] The speed or frequency with which the needle bar is moved up and down is controlled by the user as noted above. While the needle bar typically moves up and down in a cyclical motion to form a stitch in the workpiece, the needle bar can also be moved simultaneously from side-to-side to form a different stitch, such as

a zig-zag stitch or a tapered stitch, or to alter the width of a stitch. The type and pitch of the stitch performed by the machine can be selected by the user via a manual interface including buttons, knobs, levers, or the like, via a user interface presented on a touch screen by a computer, or via a voice control interface.

[0036] Different types of sewing machines can include additional components for forming stitches in or otherwise manipulating the workpiece during the sewing process. For example, in a serger, a type of sewing machine that can be used for forming edges of a workpiece, among other functions, needles called loopers operate below the sewing bed to deliver lower threads for forming various stitches. A serger can also include two, three, or more needles above the needle plate and a knife for cutting the edge of the workpiece. A sewing machine can also be used to create embroidery patterns in a workpiece by including a holder for an embroidery hoop on the sewing bed (e.g., Figure 6). The embroidery hoop holder can be actuated in at least two axes so that a controller of the sewing machine can cause the embroidery frame to be moved so that the needle traces out an embroidery pattern on the workpiece.

[0037] Thread used during sewing is held in various locations on the sewing machine, such as, for example, inside the bobbin (Figures 13–15) or on a spool held by a spool holder that is part of or extends above the arm of the sewing machine (Figures 10–12). Thread is led from the thread source (e.g., a bobbin or spool) and to the needle or needles of the sewing machine through various other elements of the sewing machine arranged to change the direction of the thread so that the thread is smoothly withdrawn and delivered to the workpiece with as little damage to the thread as possible (Figures 7–9). The tension of the thread can also be altered by various tensioning devices arranged along the thread path or within the thread source. Thread tensioning devices and

portioning devices ensure that only a desired amount of thread is dispensed and that the thread forming stitches in the workpiece is appropriately tightened. Loose threads can allow stitches to come undone and tight threads can cause stitches to be formed incorrectly. The thread tension on the upper and lower threads can also be adjusted to ensure that tension forces are balanced from above and below so that stitches are properly formed along the desired sewing path in the workpiece.

[0038] Referring now to Figure 16, a block diagram of the computer-based control system for the sewing machine 100 is shown. The sewing machine includes: one or more data gathering devices 118, one or more data storage devices 120, a processor 122, a user interface 124, and motors and actuators 126. The sewing machine 100 can also include a network interface that interfaces with the processor 122 and is used to connect the sewing machine 100 to a cloud system and/or other sewing machines or devices via a wireless network. The data gathering devices 118 include a wide variety of digital sensors, analog sensors, active sensors, passive sensors, and software components, as are described in greater detail below. These sensors gather data related to the sewing machine itself, the workspace or environment surrounding the sewing machine, the sewing operation being performed by the sewing machine, the interaction of the user with the sewing machine, and the sewing material operated on by the sewing machine (e.g., fabric and thread). The data storage devices 120 include one or more computer memory chips for storing data gathered by the data gathering devices 118 and the operating software of the sewing machine 100. The structure, various functions, and parameters of one or more neural networks 128 is also be stored by the data storage devices 120. The processor 122 accesses the data stored on the data storage devices 120 and executes the operating software to give function to the sewing machine 100. The user interface 124 is presented to the user via

the touch screen display 112 and via physical controls such as buttons, levers, dials, lights, speakers, actuators, and the like. The motors and actuators 126 include electro-mechanical actuators, motors, general mechanical components that are controlled by the control system to cause the movement of the various moving parts of the sewing machine—i.e., the needle bars, feed dogs, bobbin, loopers, and the like. For example, the speed of the motors can be controlled directly by input from a foot pedal that is actuated by the user or can be controlled via the computer that receives and interprets the foot pedal input before sending a signal to one or more motor controllers that control the motors of the sewing machine.

[0039] "Computer" or "processor" as used herein includes, but is not limited to, any programmed or programmable electronic device or coordinated devices that can store, retrieve, and process data and may be a processing unit or in a distributed processing configuration. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), floating point units (FPUs), reduced instruction set computing (RISC) processors, digital signal processors (DSPs), field programmable gate arrays (FPGAs), etc. One or more cores of a single microprocessor and/or multiple microprocessor each having one or more cores can be used to perform the operations described as being executed by a processor herein. The processor can also be a processor dedicated to the training of neural networks and other artificial intelligence (AI) systems. The processor or processors can be locally installed on the sewing machine and can be provided in a remote location that can be accessed via a network interface.

[0040] "Network interface" or "data interface" as used herein includes, but is not limited to, any interface or protocol for transmitting and receiving data between electronic devices. The network or

data interface can refer to a connection to a computer via a local network or through the internet and can also refer to a connection to a portable device—e.g., a mobile device or a USB thumb drive—via a wired or wireless connection. A network interface can be used to form networks of computers to facilitate distributed and/or remote computing (i.e., cloud-based computing). "Cloud-based computing" means computing that is implemented on a network of computing devices that are remotely connected to the sewing machine via a network interface.

[0041] "Logic," synonymous with "circuit" as used herein includes, but is not limited to, hardware, firmware, software and/or combinations of each to perform one or more functions or actions. For example, based on a desired application or needs, logic may include a software-controlled processor, discrete logic such as an application specific integrated circuit (ASIC), programmed logic device, or other processor. Logic may also be fully embodied as software. "Software," as used herein, includes but is not limited to one or more computer readable and/or executable instructions that cause a processor or other electronic device to perform functions, actions, processes, and/or behave in a desired manner. The instructions may be embodied in various forms such as routines, algorithms, modules, or programs including separate applications or code from dynamically linked libraries (DLLs). Software may also be implemented in various forms such as a stand-alone program, a web-based program, a function call, a subroutine, a servlet, an application, an app, an applet (e.g., a Java applet), a plug-in, instructions stored in a memory, part of an operating system, or other type of executable instructions or interpreted instructions from which executable instructions are created.

[0042] As used herein, "data storage device" means a device or devices for non-transitory storage of code or data, e.g., a device with a non-transitory computer readable medium. As used herein, "non-

transitory computer readable medium" mean any suitable non-transitory computer readable medium for storing code or data, such as a magnetic medium, e.g., fixed disks in external hard drives, fixed disks in internal hard drives, and flexible disks; an optical medium, e.g., CD disk, DVD disk, and other media, e.g., ROM, PROM, EPROM, EEPROM, flash PROM, external flash memory drives, etc.

[0043] The user interface of the sewing machine can include a wide variety of input devices and means of communicating with the user, such as, for example, buttons, knobs, switches, lights, displays, speakers, touch interfaces, and the light. The user interface for the sewing machine can be presented graphically to the user via one or more displays, including the touch-screen display 112 that includes a touch sensitive overlay to detect the location of the fingers of the user that are touching the display. Thus, the user can interact with the user interface by directly touching the screen in particular locations and by performing touch gestures, such as the touch, touch and hold, pinch or spread, and touch and move gestures shown in Figure 2. The presence, position, and movement of the hands, fingers, or eyes of the user can also be detected via analysis of data from an optical sensor (e.g., a camera) or a proximity sensor (e.g., Figure 3) via disturbances of sound, light, infrared radiation, or electromagnetic fields. A graphical user interface can also be projected by one or more projectors of the sewing machine onto the sewing bed 104, a workpiece, an adjacent surface such as a wall or a table, or any other suitable surface. Alternatively, the sewing machine 100 can be operated without a graphical user interface via voice commands and audible feedback in the form of certain sounds and/or a computerized voice. Tactile feedback can also be provided via actuators that cause various portions of the machine to vibrate when acted upon or in response to a wide variety of conditions of the workpiece, machine, or the like.

Audible and tactile interaction with the sewing machine is particularly useful to users whose vision is impaired.

[0044] As can be seen in Figure 17, the sewing machine 100 can provide notifications and feedback to the user through visual, audible, and tactile means. For example, an indication that an incorrect accessory has been installed on the machine can be presented to the user via the user interface on the display of the sewing machine while a notification sound—e.g., a beep or a computerized voice—is transmitted to the user via speakers in the sewing machine. The notification can also be transmitted to the user via haptic or tactile feedback through vibration of portions of the sewing machine 100 being touched by the user. That is, the sewing bed 104 can be vibrated by the sewing machine to provide a warning to the user that the machine is not properly configured for the particular sewing operation selected by the user. The user would feel the vibrations below their fingers that are in contact with the workpiece and sewing bed, thereby prompting the user to look at the display for further information. The illuminating lights of the sewing machine can also be controlled to alert the user, such as by changing the color of flashing when an incorrect accessory is installed so that the user is prompted to look at the display for additional information.

[0045] A projector 114 can also be provided in the sewing head 102 and directed downward toward the sewing bed 104 and workpiece, as is shown in Figures 1, 4, 92, and 94. The projector 114 is arranged to project useful information onto the workpiece to aid the user in the use of the sewing machine. For example, the projector 114 can project the needle drop point down onto the fabric so that the user can see the location of the needle before a stitch is made. Lines or other guides can also be projected onto the workpiece to assist the user in sewing in a straight line or along a desired path. Similar to a guide, the projector 114 can project a selected stitch pattern

onto the workpiece to represent stitches that are planned. The projector 114 is also capable of projecting images onto the workpiece to display a chosen embroidery pattern onto the workpiece so that the user can position the embroidery pattern onto the workpiece in a desired location. The information projected by the projector 114 can also include feedback to the user as to the status of the machine or a particular sewing operation. For example, the projector 114 could project a warning notification onto the workpiece that the incorrect needle has been installed for the type of material being used as the workpiece. The projector 114 can also provide visual instructions to aid the user, such as, for example, still or animated images instructing the user in how to change a needle, thread the machine, or rotate a workpiece. In other words, the projector 114can be used by the computer as another means of providing feedback and instructions to the user. It should also be noted that the images projected by the projector 114 can also be detected by an optical sensor so that the user's interaction with those images, such as, for example, by touching the projected images of a button or series of buttons so that the sewing machine can respond to the interaction of the user with the projected images.

[0046] A wide variety of data gathering devices 118—i.e., digital sensors, analog sensors, active sensors, passive sensors, and software components—can be employed by the sewing machine 100 to acquire data related to the sewing machine itself, the workspace or environment surrounding the sewing machine, the sewing material operated on by the sewing machine (e.g., the fabric workpiece and thread used to form stitches), the sewing operation performed by the sewing machine, and interactions of the user with the sewing machine. A non-exhaustive list of the types of sensors for the sewing machine 100 includes: acoustic, sound, vibration, chemical, biometric, sweat, breath, fatigue detection, gas, smoke, retina, fingerprint, fluid velocity, velocity,

temperature, optical (e.g., a camera), light, infrared, ambient light level, color, RGB color (or another color space sensor, such as those using a CMYK or grey scale color space), touch, tilt, motion, metal detector, magnetic field, humidity, moisture, imaging, photon, pressure, force, density, proximity, ultrasonic, load cell, digital accelerometer, motion, translation, friction, compressibility, voice, microphone, voltage, current, impedance, barometer, gyroscope, hall-effect, magnetometer, GPS, electrical resistance, tension, strain, and many others. Software-based data gathering devices 118 can include various data logs that are populated as the sewing machine 100 is used. For example, user activity logs can record events involving input from the user via the user interface 124 and system event logs can record software events that occur during the normal use of the sewing machine 100 that can be used for machine learning or diagnostic purposes.

[0047] The sensors can be arranged in a wide variety of locations on the machine and can be employed by the sewing machine in a wide variety of ways. For example, the sewing machine can include touch and proximity sensors (e.g., the proximity sensor shown in Figure 3) for providing touch control of the user interface presented on a display of the sewing machine. Similar touch or proximity sensors can also be provided in other locations of the sewing machine, such as on the arm or the sewing bed. Touch sensors in these other locations can be used in conjunction with a user interface presented to the user or can be used to monitor the location of the user's hands (or other foreign objects, such as the user's hair or loose sewing pins) on the machine during the sewing process for safety purposes. The sewing machine can also include eye tracking sensors that incorporate optical sensors such as cameras or other detection means for tracking the eye position and/or line of sight of the user. One or more optical sensors on the machine can be used not only to collect data related to the user of the machine, but also to collect data related to the workpiece,

other sewing materials such as the thread, and the sewing machine itself. Additional examples of the use of sensors and sensor data by the sewing are provided throughout the present disclosure.

[0100] Many of the sensors used in the sewing machine require calibration after installation to ensure that the data gathered by the sensor and provided to the neural network is accurate. The calibration of the sensors can also be updated in the field on a periodic basis or when designated by the user. The sensors can be calibrated in any suitable way. Calibration of the camera, for example, can be performed using techniques described in U.S. Patent No. 8,606,390, the entirety of which is incorporated herein by reference. The camera and other sensors can also be calibrated with techniques that employ the neural network; e.g., to identify features of the sewing machine when calibrating the camera.

[0048] One or more optical sensors of the sewing machine can be arranged at a wide variety of locations around the sewing machine. An "optical sensor" as used herein means a sensor capable of gathering data from electromagnetic radiation (see Figure 18) and can include, but is not limited to, a sensor for detecting ultraviolet radiation, visible light, infrared radiation, and the like. Certain optical sensors can be tuned to a particular wavelength of electromagnetic radiation, such as, for example, a certain wavelength of laser light. One particular optical sensor that can be used in an exemplary sewing machine is a camera. A camera can include a lens for focusing or otherwise redirecting light onto a sensor that receives the optical data and transmits the optical data to another device for processing.

[0049] The one or more optical sensors can be arranged in the sewing machine to observe the workpiece during the sewing process, such as the camera 116 shown in Figures 1, 4, 6, 93, and 95. The

optical sensor or optical sensors watching the workpiece can be used to determine the color of the workpiece, the material of the workpiece, the location of the workpiece, the orientation of the workpiece, the magnitude and direction of movement of the workpiece, and the like. The same optical sensors can also be used to detect objects in the sewing area, such as the user's hands, hazardous objects (e.g., hair, clothing of the user, sewing pins, etc.), the type of needle or needles installed in the sewing machine, the type of presser foot, or the like. The optical sensors can also monitor whether the needle, presser foot, stitch plate, or accessory are properly installed and remain properly installed during use. Additional optical sensors or similar sensing devices can be arranged on the machine facing the user to provide the computer of the sewing machine with information about the user, such as, for example, the position and line of sight of the eyes of the user so that the sewing machine can determine where on the machine the user is looking. Tracking the user's eyes and current line of sight can, for example, allow the sewing machine to determine where best to illuminate the sewing bed or present useful information to the user so that an important notification or warning is not missed.

[0101] Various security features can be included in the sewing machine to restrict access to and to prevent the theft of the sewing machine. When the machine is powered on or awoken from a sleep mode, for example, the user can be presented with a prompt requiring the user to prove their identity. The user can then enter a predetermined code to prove that they are a user with permission to access and use the sewing machine. In addition to or in place of the predetermined code, the user can provide biometric information as proof of identity, for example, via a fingerprint sensor or facial recognition. The fingerprint sensor can be included on the sewing bed or in another location where the user typically places their hands to use the machine. One or more

user-facing cameras enable the sewing machine to use facial recognition techniques to identify the user for the purposes of providing access to the machine.

[0050] The user can also associate another device with their account on the sewing machine and use that device to unlock the sewing machine. For example, an app on a smart phone or tablet can be associated with a user account so that the sewing machine can be unlocked via the app or by holding the smart phone or tablet within a predetermined range of the sewing machine. Any of these means of authenticating the user can be used individually and can also be used together to provide two-factor authentication. A phone number that can receive text messages can also be associated with the account of the user so that a code can be sent for use in two-factor authentication. These other devices or phones can also receive alerts from the sewing machine that are generated when other attempts to access the machine fail, for example, after a predetermined number of attempts to access the sewing machine. If the sewing machine is believed to be stolen, these other devices can be used to determine the location of the sewing machine via the GPS sensor in the sewing machine or via other means, such as local networks detected by the sewing machine. Additionally, alerts resulting from the machine being moved from its normal location(s) or failed attempts to access the machine can include the location of the sewing machine as determined by the onboard GPS sensor to facilitate the recovery of the sewing machine if relevant.

[0051] To process and act on the wide variety of data provided to the computer or computers located internal to and/or external of the sewing machine via the sensors described above, various artificial intelligence ("AI") tools and techniques are employed (see, e.g., Figure 19), enabling analysis of extremely large structured or unstructured and changing data sets, deductive or inductive

reasoning, complex problem solving, and computer learning based on historical patterns, expert input, and feedback loops. "Artificial intelligence," as used herein, means a wide field of tools and techniques in the field of computer science that enable a computer to learn and improve over time. Figure 19 shows a non-exhaustive outline of these tools, such as, for example, symbolic artificial intelligence, machine learning, and evolutionary algorithms. As can be seen from Figure 19, artificial neural networks can be used in a variety of machine learning applications and can employ various learning methods including, but not limited to, statistical learning, deep learning, supervised learning, unsupervised learning, and reinforcement learning. Artificial intelligence enables the sewing machine to adapt to situations not anticipated or exactly predicted by the programmers of the software and facilitates sophisticated yet intuitive ways of interacting with the sewing machine to achieve a desired outcome. That is, the AI tools and techniques described herein are used by the computer or computers that are integrated in or external to the sewing machine to make decisions in support of or to benefit the user based on the data provided to the computer via the sensors described herein. While a particular artificial intelligence tool may be described below (e.g., a neural network), other artificial intelligence tools can be used for the same task so that the description of one tool or technique should not be viewed as limiting the application to only that tool or technique unless otherwise stated herein.

[0052] Neural network diagrams and processes related to the same are shown in Figures 20–23. A "neural network" as used herein, includes, but is not limited to, a plurality of interconnected software nodes or neurons that are arranged into a plurality of layers, such as, for example, input layers, hidden layers, and output layers as can be seen in Figure 20. Figure 20 shows a diagram of a neural network 128 that includes nodes 130

arranged in various layers. Like neurons in the human brain, each node 130 can have one or more input connections 132 and output connections 138 to create a many-to-many relationship with the other nodes 130 in the network. That is, the output of a single node can be connected to the input of many different nodes and a single node can receive as input the output of many different nodes.

[0053] Each node 130 of the network is configured to perform calculations on the data from other nodes and to calculate output data in conjunction with node parameters that are adjusted during the training process for the neural network (Figure 21). That is, each node of the network is a computational unit that has one or more input connections for receiving input data from nodes in a previous layer of the network and one or more output connections for transmitting output data to nodes in a subsequent or next layer in the network. Each node 130 includes a calculation unit 136 for calculating the result of an activation function that can incorporate the input data received via the input connections, input parameters associated with each input connection, and an optional function parameter 134 to compute output data that can be further modified by an output parameter. For example, the input data from each input connection can be modified by the associated input parameter—e.g., a weight parameter—for that input connection to provide a relative weight for the input connection. The result of the activation function—which can be modified by the optional function parameter—is transmitted as output data via the output connection to nodes in subsequent layers of the neural network. The optional function parameter can be, for example, a threshold value so that the calculated result of the activation function is only transmitted to other nodes as output data when the combined weighted input data exceeds the threshold set by the threshold value.

[0054] All forms of data available to the sewing machine, that is, from the sensors, software, data storage devices, user input via software, and the like can be processed through a neural network. The information to be processed first encounters the input layers which perform an initial processing of the input data and output the results to one or more hidden layers to process the output values from the input layers. Information that has been processed through the hidden layers is presented at the output layer as a probability of confidence in a given result, such as, for example, the location of a detected object in an image and the classification of that object. The software in the computer of the sewing machine receives the information from one of the layers of the neural network and can take action accordingly to adjust the parameters of the sewing machine and/or to inform the user based on the results of the neural network processing (Figure 22).

[0055] During training of the neural network 128, the node parameters (i.e., at least one of the input parameters, function parameters, and output parameters) for each node in the neural network are adjusted via a backpropagation algorithm until the output of the neural network corresponds to a desired output for a set of input data. Referring now to Figure 21, a process for training a neural network is shown. The neural network begins the training process with node parameters that can be randomized or can be transferred from an existing neural network. The neural network is then presented with data from the sensors to process. For example, an object can be presented to the optical sensor to provide the neural network with visual data. The data is processed by the neural network and the output is tested so that the node parameters of the various nodes of the neural network can be updated to increase the probability of confidence in the detection and classification performed by the neural network. For example, when a presser foot is shown to the optical sensor for identification by the neural network, the neural network will

present a probability of confidence that the object being shown to the optical sensor is located in a range of coordinates of the image and can be classified as a particular presser foot. As the training process is carried out, the node parameters of the nodes of the neural network are adjusted so that the neural network becomes more confident that a particular answer is correct. Thus, the neural network comes to "understand" that when presented with certain visual data, a particular answer is the most correct answer, even if the data is not exactly the same as what has been "seen" before.

[0056] A neural network is considered "trained" when the decisions made by the network reach a desired level of accuracy. The trained neural network can be characterized by the collection of node parameters that have been adjusted during the training process. The collection of node parameters can be transmitted to other neural networks having the same node structure so that those other neural networks process data in the same manner as the initially trained network. Thus, a neural network stored in a data storage device of a particular sewing machine can be updated by downloading new node parameters, as is shown in Figure 23. It should be noted that the node parameters of a neural network—such as input weight parameters and threshold values—tend to take up significantly less storage space than image libraries used for comparisons with image or visual data gathered by optical sensors. Consequently, neural networks files and other critical files can be updated via the network quickly and efficiently. For example, the structure of the neural network—i.e., the map of connections between nodes and the activation function calculated in each node—can also be updated in this way.

[0057] A neural network can also be trained continuously such that the node parameters are updated periodically based on feedback provided from various data sources. For example, node

parameters of a neural network stored locally or externally can be updated periodically based on data gathered from sensors that agree or disagree with the output of the neural network. These adjusted node parameters can also be uploaded to a cloud-based system and shared with other sewing machines so that the neural networks of all of the sewing machines improve over time. Input data for a neural network can also be shared with a server or cloud-based system to provide further training information for a neural network. The large amount of data from the sewing machines in the field can, through training, improve the accuracy of the predictions made by the neural network.

[0058] Referring now to Figure 96, an exemplary process 200 for controlling the sewing machine 100 is shown. The process 200 includes steps of gathering data 202, storing the gathered data in a data storage device 204, processing the gathered data through a neural network 206, and controlling the sewing machine based on the processed data 208. The gathered data is related to at least one of the sewing machine, the workspace or environment surrounding the sewing machine, the sewing material (e.g., thread and workpiece), the sewing operation performed by the sewing machine, and interactions with the user of the sewing machine (e.g., as recorded by the user interface or by other sensors). The neural network includes a plurality of nodes that each include input and output connections, a node parameter, and a calculation unit. Based on the processed data, the user interface can be controlled to interact with the user (e.g., by presenting an alert and/or prompt), the data storage device can be controlled to store the processed data (e.g., as a separate record or by updating the neural network parameters), and a regulatable component can be regulated to alter the current state of the sewing machine (e.g., to change the motor speed, activate a light, move the needle, or any other action that alters the sewing machine or sewing operation performed by the sewing machine). As can be seen in

Figure 22, data gathered by the sensors of a sewing machine can be processed locally on the sewing machine or via external processors in a cloud-based neural network. The locally stored neural network can be pre-trained or can be a continuously updating neural network. The data processed by the neural network—locally or remotely—is then used by the software of the sewing machine to make a decision that results in machine and/or user interaction.

[0059] Referring now to Figures 24–33 and 104–105, various views and diagrams are shown that are related to the use of artificial intelligence in the sewing machine to control the location of the stitch made in the fabric during sewing. The position of stitches has typically been left to the user during normal sewing operations. That is, the user can be provided with various visual aids—guides on the needle plate, projected guides, markings on the workpiece, or the like—and it is up to the user to maintain the sewing path in the correct location. Visual aids do not control the location of the workpiece, however, so the ultimate location of any stitch is up to the skill of the user to hold and steer the fabric in the proper direction. The sewing machine described herein, however, can use one or more optical sensors and a depth perception system (that is described in greater detail below and can include optical sensors, a projector, ultrasonic, and thermal vision systems) to find a desired path on the workpiece and can manipulate the lateral position of the needle bar and workpiece by the feed dog so that stitches are placed along the desired path even if the user happens to move the workpiece out of line. The feed dogs used to influence the feed direction of the workpiece can include linear translating feed dogs, linear translating feed dogs in combination with circular rotating feed dogs, and multi-part feed dogs having two or more independently moving parts, such as left and right portions that translate different distances and/or speeds (similar to tank treads) to cause the workpiece to turn

during feeding. The two or more parts of a feed dog can also be arranged at different heights to accommodate sewing together fabrics having different thicknesses.

[0060] When quilting, it is common to have a need to form a line of stitches along an already formed seam between two or more pieces of fabric, as can be seen in Figure 24. Sewing along the ditch is known colloquially as forming a "stitch in the ditch" as the two fabrics tend to rise up away from the seam so that the seam appears to have a long low groove having a relatively deep wedge-shaped cross-section between the two pieces. Forming stitches along the ditch helps to conceal the stitches in the finished quilt. Maintaining a constant placement of stitches along the ditch is quite challenging as the ditch is a moving and very narrow target. Thread with a color that somewhat matches the surrounding quilt pieces or even transparent threads may be used to attempt to conceal the thread in the case of missed stitches.

[0061] Referring now to Figure 25, the field of view of an optical sensor or optical sensor and depth perception system of the sewing machine is shown overlaid on the image of Figure 24. As can be seen in Figure 104, a user initiates stitch-out and activates the "stitch-in-ditch" feature. When the workpiece is arranged on the sewing bed, data is gathered continuously from sensors and processed through the neural network. The gathered data includes data gathered from camera(s) directed toward the sewing area upstream and/or downstream from the needle drop location, data related to the sewing operation (e.g., the stitch type and parameters), thread data (e.g., thread tension), and data gathered that is related to the sewing material (e.g., the feed rate, movement vector, and topography of the workpiece). The data is processed through a neural network that has been trained to detect and recognize the ditch formed between two or more pieces of fabric. That is, the neural network provides a probability of

confidence as to the location of the ditch and specifics about its appearance. As the user begins sewing—such as by pressing down on the foot pedal, pressing a button, giving a voice command, etc.—and moves the workpiece into position under the needle, the sewing machine detects and recognizes the ditch and controls the position of formed stitches on the workpiece via swinging of the needle bar and/or lateral feed of the workpiece so that the ditch is followed and stitches are formed in the ditch. An actuator, shown in Figures 26–33, can be used to alter the lateral position of the needle bar so that the needle places a stitch through the ditch. As the workpiece is moved, the feed dogs can also be controlled using an actuator shown in Figures 30–33 to move the workpiece somewhat laterally during the usual forward-to-back feeding of the workpiece. That is, the feed dogs are capable of moving in two axes so that the direction of the sewing path can be altered in addition to the feed rate of the workpiece that is typically controlled by the feed dogs.

[0062] Referring now to Figure 105, a process similar to that of the "stitch-in-ditch" feature can be used to form stitches at a predetermined offset distance or allowance from a feature of the workpiece. When the workpiece is arranged on the sewing bed, data is gathered continuously from sensors and processed through the neural network. The gathered data includes data gathered from camera(s) directed toward the sewing area upstream and/or downstream from the needle drop location, data related to the sewing operation (e.g., the stitch type and parameters), thread data (e.g., thread tension), and data gathered that is related to the sewing material (e.g., the feed rate, movement vector, and topography of the workpiece). The data is processed through a neural network that has been trained to detect and recognize a feature of the workpiece, such as, for example, an edge, a seam, a "ditch" between two pieces of fabric, a buttonhole, a pocket, or the like. That is, the neural network provides a probability of

confidence as to the location of the feature and specifics about its appearance. As the user begins sewing—such as by pressing down on the foot pedal, pressing a button, giving a voice command, etc.—and moves the workpiece into position under the needle, the sewing machine detects and recognizes the feature and controls the position of formed stitches on the workpiece via swinging of the needle bar and/or lateral feed of the workpiece so that the stitches are formed at a predetermined offset distance from the identified feature. For example, the user can specify a seam allowance of one-half inch and can begin sewing with the workpiece with the edge arranged within the range of lateral movement of the needle bar. As the workpiece is moved through the sewing machine, the edge of the workpiece is detected and stitches are formed one-half inch away from the edge without the user having to precisely follow an edge guide.

[0063] Referring now to Figures 34–39, diagrams for various computer vision systems are shown. In addition to the visual data provided by the optical sensor, the neural network can receive input from a depth perception system to provide a more accurate calculation of the position and three-dimensional topography of the ditch. The depth perception system can use any of the stereoscopic and other computer vision techniques, but not limited to, shown in Figures 34–39 that use two optical sensors, two optical sensors and a projector, a projector and a single optical sensor, an optical sensor and laser light source, a thermal vision system, or an ultrasonic vision system to calculate the distance to the workpiece. Referring now to Figure 34, a passive stereo depth perception system is shown that uses two cameras—similar to stereo vision in humans—to determine a distance to a target object based on a comparison between the two images captured by the camera. An active stereo vision system shown in Figure 35 is similar but includes a projector for projecting a graphic onto the target object for enhancing the measurement of distance by the two cameras. A

projector is also used in the structured light vision system in Figure 36 to project lines or some other visual pattern onto the target object that can be observed by the camera to determine distance from the camera to the target object. Another depth perception system is shown in Figure 37 that calculates a distance to the target object with a camera that measures the time it takes for light from a laser to travel from the laser to the target object, and back to the camera. This distance information can also be provided to the neural network that is processing the visual data of the workpiece from the optical sensor to calculate the position of the ditch as the workpiece is moved underneath the sewing head for forming stitches in the workpiece. That is, the line of points on the workpiece that are located furthest from the sewing head can be identified as a ditch in the fabric.

[0064] It should also be noted that the optical sensor and depth perception systems described above can have a wide variety of uses. That is, the one or more optical sensors and depth perception arrangements can be used to recognize the textile and thread topography in three dimensions to identify types of fabric materials and thread types already in use in a workpiece. The density and type of the fabric material can also be determined using an ultrasonic or thermal vision system that can be part of the depth perception system. That is, more dense materials respond differently to an ultrasonic pulse than lighter materials. A laser, infrared radiation, or some other heat source can be used to heat up a portion of the workpiece that can be detected by a thermal vision system including, for example, an infrared sensor. Thus, the thermal conductivity of the fabric can be measured and compared to known values for different types of fabric. This feature can be particularly useful in an embroidery process when working on a workpiece with existing stitches. The information provided by these systems can also be used to identify the type of fabric and thread used in a workpiece to automatically adjust the

sewing machine for sewing that type of material and to recommend to the user a particular needle or other accessory that might be installed in the machine for use with that workpiece. Automatic lighting adjustments can be made to enable the user and sensors of the sewing machine to view the workpiece material in a manner particularly suited for sewing (i.e., lower light levels improve the visibility of highly reflective fabrics). Additionally, as is described in further detail below, the sewing machine can provide recommendations and even warnings to the user based on the identified combination of thread and fabric types. The 3D topography of the workpiece can also be used to determine when to release pre-tension on the presser foot to more easily climb over multiple layers of fabric, such as, for example, when sewing a hem.

[0065] Processing the distance information through the neural network alongside the visual data further improves the accuracy of the information as the neural network can be trained to take both the appearance and the shape of the workpiece into account when determining the location of the ditch. The neural network used to process the visual and distance data can be trained elsewhere and the node parameters and other necessary information transmitted to the sewing machine via a cloud connection with the computer of the sewing machine (Figure 23) and/or the neural network can be trained during the sewing process. For example, the same or an additional optical sensor can be used to observe the stitches formed in the workpiece to identify stitches that missed the ditch. As the computer knows the sewing pitch, the control data for the particular missed stitch can be determined and used to adjust the node parameters of the neural network to reduce the chance that stitches are missed. The computer on the sewing machine can work in conjunction with a cloud-based neural network that can provide additional computing power for processing the data provided to the neural network and for training the neural

network during operation of the sewing machine so that the neural network is a continuously learning neural network.

[0066] The techniques implemented to accurately form a "stitch in the ditch" described above can have a broader application to sewing in a wide variety of contexts to form a "perfect stitch." That is, data from one or more optical sensors and a depth perception system can be processed through a neural network to provide control data to the one or more motors and actuators of the sewing machine to accurately and precisely form any kind of desired stitch in any particular location on the workpiece. In addition to using visual data from the optical sensor and depth perception data from the depth perception system, a perfect stitch control system can take into account data from thread tension sensors, needle position sensors, needle force sensors, fabric feed rate sensors, the speed and frequency of the needle bar movement, the pressure applied by the presser foot, the feed rate of the feed dogs, and the like. Data from these sensors can be processed through the neural network to predict whether an incorrect stitch is likely to be made and can direct the control system to adjust various parameters accordingly to compensate for whatever factor may be likely to cause the error. Upon processing the data provided by these sensors, decision information from the neural network can be used by the computer of the sewing machine to adjust a wide variety of sewing parameters, such as, for example: thread tension; needle position, force, speed, and timing; stitch length and type; motor speed; and fabric feeding settings to actively achieve ideal stitch precision and accuracy. All of these features can be combined to correlate the machine performance to the skill level of the user. That is, the sewing machine can learn to work with beginner, intermediate, and advanced users to adapt the speed of the machine, the presentation of corrections and alerts, the recommendation of guides or aids, and the like to the user.

[0067] As with the stitch-in-a-ditch example described above, the sewing machine can also check for errors in stitches that have already been formed. That is, each completed stitch can be actively monitored for quality purposes. If data collected by the sensors of the sewing machine indicates that an imperfect stitch has been formed (e.g., a stitch has been skipped or is misaligned), the output data generated by the neural network can be used to make decisions regarding adjustments that can be made to the parameters of the sewing machine. These adjustments can be made and the resulting stitches monitored until the stitches formed are perfect and error-free. The sensors can also be used to detect a thread break so that sewing can be stopped and the thread replaced. Thus, the quality of the stitches can improve over time as the neural network is continuously trained. For example, a zig-zag stitch might be controlled to maintain a particular width on either side of a seam of fabric such that successive stitches are formed in opposing pieces of fabric. Or, when performing a simple straight stitch, the tension of the upper and lower threads can be controlled to avoid the stitch pulling through to one side of the workpiece. The optical sensors can also identify lines of a pattern that are pre-existing as part of a pattern on the workpiece (e.g., by weaving into or by printing on the fabric), drawn, overlain, drawn, or projected onto the fabric so that stitches are formed along the line or at a constant offset distance from the line. That is, the optical sensors can be used to detect the edge of the fabric and help the user to sew along the edge of the fabric with a constant seam allowance. Two or more pieces of material might have edges that the users is attempting to align during sewing and the sewing machine can detect misaligned workpieces and recommend corrections to the user.

[0068] An example of a process for detecting and adjusting for sewing errors is shown in Figure 106. As the user is sewing, data is continuously gathered from camera(s) directed toward the sewing

area upstream and/or downstream from the needle drop location, the sewing operation (e.g., the stitch type and parameters), thread data (e.g., thread tension), and the sewing material (e.g., the feed rate, movement vector, and topography of the workpiece). Input data can also be provided from a database of known sewing errors and their causes—for example, a puckering seam can be caused by an imbalance in the thread tension of upper and lower threads. The data is processed through a neural network that has been trained to identify sewing errors and identified errors can be recorded along with contextual information—such as the parameters of the sewing machine at the time of the error or the movement of the workpiece when the error occurred—and reported to the user. The recorded information can be used to update local and remote neural networks to improve error detection and prediction. The sewing machine can also control actuators or motors in response to the identified sewing errors to correct the error in the next stitch or to prevent a recurrence of similar errors. A non-exhaustive list of sewing errors includes a skipped stitch, an unbalanced stitch, a misaligned stitch, a seam pucker, a stitch density variation, a bobbin thread break, a looper thread break, a needle thread break, a fused thread, a needle break, a stuck needle, a needle striking the needle plate, a thread cut by the needle, inconsistent thread tension, a wavy seam, an unthreaded needle, a loose needle holder, a loose presser foot, a mislocated presser foot, an immobile needle, an immobile workpiece, a bunching workpiece, a bunching thread, a knot in the thread, a loose stitch, a tangle in the thread, a frayed thread, a shredded thread, a workpiece feed variation, a bent needle, a damaged looper, a damaged stitch finger, a mislocated looper, a mislocated stitch finger, and a dull fabric knife.

[0069] A continuously trained neural network—i.e., a neural network that is trained and can be adjusted during the sewing process may end up adjusting numerous parameters of the sewing process

in unpredictable ways that compensate for unforeseen issues that would be very difficult or impossible to anticipate and address via traditional control software or by the user by adjusting settings of the sewing machine. For example, the sewing machine can adjust the feed rate and sewing pitch in response to the user applying external forces to the sewing machine that would have otherwise moved the workpiece out of line. In doing so, adjustments to the thread tension or presser foot presser might also be determined to be useful by the neural network. That is, the sewing machine can learn to compensate for and even to resist incorrect movements by the user to further guarantee that the stitches formed are accurate and precise.

[0070] The projector of the sewing machine can be used in conjunction with the artificial intelligence techniques described herein to improve the placement of images projected onto the workpiece. For example, as is shown in Figure 107, a neural network can be used to identify a feature of a workpiece so that a sewing guide can be projected at the location of the feature or at a predetermined distance from the feature. When the workpiece is arranged on the sewing bed, data is gathered continuously from sensors and processed through the neural network. The gathered data includes data gathered from camera(s) directed toward the sewing area upstream and/or downstream from the needle drop location, data related to the sewing operation (e.g., the stitch type and parameters), thread data (e.g., thread tension), and data gathered that is related to the sewing material (e.g., the feed rate, movement vector, and topography of the workpiece). The data is processed through a neural network that has been trained to detect and recognize a feature of the workpiece, such as, for example, an edge, a seam, a “ditch” between two pieces of fabric, a buttonhole, a pocket, or the like. That is, the neural network provides a probability of confidence as to the location of the feature and specifics about its appearance. As the user begins

sewing—such as by pressing down on the foot pedal, pressing a button, giving a voice command, etc.—and moves the workpiece into position under the needle, the sewing machine detects and recognizes the feature and controls the projector to project a sewing guide, such as a straight line in the feed direction, at the location of the feature or at a predetermined offset distance from the identified feature. For example, the user can specify a seam allowance of one-half inch and can activate a sewing guide that projects a line one-half inch from the edge of the workpiece that moves with the workpiece when the workpiece is moved by the user so that the user can correct the lateral position of the workpiece to form stitches in a desired location.

[0071] Referring now to Figures 40–42, various views and diagrams are shown that are related to the use of artificial intelligence in the sewing machine to predict the path of the stitches being formed so as to project an image of the predicted stitches onto the fabric ahead of the needle position to inform and guide the user. As with the stitch regulation and control features described above, the optical sensor gathers visual data from the fabric workpiece and provides that data to the computer. The computer processes the data through a neural network that has been trained to predict the sewing path based on visual data regarding the already formed stitches and the parameters of the sewing machine, such as, for example, the needle position and speed, the fabric position and speed, the feed dog rate, the force applied by the presser foot, the tension in the upper and lower threads, the speed selected by the user, and the like. The neural network processes the data and provides a predicted sewing path to the computer of the sewing machine which then projects a series of stitches along the predicted path in front of the needle. The type of stitch selected by the user via the user interface (Figure 40) is incorporated into the projected view (Figure 41) so that the user can see the shape of the stitches to be formed along the predicted sewing path. As the

workpiece is moved by the user or the fabric translating portions of the sewing machine, the projected path of stitches moves as well so that the path appears in a constant location on the workpiece. (In an embroidery machine, a projected embroidery pattern can move with the workpiece during movement of the embroidery frame.) The predicted path can also be adjusted to suggest a path that the user can follow to return to a pattern that has been deviated from. The projected path of stitches can also start at the needle drop point and extend in a straight or curved line in the feed direction that does not move when the workpiece is rotated or translated.

[0072] Referring now to Figure 42, a line of predicted stitches is shown projected in a black color, and the formed stitches are shown in blue. The projected stitch appears to be consumed by the real stitch being formed in the workpiece. A prediction distance can also be set by the user so that only a few predicted stitches are shown or a line of stitches is shown extending to the limits of the range of the projector. An embroidery pattern can also be projected in a similar fashion so that the projected stitches disappear as the pattern is formed in the workpiece. As the workpiece held by the embroidery frame is moved, the projected image also moves to track with the workpiece so that the needle follows the projection of the predicted sewing patch.

[0073] Projecting a predicted path of stitches along the workpiece ahead of the needle has many benefits. In some situations, a user may want to place a smooth curve of stitches that ends up near or a certain distance from an existing feature of the workpiece. Or, the user may want to avoid contacting or overlapping existing features of the workpiece. In these cases, a predicted sewing path that moves with the workpiece would facilitate the creation of the desired seam in a single pass. Additional information can also be provided other than the predicted sewing path. For example, the

projected stitches might change color if the projected path is predicted to encounter or come too close to a feature of the workpiece that the user has designated as an object to avoid, or that the sewing machine identifies and predicts that the user would want to avoid, such as a pin, a button, another seam, a button hole, a decorative element, the edge of the fabric, or the like. The projected stitches might also flash on and off in these scenarios and can be combined with other notifications, such as audible or tactile feedback as is discussed in the present disclosure. Alternatively, the projected path could automatically be altered by the sewing machine to steer the user around the obstacle, with the original path and the new, altered path being projected in different colors and/or with motion cues that clearly indicate that the path has changed—such as, for example, by flashing or otherwise animating arrows near the path.

[0074] Such cautionary signals and warnings could also be sent if the users fingers are moved into the predicted sewing path or in the path of another component of the sewing machine, such as the presser foot or an attached accessory. It should be noted that the projector is not limited to projecting only the predicting sewing path and can also project many other symbols and/or words near the projected path to inform and alert the user as to changes in the path or obstacles to watch out for. For example, the neural network can identify a button on the fabric and provide the computer system with location and size data for the button so that the computer can instruct the projector to project an outline of the button around the button on the workpiece so that the attention of the user is drawn to that feature.

[0075] As a final measure, the sewing machine can stop altogether if an obstacle is about to be hit by the needle and the user has not responded to override the warning—for example, via the touch screen interface or via a voice-control system—to avoid the

obstacle. Figure 108 shows a flow diagram that illustrates the use of a neural network to avoid harm to the user or damage to the sewing machine during a sewing operation. When the user initiates stitch-out on the sewing machine, data is gathered from camera(s) directed toward the sewing area and can also be gathered from other sensors, such as, for example, one or more microphones listening to the environment to capture vocal cues or other expressions made by the user. The gathered data is processed through a neural network that has been trained to detect foreign objects that can be harmed by the sewing machine or could cause damage to the sewing machine. For example, the neural network can identify the fingers of the user below the presser foot or in the path of the needle. The audio data may also be helpful to determine if the user is having a conversation and may be distracted, thereby increasing the probability of an unintended finger or hand placement. Once the object is identified, the sewing machine can alert the user and stop the sewing operation or lowering of the presser foot to avoid harm to the user and sewing machine. The foreign object might not be directly in the sewing path but can be near the path, thereby leading to an alert being generated by the sewing machine. For example, the sewing machine can alert the user audibly or could project a warning on the workpiece, as described above. If no foreign objects are detected, the sewing operation proceeds in a normal fashion.

[0076] In addition to compensating for deviations from a desired sewing path, the data gathered by the sewing machine during the sewing performed by the user can be analyzed via a neural network to detect the level of expertise of the user. For example, frequent deviations from a desired sewing path may indicate that the user is a novice while a low number of deviations may indicate that the user is an expert. Instructions and training exercises can then be suggested to the user by the sewing machine for improving.

Feedback may be shared via any single or combined means, including audio, text, video, image projection, and augmented reality configurations from the sewing machine or a connected device. Adjustments to the settings of the sewing machine can also be recommended to improve the sewing of the novice sewer and to improve the efficiency of an expert sewer. The sewing machine can also suggest new opportunities and challenges for advanced users to help them further enhance and expand their skill set.

[0077] An example flow diagram for using a neural network to detect thread issues is shown in Figure 109. When the user uses the sewing machine in any way, data is gathered from user facing sensors such as a camera, real time interaction of the user with the user interface, a log of historical interaction with the sewing machine, and also information related to the current sewing operation, if any. The gathered data is processed through a neural network that has been trained to detect the skill level of the user, as described above. If the neural network has assessed the skill level of the user, the sewing machine can proceed to warn the user that the difficulty of a task exceeds the detected skill level or can provide useful tips or prompts as appropriate. As noted above, the sewing machine can also provide recommended training exercises based on the detection of the skill level of the user.

[0078] An analysis of the level of expertise of the user can also be applied to the interaction between the user and the sewing machine. That is, the sewing machine can detect via neural network analysis that the user is struggling to properly use a feature of the sewing machine and can suggest tutorial videos or instructions and can provide prompts on the screen to help the user know which user interface control to interact with next. User interaction data can include the user-facing camera data described above and can also include timing information from the user interface that indicates

the speed at which a user interacts with the settings of the sewing machine. The timing of the user's interaction with the sewing machine can be one indicator of the skill level of the user; i.e., a user who more swiftly selects menu items in a user interface is likely more familiar with the sewing machine and, combined with other data, can help the sewing machine identify an estimated skill level of the user. As an example, after a feature is activated the sewing machine may highlight a button and present a pop-over message that prompts the user to take a next step to use the activated feature. Input from a user-facing camera and facial recognition techniques provide further input as to the emotional state of the user when interacting with the sewing machine. That is, graphical and audible prompts can be provided when the user appears to be frustrated or confused. Or, the sewing machine can refrain from presenting further prompts that may be perceived as irritating and unhelpful so as to best support and coach the user through whatever problem they are trying to solve.

[0079] Based on the data gathered from monitoring the use of the sewing machine, the sewing machine can also provide helpful recommendations for additional products or accessories. The advertisement of the product can be made via any single or combined means, including audio, text, video, image projection, and augmented reality configurations from the sewing machine or a connected device. In recommending products, the sewing machine or external processors collect and monitor data through real time or retrospective data analytics, specifically, for example, the frequency and preferences of the user's selection of sewing accessories, programs, and machines. For example, the sewing machine can keep track of how much of each kind of thread is used and, understanding typical thread purchase quantities, can recommend purchasing more of that thread when supplies are estimated to be running low. Another example would be when the user uses a certain presser foot for certain purposes and a more

appropriate presser foot exists, the sewing machine can recommend purchasing the more appropriate option if the user has not entered it in a list of currently owned sewing accessories. The list of sewing accessories can be stored on one or both of the sewing machine and an app on a connected device. This data can be sent back to the manufacturer to enable engineering, marketing, and customer service groups to improve the quality of the sewing machine and other product offerings.

[0080] Referring now to Figures 43–65, various views and diagrams are shown that are related to the use of artificial intelligence in the sewing machine to identify the thread used in the sewing machine and the textile material of the workpiece to adjust sewing parameters and to provide information to the user regarding the combination of thread and fabric identified by the sewing machine. Referring now to Figures 43–49, portions of the sewing machine are shown that illustrate the path that a thread can follow to the sewing needle from a spool mounted on top of the sewing machine (Figures 43–45) and from a bobbin mounted below the needle plate (Figures 46–49).

[0081] The sewing machine can include a variety of sensors along these thread paths to detect the type of thread that has been installed in the machine by the user. These sensors can include, but are not limited to, RGB sensors, light sensors, optical sensors, such as cameras, or the like. A source of illumination and a magnifying lens can also be provided with particular sensors. For example, an optical thread sensor can be included on top of the arm of the sewing machine and behind the location that the spool is mounted, as indicated in Figure 50. An exemplary thread sensor 140 is shown in Figure 87 that includes a tube-shaped housing 142 through which the thread 141 passes. The tube-shaped housing 142 blocks ambient light from impinging on the thread 141 so a light source 144 is provided to illuminate the thread 141

for detection with an optical sensor 146, such as a camera or RGB sensor, used to collect thread data. The sewing machine can also include sensors for detecting parameters of the thread and mechanisms for adjusting the same. The tube-shaped geometry of the sensor assembly provides a known background for the illumination of the thread, thereby increasing the accuracy and precision of the thread information gathered by the RGB or other sensor. The sensors provided in the tunnel shaped housing can detect light, sound, or other parameters of the thread to determine the color, the density or weight, the surface quality, the material or fiber type, and the overall quality of the thread. That is, the RGB or other sensors can be used to detect the intrinsic properties of the thread as the thread passes through the sensor housing.

[0082] The data gathered by the thread sensors is transmitted to the computer of the sewing machine and can be compared to a thread information database that contains information regarding a wide variety of thread types and colors. The sewing machine can therefore identify the thread and present information to the user that may be unknown to the user. If the specific thread can be identified from information on the spool (entered manually by the user or detected by the machine) the detected thread properties of the thread can be compared to the stored thread properties from the thread information database. Thus, the sewing machine can detect thread that differs significantly from the stored thread properties that may indicate a defective spool of thread so that the user can be presented with an alert indicating the same. Information on the spool of thread can be gathered by an optical or other sensor arranged near a spool pin on which the spool is mounted during sewing. The spool information can also be gathered from the spool when the user holds the spool in front of an optical or other sensor arranged in the sewing head or another location, such as, for example, a camera in the sewing head or one

or more cameras facing the user. The time and date of the identification of the thread can be stored and associated with projects, stitch types, and the like to build a history of thread use in the sewing machine.

[0083] The sewing machine can also include sensors for detecting the current condition of the thread as the thread is being manipulated by the machine and can include mechanisms for adjusting the same. For example, the sewing machine can include thread tension sensors (Figures 51–54), a thread portioning unit (Figures 55–58), and a thread tension unit (Figures 59–62). The sensors for detecting the intrinsic properties of the thread and the current condition of the thread are arranged to gather data about the quality and condition of the thread as the thread passes from a spool or bobbin, through a thread tensioner, around a hook or other element of the sewing machine, and eventually through the needle. As is described in greater detail below, the optical sensors can also be used in conjunction with a neural network to detect the type of presser foot and/or needle that are assembled to the machine.

[0084] The sewing machine also includes optical sensors or other sensors that can be used in conjunction with a neural network to detect the material or fiber type, the color, the reflectivity, the pattern, the weave direction, the orientation (i.e., right-side and wrong-side), and the topography of the fabric used in the workpiece. An exemplary sensor for gathering data regarding the fabric of the workpiece includes a source of radiation (e.g., an optical light source or an infrared light source) that is provided on the sewing head and directed downward toward the workpiece. A radiation detector, such as an optical light sensor or infrared light sensor is provided on the sewing bed, i.e., underneath the workpiece. It should be noted that the placement of the emitter and receiver can be reversed, that is, by providing the emitter in the sewing

bed and the receiver in the sewing head. Thus, the amount or fraction of the emitted radiation (e.g., optical light or infrared light) that passes through the workpiece—and, consequently, the amount of radiation that has been reflected by the top surface of the workpiece—can be detected and measured. An ultrasonic emitter and receiver can be arranged in a similar fashion—i.e., with the emitter on the sewing head and the receiver in the sewing bed to provide a means for determining the density of the fabric more accurately than other techniques. These emitters and detectors—i.e., for light (IR, camera), color (RGB), ultrasound, etc.—can be used individually or together to determine the material or fiber type, the density, and the reflectivity of the workpiece material. Additional depth perception techniques described herein can also be used to detect the topography of the workpiece.

[0085] The data gathered by the fabric sensors is transmitted to the computer of the sewing machine or any connected external processor and can be compared to a fabric information database that contains information regarding a wide variety of fabric types having various colors and patterns. The sewing machine can therefore identify the fabric of the workpiece and present information to the user that may be unknown to the user. If the specific fabric can be identified from information on the bolt of fabric (entered manually by the user or detected by the machine) the detected fabric properties of the fabric can be compared to the stored fabric properties from the fabric information database. Thus, the sewing machine can detect fabric that differs significantly from the stored fabric properties that may indicate a defective piece of fabric so that the user can be presented with an alert indicating the same. The workpiece identification data can be used in combination with stitch data to train a neural network to associate characteristics of the workpiece with different stitches. Consequently, the sewing machine can alert the user

that stitches are being formed on the wrong side of a workpiece that is facing the wrong way.

[0086] As can be seen in Figure 63, data gathered by the various sensors and other devices described above is processed through a neural network by the computer of the sewing machine. The neural network is trained to provide recommendations, alerts, and warnings to the user based on the input data. That is, the neural network is trained to recognize combinations of types of thread, fabric, presser feet, and needles that are compatible and incompatible. For example, Figure 64 shows a table of fabric and thread that indicates whether heavy or light fabric is compatible with heavy or light thread. If the sewing machine detects that there may be an issue with the combination of thread and fabric the user may be provided with a recommendation on the display that is accompanied by an audible or tactile notification. If the potential compatibility issue is more severe, the user can be alerted or even warned. In some scenarios, the sewing machine can stop altogether and provide a combination of audible, tactile, and visual warnings. In addition to notifying the user of a potential compatibility issue, the sewing machine can make adjustments—such as, for example, to the thread tension, presser foot pressure, the type and speed of the stitch, or the like—to improve the sewing performance when using heavy or light thread and/or fabric. Even when the right type of thread is selected for a given fabric, the color of the thread may not be aesthetically pleasing in view of the selected fabric color and/or pattern. Thus, the neural network can also be trained to advise the user as to the color and pattern compatibility of various threads and fabrics, as can be seen in Figure 65.

[0087] An exemplary flow diagram for using a neural network to identify the workpiece and potential issues with the workpiece is shown in Figure 102. When the user initiates stitch-out on the sewing

machine, data is gathered from: camera(s) directed toward the sewing area; the sewing operation; optical thread sensors; feed rate sensors; a database of known workpiece or fabric materials; and a log of previously identified workpiece materials. The gathered data is processed through a neural network that has been trained to detect workpiece compatibility issues, damage, and other thread quality issues. If the neural network identifies the workpiece and that the workpiece is incompatible with the current sewing operation and other sewing materials (e.g., a lightweight thread is likely to break when used with a thicker or heavier workpiece fabric) the sewing machine alerts the user and sewing can continue if the user chooses to override or disregard the notification. The user is also alerted if workpiece damage or other quality issues are identified. The sewing machine can optionally prohibit further sewing when the damage is sufficient and requires user intervention, for example, to replace or repair the workpiece.

[0088] Referring now to Figures 66–71 and 101, various views and diagrams are shown that are related to the use of artificial intelligence in the sewing machine to identify degraded thread quality to adjust sewing parameters and to provide information to the user regarding the quality of the thread being used. As is described above, the sewing machine can include a variety of sensors along the one or more paths that threads in the sewing machine take from a thread source to the sewing head, such as those shown in Figures 43–49. These sensors can include, but are not limited to, RGB sensors, light sensors, optical sensors, such as cameras, and the like. The sensors are arranged to gather data about the quality and condition of the thread as the thread passes from a spool or bobbin, through a thread tensioner, around a hook or other element of the sewing machine, and eventually through the needle. Additional sensors, such as a thermal sensor, can be

included for monitoring the temperature of various components that engage and could cause damage to the thread.

[0089] Referring now to Figures 66 and 67, examples of the appearance and characteristics of high- and low-quality thread are shown. Thread that is considered high quality or good condition thread has qualities including tight and secure fibers, consistent diameter, consistent color, consistent reflectiveness, and consistent frictional qualities. Thread that is considered low quality or poor condition thread has qualities including loose and fraying fibers, inconsistent diameter, inconsistent color, inconsistent reflectiveness, inconsistent frictional qualities, and is poorly spliced. Additional lights can be provided in or near the sensors—such as the tube-shaped sensor housing 142 described above—to provide a consistent light source when observing the thread so that thread is not misdiagnosed based on color changes in varying lighting conditions, such as, for example, daylight, cool white, horizon, and incandescent lighting. One or more optical sensors of the sewing machine can also detect build-up of debris in areas of the sewing machine where thread debris is known to build up when low quality thread is used, as can be seen in Figure 68.

[0090] Referring now to Figure 69, a flow diagram is shown for an exemplary situation in which the quality of thread used by the sewing machine is shown. In the illustrated scenario, sensors collect data related to the condition of the thread being used in the sewing machine. The data is processed via a previously trained or continuously training neural network to determine whether the thread exhibits any of the markers of a low-quality thread. When poor quality thread is detected, the user is notified (Figure 70) via the notification means disclosed herein, such as, for example, through the user interface, a computer-generated voice, an indicator light, tactile feedback, or the like. The user can

then look at the display of the sewing machine for or request an audible description of further details regarding the quality of the thread. The user can choose to override the warning or to take action, after which the user continues sewing. In sewing machines with multiple spools of thread, the sewing machine can also track the thread parameters of each spool of thread and can inform the user as to which spool, if any, contains low quality thread.

[0091] Another flow diagram for using a neural network to detect thread issues is shown in Figure 101. When the user initiates stitch-out on the sewing machine, data is gathered from: camera(s) directed toward the sewing area; the sewing operation; optical thread sensors; other thread sensors for measuring thread tension, feed rate, and apportionment; a database of known thread materials; and a log of previously identified thread materials. The gathered data is processed through a neural network that has been trained to detect thread compatibility issues, damage, and other thread quality issues. If the neural network identifies the thread and that the thread is incompatible with the current sewing operation (e.g., the thread is likely to break when used in a particular stitch) the sewing machine alerts the user and sewing can continue if the user chooses to override or disregard the notification. The user is also alerted if thread damage or other quality issues are identified. The sewing machine can optionally prohibit further sewing when the damage is sufficient and requires user intervention, for example, to replace the thread.

[0092] The sewing machine can also include multiple thread quality sensor, such as one or more sensors 140 provided in a tube-shaped housing 142 as described above, along the thread path to determine whether the quality of the thread changes along the path. If a decrease in thread quality is found after a particular feature of the thread path, for example, the sewing machine might recommend changes to the sewing parameters to reduce

the likelihood that the sewing machine is causing damage to the thread. Monitoring of the thread quality in multiple locations along the thread path also provides an opportunity for the sewing machine to recommend inspection of various components that may need to be repaired or replaced, such as a guide that may have a sharp edge that is causing fraying of the thread. Such monitoring can also allow the sewing machine to identify improper threading of the sewing machine based on where the thread seems to deviate from the intended thread path through the sewing machine.

[0093] Referring now to Figures 71–81, various views and diagrams are shown that are related to the use of artificial intelligence in the sewing machine to recognize and identify objects placed in view of the optical sensors of the sewing machine and to provide information to the user as to the characteristics of the object and the relationship between the object and the sewing machine. The optical sensors, e.g., cameras, can be those directed toward the sewing area or can be front or user-facing sensors that allow the user to hold up an object in front of the user-facing sensor to detect the component. A library or database of identified objects is stored to enable the sewing machine to build an inventory of known objects, such as components of the sewing machine or accessories for use with the sewing machine. For example, the sewing machine is capable of recognizing the type of needle mounted on the sewing machine and whether the needle is properly mounted (Figures 71–72), the type of presser foot is mounted on the sewing machine and whether the presser foot is properly mounted (Figure 73), the type and characteristics of an embroidery frame mounted on the sewing machine and whether the workpiece is properly mounted within the embroidery hoop (Figure 74), and the fingers and hands of the user and whether there is a safety risk to the user during the current operation (Figure 75). With respect to the embroidery hoop, the sewing

machine can recognize, for example, whether a clamping mechanism for securing the embroidery hoop is secured, whether the workpiece lays flat in the hoop, and that all of the fabric edges are outside of the hoop. The quality of the components can also be identified, that is, the sewing machine can also detect whether a component is damaged, rusted, bent, worn, incorrectly threaded (in the case of needles and loopers), or otherwise altered from acceptable quality standards for the component. In each of these examples, a neural network is employed to process the visual data gathered by the one or more optical sensors of the sewing machine.

[0094] Referring now to Figure 76, data gathered by the various sensors of the sewing machine is processed through a neural network by the computer of the sewing machine to determine whether a particular object is detected by the sewing machine and whether that object is supposed to be there. For example, as can be seen in Figure 77, optical data can be captured that encompasses a range that includes a presser foot of the sewing machine. The visual data of the image is processed through a neural network to determine whether a presser foot is present, what kind of presser foot is present, and whether the presser foot is appropriately mounted. A similar determination can be made for the needle mounted on the sewing machine. Once the presser foot and needle are identified, the corresponding needle translation range for the presser foot is stored and the user can be informed if the combination of needle and presser foot is not recommended. The user can then choose to override the warning, such as, for example, by selecting an “expert mode” that includes an alert as to the possible safety risks involved in choosing “expert mode.” The selected stitch is also compared to the installed presser foot and needle to determine whether the installed presser foot and needle are appropriate for and compatible with the selected stitch or series of stitches in a project. If no presser foot or needle is

installed, a presser foot and needle can be recommended by the sewing machine. Upon installation of the presser foot and/or needle, the sewing machine can examine the presser foot and needle again to confirm that the appropriate presser foot and/or needle have been installed and that the needle and/or presser foot have been appropriately installed. The sewing machine can also identify conflicts between, for example, the needle and the sewing plate, the presser foot and the selected stitch pattern, and the needle or needles and the selected stitch pattern. The incompatibility between a stitch type and a presser foot, for example, can be provided in a table or database of incompatibilities or can be learned over time by monitoring sewing errors in relationship to the identification of various components and the sewing operation performed.

[0095] Another flow diagram for using a neural network to detect objects and identify compatibility and installation issues is shown in Figure 100. When the user initiates stitch-out on the sewing machine, data is gathered from: camera(s) directed toward the sewing area; the sewing operation; a database of known components and accessories previously used with the sewing machine; and a database of known components and accessories that are compatible with the sewing machine. The gathered data is processed through a neural network that has been trained to detect components and accessories, classify those components and accessories, determine whether the components and accessories are correctly installed, and determine whether any the conflicts or other issues arise from the combination of components and accessories and the selected sewing operation. If the neural network identifies that the components are not compatible with the sewing operation or may be likely to cause issues the user is alerted and given the opportunity to override the alert (e.g., like the “expert mode” described above). The neural network identifies whether the components and accessories are correctly installed. If

not, the user is alerted and the sewing machine can be prohibited from operating until the component is removed or correctly installed.

[0096] A similar determination can be made with regards to embroidery hoops that can be mounted above the sewing bed. Once the type and size of embroidery hoop are determined, the sewing machine can inform the user if the selected embroidery pattern will extend beyond the limits of the embroidery frame. The sewing machine can also inspect the edges of the fabric held in the embroidery frame to detect incorrect mounting of the fabric in the hoop. In the event that issues with the fabric mounting or the embroidery hoop size are detected, the user can be informed via any of the notification means described herein, such as a visual display of information on the display of the sewing machine, an audible notification, or tactile feedback.

[0102] While identifying and inspecting the embroidery hoop or when specified by the user, the camera or cameras directed toward the sewing bed can be used to capture images of a workpiece mounted in the embroidery hoop. The entire workpiece can be captured in a single image or the embroidery hoop can be moved to capture multiple images of the workpiece that are stitched together to form a single image of the entire workpiece. Data gathered during the scanning process can be used as input into a neural network trained to recognize and predict colors. This pre-learned color calibration facilitates more accurate color predictions over time as the neural network learns from correct recognition of colors. The scanning data can also be used as input for a neural network that is trained to detect translation skips or other movement anomalies so that the actuation system for the embroidery hoop can be controlled to correct for the anomalies.

[0103] Other accessories can also be identified when attached to the sewing machine and the sewing machine can provide feedback as to whether the accessory is properly mounted and whether the machine is configured to operate properly with that accessory. For example, when a user attaches an accessory used to attach ribbon to a workpiece to the machine, the sewing machine can display information relating to the accessory on the screen to assist the user in the proper use of the accessory. The functions of the sewing machine can also be limited to those that are compatible with the accessory unless such limits are overridden by the user. The sewing machine can also display information on the screen related to materials that can be used with the accessory and can recommend other accessories to the user.

[0097] Referring now to Figures 78–81, various views and diagrams of exemplary presser feet, sewing needles, and other components are shown that include features designed to make the presser feet and needles more easily recognized via object recognition techniques, such as through the use of a neural network or by way of sensors—including magnetic sensors—configured to detect features of the components. The presser foot, sewing needle, needle plate, or other sewing machine component can include various markers that improve the robustness of optical or other sensor-based object recognition systems. For example, the markers or markings can include a pattern of two or more geometric shapes (Figures 78–81), a stripe of color in a particular location (Figure 80), the overall shape of the component including recognizable protrusions or recesses, painted color codes and other color treatments, reflective finishes, bar codes, QR codes, and other surface treatments enabling UV, IR, or other optical sensing techniques. The marker can include a unique pattern of etched rings or lines, a shape or a pattern that is etched, debossed, or embossed in the surface of the sewing machine component. The marker can also be made from different regions of

the surface of the sewing machine component having a surface finish with varying reflectivity; i.e., the marker can include a first region having a first surface finish and a second region having a second surface finish. The marker can employ electronic identification techniques, such as a near-field communication (NFC) device and a radio frequency identification (RFID) device.

[0098] An additional alternative identification could be based on markers having magnetic field line profiles or polarity profiles for each component that can be detected by sensors when the component is mounted in the sewing machine. For example, a needle can include a magnet for forming a particular magnetic field that is only detected when the needle is inserted into the needle bar. Similar techniques are applied to embroidery hoops to improve the recognition of such hoops via a neural network or other object recognition technique.

[0099] Referring now to Figures 82–84, various views and diagrams are shown that are related to providing tactile feedback to the user in relation to the use of the sewing machine. Tactile feedback is feedback provided to the user via means that can be felt. For example, a control component (e.g., a knob, a button, a pedal, a lever, slider, or the like, such as the components shown in Figure 83) that the user is interacting with may vibrate slightly when a particular position is reached, or there may even be resistance to further movement of the control object. Small vibrations can also be provided through surfaces of the sewing machine on which the users hands and fingers may rest during use, such as the sewing bed. Tactile feedback can be used to alert the user of a particular condition of the sewing machine or workpiece or can be used as further reinforcement to the user that an action taken by the user has been received. For example, the sewing bed can vibrate underneath the workpiece and users hands when the user has deviated from a desired sewing path. Or, the knob or a button can

vibrate to indicate that the button was pressed or the knob has reached a particular position. Tactile feedback can also replace mechanical features that would provide similar feedback, such as detents in a knob that indicate particular positions around the knob have been reached. Haptic feedback can be used on any sewing machine surface. Vibrotactile haptic feedback, via piezoelectric sensors, can be used on any surface of the sewing machine and can be used to replace mechanical user interfaces. Piezoelectric and capacitive sensors can be arranged in an array under an OLED or similar type screen that is formed such that it replaces traditional plastic sewing machine covers. The presence of the user's fingers on or near the OLED interface engages menus that are activated based on user requests or current sewing actions and relevant user interface needs, such as, for example, finger taps, sliding, and scrolling motions for threading, adjusting thread tension, and activating or deactivating sewing accessories. Other forms of haptic feedback can include force, electro-tactile, ultrasound, air vortex rings, and thermal haptic feedback.

[0100] Referring now to Figure 83, a flow diagram is shown for an exemplary situation in which tactile feedback can be employed. In the illustrated scenario, the user has attached a presser foot to the machine that is recognized via neural network processing of the visual data received from an optical sensor or other sensors of the machine. The user then selects a particular pattern or sewing stitch to perform. The sewing machine then determines whether the combination of the particular presser foot and the selected operation is a valid combination—i.e., whether the attached presser foot is capable of being used with the particular stitch selected—and provides tactile and other feedback to the user if the combination is not valid. This tactile feedback can be provided in a location of last action, such as via the touch screen when the user selected the stitch or other operation to perform. At the same

time, visual and audible alerts can be provided to the user that the presser foot and selected operation are not compatible and also prompting the user to install the correct presser foot or to choose a compatible operation (Figure 84). The interface can also provide the option for the user to override the warning.

[0101] Referring now to Figures 85–88, various views and diagrams are shown that are related to the use of artificial intelligence in the sewing machine to monitor the mechanical and electrical health of the sewing machine. Operating a sewing machine generates a wide variety of sounds and mechanical vibrations, as well as variations in the electrical signals that drive the motors and actuators of the sewing machine. An exemplary sewing machine includes sensors for monitoring sounds and noises, mechanical vibration, and electrical signals to identify patterns that relate to the performance of the associated component. Sensors can also be provided on or near various components to measure the component temperature, an increase of which may indicate excessive wear. The sensors are arranged in a wide variety of locations on the sewing machine, as can be seen in Figure 85. The sensors can be active continuously or can be turned on to gather data during particular times, such as, for example, during a start-up procedure, an idle state, an active state, and a shut-down procedure.

[0102] The gathered data can be processed through a neural network that has been trained to detect performance issues in the components of the particular sewing machine at issue. Such as, for example, certain sounds may be associated with the rubbing together of two components that in turn indicates that a bushing or bearing needs to be replaced. Or the voltage required to run a motor at a particular speed may be higher when the motor performance has degraded as compared to a motor running at a nominal condition. The motor performance can be monitored to

determine when an issue has arisen, such as when performing a certain task or when working with a certain fabric or thread material. These situations can also be recognized via an increase in the heat generated by the components of the machine and a corresponding increase in temperature of certain components. More importantly, the sensors used by the sewing machine can be significantly more sensitive to changes in the sounds or other parameters generated by the sewing machine components and can therefore make earlier predictions than might otherwise be possible, such as those made by an experienced service technician. Additionally, these performance issues can be correlated with other information from the sewing machine such as, for example, the sewing operation being performed at the time the performance issue was detected and identified. In this way, particular performance issues can be associated with particular uses of the sewing machine and the information regarding the relationship can be provide to engineers and service technicians to better identify the causes of repairs and to improve future designs. As with other data gathered by the sewing machine and generated by a neural network, data can be sent to the cloud for sharing with other sewing machines to improve the training of the neural networks of all of the sewing machines in the network.

[0103] Referring now to Figure 86, a flow chart is presented that shows various ways in which diagnostic information can be generated by the sewing machine and used by the user. When the neural network of the sewing machine computer identifies that a correction to the machine is needed, the incident is logged and the user is notified. The user can then be instructed to perform a particular task to correct the issue, such as removing thread or moving the sewing machine to a stiffer table. Having taken the action, the sewing machine can be used normally while diagnostics are performed on regular intervals to see if additional corrective measures are needed. If the user does not take

corrective action, the motor or other actuator can be calibrated to attempt to correct the issue. If calibration does not correct the issue, the user can be notified, the incident logged, and a service request can be sent to a service provider. Calibration can also be set to be performed every certain number of cycles of the motor or other component as preventative maintenance. Calibration can also be performed when changing the thread used and the fabric being worked with, or for any job performed by the sewing machine.

[0104] Once a potential issue has been diagnosed, the sewing machine can inform the user of the issue in a wide variety of means, such as those described in the present disclosure. In particular, the sewing machine can present an alert to the user via the user interface, audibly alert the user, speak to the user via a computerized voice, and/or send an email to the user via the network connection. For example, the sewing machine can present the user with an indication that maintenance is needed and prompt the user to schedule a service request with a service dealer, as shown in Figure 87. Alternatively, as is shown in Figure 88, the sewing machine can suggest changes to the operating environment to improve the performance of the sewing machine, as is described in greater detail below. When a change to the operating environment or repair actions are deemed necessary or recommendable, the user is alerted and instructional illustrations, animations, and videos on the touch screen or via localized guiding illumination or else 2D or 3D static or dynamic light projection, can be used to guide the user to alter the user's working environment by placing the sewing machine on a stiffer table to reduce vibration or to guide the user through a simple repair or a technician through a complex repair of the machine.

[0105] For software issues, updates can be installed automatically so that the user is unaware of the update. Alternatively, the user

can be guided through a software update process and customer service representatives can be contacted through the user interface to offer support and correction to the software issues. Referring now to Figure 99, an example flow diagram is shown for using a neural network with automatic software updates, as described above. When the sewing machine has not been used for a predetermine period of time—i.e., the user has been inactive—data can be gathered from a user interaction or activity log, user facing cameras and microphones, a network interface connected to a software update server, and a clock providing the current date and time. If a software update is available, the neural network provides an indication as to whether the user is typically away from the sewing machine at the time of day that would be long enough for the software update to be installed prior to the user returning to the machine. If enough time is available, the software update is allowed to install if the user has enabled automatic updates. A similar process can be followed for calibration of the various sensors, motors, actuators, and the like.

[0106] The sewing machine can also include light sources, such as LED lights, arranged near various components that are known to wear out during use so a particular component can be illuminated with a light—for example, with a yellow, orange, or red color—to indicate that the component has degraded performance and may need to be serviced or replaced. These lights can be activated when the machine is placed in a maintenance or service mode and can quickly provide a picture of the overall health of the machine.

[0107] The information pertaining to the health of the sewing machine can be stored in a health log and can be transmitted to a remote customer service representative or service technician to assist the remote worker in determining what maintenance, if any, may need to be performed on the machine and whether the sewing machine needs to be sent to a service center for repairs. The

health data for the sewing machine, with permission from the user, might also be automatically sent to a dealership, service center, and/or the manufacturer so that the recipient of the data can take proactive steps to order replacement components and to notify customers that particular component(s) of the sewing machine may soon need to be replaced. In a commercial setting, the owner of the sewing machine may choose to subscribe to a maintenance plan where such replacement parts are delivered or service calls are scheduled automatically so that the sewing machine maintains a particular uptime.

[0108] The historical data recorded in health logs can be particularly helpful when diagnosing the cause of a sewing machine failure. For example, historical temperature data can include both ambient temperature readings and temperature readings at various points throughout the machine. Ambient temperature history can reveal that the sewing machine has been exposed to excessive heat that damaged the sewing machine. Point temperature readings—i.e., temperature readings at specific locations within the sewing machine—can aid the technician in determining the root cause of damage to the sewing machine, such as wear between components that are damaged. Historical vibration or acceleration data can be used similarly. Acceleration data can also indicate whether the machine has experienced a drop or fall that is the cause of the damage.

[0109] As has been described above, the optical sensors can be used in conjunction with the neural network to detect when the user's fingers or some other foreign object would be in the way of the sewing head and could cause injury to the user or damage to the machine. Similarly, a neural network can be trained to recognize whether the user's fingers or other foreign objects are in the way of the presser foot, a cutting accessory, or any other moving component of the sewing machine that could cause harm to the

user during use of the machine. When fingers or other foreign objects are detected, the sewing machine can control the needle and other components to avoid the object or can prohibit further sewing if avoidance is impossible or the potential for harm is sufficiently great to warrant prohibition of further operating of the sewing machine. For example, the sewing machine can prohibit lowering of the presser foot when fingers are detected beneath the presser foot. Or the sewing machine can prohibit further sewing when fingers or the user's hand are detected in the sewing path. If a foreign object detected is a pin inserted into a seam, the sewing machine can adjust the feed rate or other sewing parameters to avoid the needle striking the pin.

[0110] The neural network can also take into consideration the orientation of the sewing machine (via accelerometers and/or pressure sensors on the base) so that the sewing machine can be turned off or be prevented from starting if the sewing machine is tipped over is leaning far enough to top over and possibly injure the user. The accelerometer can also be active when the sewing machine is in sleep mode or standby mode to detect movement of the machine and prohibit powering the machine if the sewing machine is moved or picked up or knocked over. Heat data from temperature sensors can be fed into the neural network so that the machine can be automatically turned-off to prevent overheating of components or because the heat build-up may be a symptom of an electrical anomaly.

[0111] User-facing proximity sensors (e.g., infrared sensors) and/or cameras can be used to monitor the presence of the user of the sewing machine so that the sewing machine can be automatically turned off after the user has been absent for a predetermined time to save energy. These user-facing sensors can also prevent activation of the sewing machine after determining, via a neural network or other means, that an unauthorized person is

attempting to access the machine. For example, the neural network can be trained to recognize a child attempting to access the sewing machine. In response, the computer can prevent activation of the sewing machine and notify authorized users of the attempted access by generating an audible sound or by sending a notification to the user via an internet connection, a text message, or a smart phone app. An exemplary flow diagram for a child safety feature is shown in Figure 98. The child safety analysis can be trigger for a wide variety of reasons, such as after an unsuccessful attempt to access the sewing machine is made or during a long embroidery stitch-out when the user may want to leave the machine. Data is then gathered from a user-facing camera, microphones, and various user interface elements such as the touch screen, buttons, and knobs. If the neural network determines that a child is attempting to access the sewing machine or is approaching operating components of the sewing machine, the sewing machine can emit an audible alert and send an alert to a mobile device assigned to an authorized user. If the child does not respond to the alert, the sewing machine can repeat the alert and stop the sewing operation to prevent harm. If the neural network determines that the unsuccessful attempt is not made by a child, the sewing machine can still emit an audible alert and send a message to the authorized user. As another example, the sewing machine can periodically monitor the environment surrounding the sewing machine to identify the presence of a person, such as the user or a child. This periodic monitoring can be, for example, performed when a longer embroidery stitch-out is in progress and there is a possibility of disruption to the embroidery workpiece or harm to a person if a child were to get too close to the sewing operation that is in progress. If a child is detected, the stitch-out operation can be stopped and an alert can be sent to the user to notify the user that the sewing operation has stopped and the reason for doing so.

[0112] As the sewing machine is used, the profile settings set by the user, user preferences, graphical user interface settings, feedback settings, object recognition preferences, tutorial preferences, and the like are monitored and stored. Going beyond the machine settings, every interaction between the user and the sewing machine can be recorded and stored. This collection of data pertaining to the interaction between the user and the sewing machine is processed through a neural network so that the sewing machine can learn how the user prefers to interact with the sewing machine and can anticipate what the user might prefer in a new situation. That is, the setting changes can be related to the project, stitch type, thread type, material type, or the like, as detected by the sewing machine or provided by the user. This collection of data enables the sewing machine to assist the user, for example, by suggesting a feed rate setting for a stitch that the user has never sewn based on the characteristics of the new stitch and the feed rates that the user has set for other stitch patterns. As another example, the sewing machine can remind the user of settings that are usually set given the current context, that is, by suggesting a certain feed rate or sewing pitch for a thinner material and a different feed rate or sewing pitch for a thicker material. An exemplary workflow for recommending setting changes using a neural network is shown in Figure 97. When settings are changed, the data is gathered from user interaction logs, current real-time interaction with the user, from other sensors and neural networks regarding the sewing material, and from data pertaining to the current sewing operation. If the neural network identifies that the user typically makes the same change in similar contexts, the sewing machine prompts the user to decide if the default setting should be changed. If the change to the setting is not typically made in similar contexts, the sewing machine can prompt the user to confirm that the change was intended. Also, the neural network can identify other settings

that might typically be changed in a similar context and suggest those other changes to the user.

[0113] The sewing machine can also suggest that the user take a break from using the machine from time to time or perform exercises to improve the ergonomic health of the user. The timing of the suggestions and the type of exercises and break durations suggested are based on an analysis of the use of the machine by a neural network trained to monitor the health of the user. The posture of the user can also be detected via neural network analysis of data from one or more user-facing cameras so that the exercise suggestions can be further customized to benefit the user.

[0114] Conditions of the user's workspace can also be detected by the sewing machine and analyzed by a neural network. Ambient light sensors can allow the neural network to consider the lighting conditions of the sewer's room and workspace lighting to reduce or soften the contrast between the working area and the room. For example, the sewing machine can suggest that the room lights be brightened to reduce eye strain caused by the contrast between a bright work surface at the sewing machine and a dark room. The sewing machine can also connect to the lighting system of the workspace and room, for example, through a wi-fi network, to manage adjustments to the brightness automatically. User-facing cameras can be used to determine the height of the work surface, the position of the user's chair, and other environmental conditions. Where active control surfaces can be accessed by the sewing machine—such as, for example, a worktable with a controllable height—the sewing machine can suggest and make adjustments to improve the ergonomics of the work environment. Figure 103 shows an exemplary flow diagram that demonstrates how the sewing machine can reduce strain on the user by monitoring the environment around the sewing machine. During use of the sewing machine, data gathered from accelerometers,

photo sensors, user-facing cameras, and historical logs from previous sessions can be processed through the neural network to identify user-health issues. For example, the neural network can identify if the user is tending to sit with a poor posture and can recommend changes, such as, for example, adjustments to the user's chair. The neural network can also identify if the work surface is unstable by monitoring vibration and acceleration data and recommend adjustments to the work surface so that it is level and less prone to movement during use of the sewing machine.

[0115] As has been noted above, the data gathered by the various sensors on the sewing machine and data generated by monitoring how the sewing machine is used can be stored in a database on the machine and can be transmitted to a remote server. Data transmitted to various remote servers can be gathered into a central database and used to analyze sewing machine performance and user sewing behavior across a much larger data set. So-called "big data" analysis can reveal patterns that are not otherwise detectable in smaller data sets. The results of this analysis can be fed back into the neural networks of the sewing machines or remote neural networks that operate to support the operation of the sewing machines, thereby improving the quality of the results determined by the neural networks. Big data analysis can also help research and development teams improve quality control processes at the factory and the testing of various components performed in a lab environment. For example, failure modes can be identified via big data analysis that may not have been predicted during initial development of a machine and future generations of parts and processes can be changed in response.

[0116] While various inventive aspects, concepts and features of the disclosures may be described and illustrated herein as embodied in combination in the exemplary embodiments, these various

aspects, concepts, and features may be used in many alternative embodiments, either individually or in various combinations and sub-combinations thereof. Unless expressly excluded herein all such combinations and sub-combinations are intended to be within the scope of the present application. Still further, while various alternative embodiments as to the various aspects, concepts, and features of the disclosures—such as alternative materials, structures, configurations, methods, devices, and components, alternatives as to form, fit, and function, and so on—may be described herein, such descriptions are not intended to be a complete or exhaustive list of available alternative embodiments, whether presently known or later developed. Those skilled in the art may readily adopt one or more of the inventive aspects, concepts, or features into additional embodiments and uses within the scope of the present application even if such embodiments are not expressly disclosed herein.

[0117] Additionally, even though some features, concepts, or aspects of the disclosures may be described herein as being a preferred arrangement or method, such description is not intended to suggest that such feature is required or necessary unless expressly so stated. Still further, exemplary or representative values and ranges may be included to assist in understanding the present application, however, such values and ranges are not to be construed in a limiting sense and are intended to be critical values or ranges only if so expressly stated.

[0118] Moreover, while various aspects, features and concepts may be expressly identified herein as being inventive or forming part of a disclosure, such identification is not intended to be exclusive, but rather there may be inventive aspects, concepts, and features that are fully described herein without being expressly identified as such or as part of a specific disclosure, the disclosures instead being set forth in the appended claims. Descriptions of exemplary

methods or processes are not limited to inclusion of all steps as being required in all cases, nor is the order that the steps are presented to be construed as required or necessary unless expressly so stated. The words used in the claims have their full ordinary meanings and are not limited in any way by the description of the embodiments in the specification.

CLAIMS

What is claimed is:

1. A sewing machine comprising:

a sewing head attached to an arm suspended above a sewing bed by a pillar;

a needle bar extending from the sewing head and toward the sewing bed, wherein the needle bar holds a needle for forming stitches in a workpiece with a thread;

a regulatable component of the sewing machine, wherein the regulatable component can be regulated to alter a current state of the sewing machine;

a user interface for receiving input from the user of the sewing machine and for communicating feedback information to the user;

at least one data gathering device for gathering data related to at least one of the sewing machine, an environment surrounding the sewing machine, a sewing material, the sewing operation performed by the sewing machine, and one or more interactions of the user with the sewing machine;

at least one data storage device for storing data gathered by the data gathering device as gathered data and for storing data related to a neural network, the neural network comprising a plurality of nodes, wherein each node comprises:

an input connection for receiving input data;

at least one node parameter;

a calculation unit for calculating an activation function based on the input data and at least one node parameter; and

an output connection for transmitting output data; and

at least one processor configured to:

processes the gathered data through the neural network to generate processed data; and

control, based on the processed data, at least one of the user interface to interact with the user, the data storage device to store the processed data, and the regulatable component to alter the current state of the sewing machine.

2. The sewing machine of claim 1, wherein:

the data gathering device comprises an optical sensor for gathering data from a field of view that encompasses at least a portion of any of the needle, a presser foot, a needle plate, and a sewing accessory; and

the processor is configured to process the data generated by the optical sensor through the neural network to generate object detection data and object classification data related to at least one of the needle, the presser foot, the needle plate, and the sewing accessory.

3. The sewing machine of claim 2, wherein the processor is configured to control the user interface to present the object detection data and the object classification data to the user.

4. The sewing machine of either claim 2 or claim 3, wherein the object classification data comprises object position data and object orientation data.

5. The sewing machine of claim 4, wherein the processor is configured to determine whether at least one of the needle, the presser foot, the needle plate, and the sewing accessory are incorrectly installed based on the object position data and object orientation data.

6. The sewing machine of claim 5, wherein the processor is configured to control the user interface to alert the user based on a determination that any of the needle, the presser foot, the needle plate, and the sewing accessory are incorrectly installed.

7. The sewing machine of any of claims 2–6, wherein the processor is configured to determine whether an incompatible combination exists between at least two of the needle, the presser foot, the needle plate, and the sewing accessory based on the object classification data and user input received from the user interface.

8. The sewing machine of claim 7, wherein the processor is configured to prohibit operation of a motor of the sewing machine based on a determination that an incompatible combination exists.

9. The sewing machine of either of claim 7 or claim 8, wherein the processor is configured to control the user interface to alert the user based on a determination that an incompatible combination exists.

10. The sewing machine of any of the above claims, wherein the regulatable component comprises at least one of a motor, an actuator, a light, a speaker, a thread tensioner, a thread portioner, a knife, a presser foot, a needle bar, and a feed mechanism.

11. The sewing machine of any of the above claims, further comprising a projector for projecting a sewing guide onto at least one of the workpiece and the sewing bed.

12. The sewing machine of claim 11, wherein the element of the user interface comprises at least one sewing guide.

13. The sewing machine of any of the above claims, wherein:

    the data gathering device comprises at least one of an optical sensor, an ultrasonic vision system, and a thermal vision system for gathering sewing material data comprising workpiece data; and

    the processor is configured to process the workpiece data through the neural network to generate workpiece detection data and workpiece classification data.

14. The sewing machine of any of claim 13, wherein the workpiece classification data comprises at least one of color, pattern, reflectivity, thickness, density, fiber type, weave type, weave orientation, topography, orientation, and damage.

15. The sewing machine of any of the above claims, wherein:

    the data gathering device comprises at least one of an optical sensor, a color sensor, a light sensor, a camera, and a thermal sensor for gathering sewing material data comprising thread data; and

    the processor is configured to process the thread data through the neural network to generate thread classification data.

16. The sewing machine of any of claim 15, wherein the thread classification data comprises at least one of color, density, thickness, surface quality, material, and damage.

17. The sewing machine of any of the above claims, wherein the processor is configured to determine whether an incompatible combination exists between the workpiece and the thread based on the workpiece classification data and the thread classification data.

18. The sewing machine of any of the above claims, wherein the processor is configured to determine whether an incompatible combination exists between at least two of workpiece, the thread, the needle, the presser foot, the needle plate, and the sewing accessory based on the workpiece classification data, the thread classification data, and the object classification data.

19. The sewing machine of either of claim 17 and claim 18, wherein the processor is configured to control the user interface to alert the user based on a determination that an incompatible combination exists.

20. The sewing machine of any of claims 13–19, wherein the processor is configured to process the workpiece data through the neural network to generate feature detection data and feature classification data related to at least one of a seam, an edge, a pocket, a button hole, a pattern, a weave orientation, a defect, and a stitching of the workpiece.

21. The sewing machine of claim 20, wherein the processor is configured to control the projector to project the sewing guide at a location of a detected feature of the feature detection data.

22. The sewing machine of claim 20, wherein the processor is configured to control the projector to project the seam sewing at a predetermined distance from a location of a detected feature of the feature detection data.

23. The sewing machine of any of claims 20–22, further comprising:

a swing motor for laterally swinging the needle bar during a sewing operation; and

a feed mechanism for translating the workpiece forward, backward, left, and right and for rotating the workpiece.

24. The sewing machine of claim 23, wherein the processor is configured to control the swing motor and the feed mechanism to form stitches in the workpiece at the location of a detected feature of the feature detection data.

25. The sewing machine of claim 23, wherein the processor is configured to control the swing motor and the feed mechanism to form stitches in the workpiece at a predetermined distance from the location of a detected feature of the feature detection data.

26. The sewing machine of any of the above claims, wherein:

the data gathering device comprises an optical sensor for gathering optical data from a field of view that encompasses at least a portion of the needle, the workpiece, the thread, and stitches formed in the workpiece; and

the processor is configured to process the optical data through the neural network to generate stitch recognition data, stitch classification data, sewing operation data, and sewing error data.

27. The sewing machine of claim 26, wherein the sewing error data comprises sewing operation error events comprising at least one of a skipped stitch, an unbalanced stitch, a misaligned stitch, a seam pucker, a stitch density variation, a bobbin thread break, a looper thread break, a needle thread break, a fused thread, a needle break, a stuck needle, a needle striking the needle plate, a

thread cut by the needle, inconsistent thread tension, a wavy seam, an unthreaded needle, a loose needle holder, a loose presser foot, a mislocated presser foot, an immobile needle, an immobile workpiece, a bunching workpiece, a bunching thread, a knot in the thread, a loose stitch, a tangle in the thread, a frayed thread, a shredded thread, a workpiece feed variation, a bent needle, a damaged looper, a damaged stitch finger, a mislocated looper, a mislocated stitch finger, and a dull fabric knife.

28. The sewing machine of either of claim 26 and claim 27, wherein the processor processes the sewing error data and at least one of the object recognition data, object classification data, workpiece classification data, thread classification data, stitch recognition data, stitch classification data, and sewing operation data through the neural network to generate error relationship data.

29. The sewing machine of claim 28, wherein the processor controls the user interface to communicate the error relationship data to the user.

30. The sewing machine of either of claim 28 and claim 29, wherein the processor controls at least one of the regulatable component and the actuator to prevent sewing operation error events based on the error relationship data.

31. The sewing machine of any of the above claims, wherein:

the data gathering device comprises at least one of a microphone, an accelerometer, a temperature sensor, a current sensor, and a voltage sensor for gathering sewing machine data comprising performance data; and

the processor is configured to process the performance data through the neural network to generate at least one of defect classification data and fault prediction data.

32. The sewing machine of any of the above claims wherein:

the data gathering device comprises at least one of a microphone, an accelerometer, a temperature sensor, a photo sensor, and an optical sensor having a field of view including at least a portion of the user for gathering environment data; and

the processor is configured to process the environment data through the neural network to generate at least one of object detection data, object classification data, user detection data, user classification data, user command data, and environment classification data.

33. The sewing machine of any of the above claims wherein:

the data gathering device comprises at least one of a microphone, an optical sensor having a field of view including at least a portion of the user, and a user interaction log of the user interface for gathering user interaction data; and

the processor is configured to process the user interaction data through the neural network to generate skill level classification data to estimate the skill level of the user.

34. The sewing machine of claim 33, wherein the processor controls the user interface to recommend training exercises based on the skill level classification data.

35. The sewing machine of any of the above claims, wherein the processor is configured to update the node parameters of the neural network based on the processed data generated by the neural network and the gathered data.

36. The sewing machine of either of claim 34 and claim 35, wherein the processor is configured to update the node parameters of the

neural network according to a plurality of trained node parameters of a trained neural network.

37. The sewing machine of claim 36, wherein the trained node parameters are downloaded via a network interface.

38. The sewing machine of any of claims 34–37, wherein the node parameters comprise at least one of an input parameter, a function parameter, and an output parameter.

39. The sewing machine of claim 38, wherein the input parameter is a weight parameter associated with the input connection.

40. The sewing machine of claim 38, wherein the function parameter is a threshold value.

41. The sewing machine of any of the above claims, further comprising a network interface configured to:

transmit gathered data to a remote processor for processing the gathered data through a remote neural network to generate remote processed data; and

receive the remote processed data.

42. The sewing machine of any of the above claims, wherein the processor is configured to determine whether at least one of the needle, the presser foot, the needle plate, and the sewing accessory are damaged based on the object classification data.

43. The sewing machine of any of the above claims, wherein the processor is configured to control the user interface to alert the user based on a determination that any of the needle, the presser foot, the needle plate, and the sewing accessory are damaged.

44. The sewing machine of any of the above claims, wherein the processor is configured to prohibit operation of the sewing

machine based on a determination that any of the needle, the presser foot, the needle plate, and the sewing accessory are damaged.

45. The sewing machine of any of the above claims, wherein the data gathering device comprises at least one of an acoustic sensor, a sound sensor, a vibration sensor, a chemical sensor, a biometric sensor, a sweat sensor, a breath sensor, a fatigue sensor, a gas sensor, a smoke sensor, a retina sensor, a fingerprint sensor, a fluid velocity sensor, a velocity sensor, a temperature sensor, an optical sensor (e.g., a camera), a photosensor, an infrared sensor, an ambient light level sensor, a color sensor, an RGB color sensor, a CMYK color sensor, a gray scale color sensor, a touch sensor, a tilt sensor, a motion sensor, a metal sensor, a magnetic field sensor, a humidity sensor, a moisture sensor, an imaging sensor, a photon sensor, a pressure sensor, a force sensor, a density sensor, a proximity sensor, an ultrasonic sensor, a load cell, a digital accelerometer, a translation sensor, a friction sensor, a compressibility sensor, a voice sensor, a microphone sensor, a voltage sensor, a current sensor, an impedance sensor, a barometer, a gyroscope, a hall-effect sensor, a magnetometer, a GPS receiver, an electrical resistance sensor, a tension sensor, and a strain sensor.

46. The sewing machine of any of the above claims, wherein the data gathering device comprises at least one of a user activity log and a system event log.

47. A method of controlling a sewing machine, the method comprising:

gathering data related to at least one of the sewing machine, an environment surrounding the sewing machine, a sewing material, a sewing operation performed by the sewing

machine, and one or more interactions of a user with the sewing machine;

storing the gathered data in a data storage device;

processing the gathered data through a neural network, the neural network comprising a plurality of nodes, wherein each node comprises:

an input connection for receiving input data;

a node parameter;

a calculation unit for calculating an activation function based on the input data and a node parameter; and

an output connection for transmitting output data; and

controlling, based on the processed data, at least one of the user interface to interact with the user, the data storage device to store the processed data, and a regulatable component to alter at least one of a state of the sewing machine and a performance of the sewing machine.

48. A control system for a sewing machine, the control system comprising:

a data gathering device for gathering data related to at least one of the sewing machine, an environment surrounding the sewing machine, a sewing material, the sewing operation performed by the sewing machine, and one or more interactions of the user with the sewing machine;

a data storage device for storing data gathered by the data gathering device as gathered data and for storing data related to a neural network, the neural network comprising a plurality of nodes, wherein each node comprises:

an input connection for receiving input data;

a node parameter;

a calculation unit for calculating an activation function based on the input data and a node parameter; and

an output connection for transmitting output data; and

a processor configured to:

processes the gathered data through the neural network to generate processed data;

store processed data in the data storage device; and

control, based on the processed data, at least one of a user interface to interact with the user and a regulatable component to alter the current state of the sewing machine.

49. The control system of claim 48, wherein the data gathering device comprises a local data gathering device and a remote data gathering device.

50. The control system of either of claim 48 and claim 49, wherein the data storage device comprises a local data storage device and a remote data storage device.

51. A component for a sewing machine comprising:

an attachment portion for removably attaching the component to the sewing machine; and

a marker for indicating at least one of the identity and the orientation of the component, wherein the marker is detectible via a detection system of the sewing machine.

52. The component for a sewing machine of claim 51, wherein the component comprises at least one of a needle, a needle plate, a presser foot, and an embroidery frame.

53. The component for a sewing machine of either claim 51 and claim 52, wherein the marker comprises a plurality of geometric shapes.

54. The component for a sewing machine of any of claims 51–53, wherein the marker comprises a colored stripe.

55. The component for a sewing machine of any of claims 51–54, wherein the marker comprises a painted color code.

56. The component for a sewing machine of any of claims 51–55, wherein the marker comprises a reflective finish.

57. The component for a sewing machine of any of claims 51–56, wherein the marker comprises a ultraviolet reactive surface treatment.

58. The component for a sewing machine of any of claims 51–57, wherein the marker comprises a infrared reactive surface treatment.

59. The component for a sewing machine of any of claims 51–58, wherein the marker comprises a magnet having a distinct magnetic field line profile.

60. The component for a sewing machine of any of claims 51–59, wherein the marker is invisible to the naked eye of a user of the sewing machine.

61. The component for a sewing machine of any of claims 51–60, wherein the marker comprises a near-field communication device.

62. The component for a sewing machine of any of claims 51–61, wherein the marker comprises a radiofrequency identification device.

63. The component for a sewing machine of any of claims 51–62, wherein the marker comprises a pattern of at least one of etched rings and etched lines.

64. The component for a sewing machine of any of claims 51–63, wherein the marker comprises of at least one of an etched portion, a debossed portion, and an embossed portion.

65. The component for a sewing machine of any of claims 51–64, wherein the marker comprises a first region having a first surface finish and a second region having a second surface finish.

66. A sewing machine comprising:

a sewing bed, the sewing bed comprising a feed mechanism and a needle plate, wherein a workpiece can be placed on and moved across the sewing bed;

a sewing head arranged above the sewing bed, the sewing head comprising:

a needle bar extending toward the sewing bed to a distal end;

at least one needle attached to the distal end of the needle bar;

an accessory bar extending toward the sewing bed to a distal end;

at least one accessory attached to the distal end of the accessory bar;

a camera having a field of view encompassing at least a portion of any of the sewing bed, the needle plate, the workpiece, the needle, and the accessory, wherein the camera generates a camera data signal related to the portions of the sewing bed, the needle plate, the workpiece, the needle, and the accessory in the field of view of the camera;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine;

at least one component recognition neural network that is trained to identify at least one of the needle plate from a plurality of needle plates, the needle from a plurality of needles, and the accessory from a plurality of accessories from the camera data signal, wherein the neural network generates a component identity data signal comprising an identified component; and

at least one processor configured to:

receive, from the user interface, an indication of a stitch pattern selected by the user of the sewing machine;

receive, from the neural network, an indication of the identified component via the component identity data signal;

determine whether the stitch pattern selected by the user is compatible with the identified component; and

control the user interface to present an indication of the compatibility between the selected stitch pattern and the identified component.

67. The sewing machine of claim 66, wherein the accessory bar is a presser bar and the at least one accessory is a presser foot.

68. The sewing machine of claim 66 or claim 67, wherein:

the at least one component recognition neural network is trained to determine whether at least one of the needle plate, the needle, and the accessory are incorrectly installed, wherein the neural network generates an incorrect assembly data signal comprising an incorrectly installed component; and

the processor is configured to control the user interface to present an indication of the incorrectly installed component.

69. The sewing machine of claim 68, wherein the processor is configured to prohibit operation of the sewing machine while the incorrectly installed component remains incorrectly installed.

70. The sewing machine of any of the above claims, wherein:

the identification data signal comprises data related to two or more identified components; and

the processor is configured to determine whether an incompatibility exists between the two or more identified components.

71. A sewing machine comprising:

a sewing bed, the sewing bed comprising a feed mechanism and a needle plate, wherein a workpiece can be placed on and moved across the sewing bed;

a sewing head arranged above the sewing bed, the sewing head comprising a needle bar extending toward the sewing bed to a distal end holding a needle for performing a sewing operation with the workpiece;

a control system of the sewing machine having a plurality of settings for altering at least one of a current state of the sewing machine and a performance characteristic of the sewing machine;

a user interaction log comprising at least one of historical current state data and historical performance characteristic data;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine, wherein the input received from the user changes a setting of the control system;

a neural network that is trained to identify a setting context related to the changed setting from the current state of the sewing machine, the performance characteristic of the sewing machine, and the user interaction log, wherein the neural network generates a setting context data signal comprising an identified setting context; and

at least one processor configured to:

receive, from the user interface, an indication of the changed setting of the control system;

receive, from the neural network, an indication of the identified setting context via the setting context data signal;

determine a suggested default setting change based on the changed setting and the identified setting context; and

control the user interface to present the suggested default setting change.

72. The sewing machine of claim 71, wherein the processor is configured to:

determine a suggested related setting change based on the changed setting and the identified setting context; and

control the user interface to present the suggested related setting change.

73. A sewing machine comprising:

a workspace sensor comprising at least one of:

a camera facing away from the sewing machine, wherein the camera generates a camera data signal; and

a microphone that generates a microphone data signal;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine;

a speaker;

a neural network that is trained to identify that a child is attempting to interact with the sewing machine from at least one of the camera data signal, the microphone data signal, and the input received by the user interface, wherein the neural network generates a child detection data signal; and

at least one processor configured to:

receive, from the neural network, an indication of a detected child from the child detection signal; and

control the speaker to generate an audible alert based on the indication of the detected child.

74. The sewing machine of claim 73, further comprising:

a user device, wherein the user device is configured to receive alerts from the sewing machine; and

wherein the processor is configured to transmit an alert to the user device based on the indication of the detected child.

75. A sewing machine comprising:

a data storage device for storing a current version of software for operating the sewing machine, wherein the current version of software has a version number and an installation date;

a workspace sensor comprising at least one of:

a camera facing away from the sewing machine, wherein the camera generates a camera data signal; and

a microphone that generates a microphone data signal;

a user interaction log comprising user activity data comprising time data and weekday data;

a clock for generating clock data indicating a current time and a current weekday;

a data interface for receiving an indication that a new version of software is available and for receiving the new version of software;

a neural network that is trained to identify a typically available time and a typically available duration from at least one of the camera data signal, the microphone data signal, the user activity data, and the clock data, wherein the neural network generates available time data and available weekday data; and

at least one processor configured to:

receive, from the data interface, the indication that the new version of software is available;

determine an install duration for installing the new version of software;

receive, from the neural network, the available time data and the available weekday data;

determining an install time and an install date for the new version of software based on the install duration, the available time data, and the available weekday data; and

install the new version of software at the install time and the install date based on a determination that the sewing machine is not in use.

76. A sewing machine comprising:

a needle for forming stitches in a workpiece with a thread;

a thread sensor, wherein the thread sensor generates a thread data signal;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine;

a thread classification neural network that is trained to identify a characteristic of the thread from the thread data signal, wherein the characteristic comprises at least one of a color, a density, a surface quality, and a fiber type, and wherein the thread classification neural network generates a thread classification data signal; and

at least one processor configured to:

receive, from the thread classification neural network, an indication of at least one thread characteristic via the thread classification data signal; and

control the user interface to present an indication of the at least one thread characteristic.

77. The sewing machine of claim 76, wherein the thread sensor comprises a tube-shaped housing through which a thread of the sewing machine travels during a sewing operation, a light source arranged inside the tube-shaped housing, and an optical sensor arranged inside the tube-shaped housing.

78. The sewing machine of claim 76 or claim 77, wherein the processor is configured to:

receive, from the user interface, a stitch pattern selected by the user; and

determine whether the stitch pattern selected by the user is compatible with the at least one thread characteristic; and

control the user interface to present an indication of the compatibility between the selected stitch pattern and the at least one thread characteristic.

79. A sewing machine comprising:

a needle for forming stitches in a workpiece with a thread;

a workpiece sensor, wherein the workpiece sensor generates a workpiece data signal;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine;

a workpiece classification neural network that is trained to identify a characteristic of the workpiece from the workpiece data signal, wherein the characteristic comprises at least one of a material type, a color, a density, a reflectance, a weave direction, a pattern, an orientation, and a topography and wherein the workpiece classification neural network generates a workpiece classification data signal; and

at least one processor configured to:

receive, from the workpiece classification neural network, an indication of at least one thread characteristic via the workpiece classification data signal; and

control the user interface to present an indication of the at least one thread characteristic.

80. The sewing machine of claim 79, wherein the workpiece sensor comprises at least one camera directed toward a sewing bed on which the workpiece is placed during a sewing operation.

81. The sewing machine of claim 79 or claim 80, wherein the processor is configured to:

receive, from the user interface, a stitch pattern selected by the user; and

determine whether the stitch pattern selected by the user is compatible with the at least one workpiece characteristic; and

control the user interface to present an indication of the compatibility between the selected stitch pattern and the at least one workpiece characteristic.

82. The sewing machine of any of claims 79–81, further comprising:

a thread sensor, wherein the thread sensor generates a thread data signal;

a thread classification neural network that is trained to identify a characteristic of the thread from the thread data signal, wherein the characteristic comprises at least one of a color, a density, a surface quality, and a fiber type, and wherein the thread classification neural network generates a thread classification data signal; and

at least one processor configured to:

receive, from the thread classification neural network, an indication of at least one thread characteristic via the thread classification data signal;

determine whether an incompatibility exists between the thread and the workpiece based on the thread characteristics and the workpiece characteristics; and

control the user interface to present an indication of the compatibility of the thread and the workpiece.

83. A sewing machine comprising:

a sewing bed, the sewing bed comprising a feed mechanism and a needle plate, wherein a workpiece can be placed on and moved across the sewing bed;

a sewing head arranged above the sewing bed, the sewing head comprising:

a needle bar extending toward the sewing bed to a distal end;

at least one needle attached to the distal end of the needle bar, wherein a thread is threaded through the needle;

an accessory bar extending toward the sewing bed to a distal end;

at least one accessory attached to the distal end of the accessory bar;

a camera having a field of view encompassing at least a portion of any of the sewing bed, the needle plate, the workpiece, the needle, and the accessory, wherein the camera generates a camera data signal related to the portions of the sewing bed, the needle plate, the workpiece, the needle, and the accessory in the field of view of the camera;

a regulatable component of the sewing machine, wherein the regulatable component can be regulated to alter a current state of the sewing machine;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine;

an object recognition neural network that is trained to recognize and to classify at least one of the needle plate, the at least one needle, the at least one accessory, the workpiece, the thread, an embroidery hoop, and a foreign object from the camera data signal, wherein the neural network generates an object recognition data signal and an object classification data signal;

at least one processor configured to:

receive, from the object recognition neural network, an indication of at least one recognized object from the object recognition data signal;

receive, from the object recognition neural network, an indication of at least one classification of the recognized object from the object classification data signal; and

control, based on the classification of the recognized object, at least one of the user interface to present the classification to the user and the regulatable component to alter a current state of the sewing machine.

84. The sewing machine of claim 83, wherein the regulatable component is a motor that moves the needle bar during a sewing operation.

85. The sewing machine of claim 83 or claim 84, wherein the classification comprises a location of the recognized object and the processor is configured to determine that the recognized object is at risk of being damaged based on the location of the recognized object.

86. The sewing machine of claim 85, wherein the processor is configured to control the user interface to present an indication that the recognized object is at risk of being damaged.

87. The sewing machine of claim 85 or claim 86, wherein the processor is configured to regulate the regulatable component to prohibit operation of the sewing machine.

88. A sewing machine comprising:

a workspace sensor comprising at least one of:

a camera facing away from the sewing machine, wherein the camera generates a camera data signal;

an accelerometer that generates a vibration data signal;

a gyroscope that generates an orientation data signal; and

a photosensor that generates a light level data signal;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine;

a workspace neural network that is trained to identify at least one of a work surface height, a work surface stability, a user posture, a chair position, and a light level from at least one of the camera data signal, the vibration data signal, the orientation data signal, and the light level data signal, wherein the workspace neural network generates an ergonomic health data signal; and

at least one processor configured to:

receive, from the neural network, an indication of a

from the child detection signal; and

control the user interface to present a recommendation of changes to the workspace to improve ergonomic health of the user.

89. A sewing machine comprising:

a sewing bed, the sewing bed comprising a feed mechanism and a needle plate, wherein a workpiece can be placed on and moved across the sewing bed;

a sewing head arranged above the sewing bed, the sewing head comprising:

a needle bar extending toward the sewing bed to a distal end;

a needle attached to the distal end of the needle bar;

a swing motor for swinging the needle bar laterally;

a camera having a field of view encompassing at least a portion of the workpiece, wherein the camera generates a camera data signal related to the portion of the workpiece in the field of view of the camera;

a workpiece neural network that is trained to identify a topography of the workpiece from the camera data signal, wherein the neural network generates a workpiece topography data signal;

at least one processor configured to:

receive, from the neural network, the workpiece topography data signal;

determine, from the workpiece topography data signal, a location of a seam in the workpiece; and

control the swing motor to move the needle bar laterally so that the needle penetrates the seam of the workpiece during the sewing operation.

90. A sewing machine comprising:

a sewing bed, the sewing bed comprising a feed mechanism and a needle plate, wherein a workpiece can be placed on and moved across the sewing bed;

a sewing head arranged above the sewing bed, the sewing head comprising:

a needle bar extending toward the sewing bed to a distal end;

a needle attached to the distal end of the needle bar;

a swing motor for swinging the needle bar laterally;

a camera having a field of view encompassing at least a portion of the workpiece, wherein the camera generates a camera data signal related to the portion of the workpiece in the field of view of the camera;

a feature detection neural network that is trained to identify at least one feature of the workpiece from the camera data signal, wherein the feature comprises at least one of an edge, a hole, a seam, and , and wherein the neural network generates a feature location data signal;

at least one processor configured to:

receive, from the neural network, the feature location data signal;

determine, from the feature location data signal, a location of a feature of the workpiece; and

control the swing motor to move the needle bar laterally so that the needle penetrates the workpiece at a predetermined distance from the location of the feature during the sewing operation.

91. A sewing machine comprising:

a sewing bed, the sewing bed comprising a feed mechanism and a needle plate, wherein a workpiece can be placed on and moved across the sewing bed;

a sewing head arranged above the sewing bed, the sewing head comprising:

a needle bar extending toward the sewing bed to a distal end;

a needle attached to the distal end of the needle bar, wherein a thread is threaded through the needle for forming stitches in the workpiece during a sewing operation;

a camera having a field of view encompassing at least a portion of any of the sewing bed, the needle plate, the workpiece, the needle, and the thread, wherein the camera generates a camera data signal related to the portions of the sewing bed, the needle plate, the workpiece, the needle, and the thread in the field of view of the camera;

a user interface configured to present information to the user of the sewing and to receive input from the user of the sewing machine;

a sewing error neural network that is trained to identify a sewing error made during the sewing operation from the camera data signal, wherein the sewing error neural network generates an sewing error data signal comprising an identified sewing error;

at least one processor configured to:

receive, from the neural network, an indication of the identified sewing error via the sewing error data signal; and

control the user interface to present an indication of the sewing error.

92. The sewing machine of claim 91, wherein the identified sewing error comprises at least one of a skipped stitch, an unbalanced stitch, a misaligned stitch, a seam pucker, a stitch density variation, a bobbin thread break, a looper thread break, a needle thread break, a fused thread, a needle break, a stuck needle, a needle striking the needle plate, a thread cut by the needle, inconsistent thread tension, a wavy seam, an unthreaded needle, a loose needle holder, a loose presser foot, a mislocated presser foot, an immobile needle, an immobile workpiece, a bunching workpiece, a bunching thread, a knot in the thread, a loose stitch, a tangle in the thread, a frayed thread, a shredded thread, a workpiece feed variation, a bent needle, a damaged looper, a damaged stitch finger, a mislocated looper, a mislocated stitch finger, and a dull fabric knife.

93. A sewing machine comprising:

a sewing bed, the sewing bed comprising a feed mechanism and a needle plate, wherein a workpiece can be placed on and moved across the sewing bed;

a sewing head arranged above the sewing bed, the sewing head comprising a needle bar that moves a needle to penetrate a workpiece with a thread during a sewing operation;

a regulatable component of the sewing machine, wherein the regulatable component can be regulated to alter a current state of the sewing machine;

a first data source that generates a first data signal comprising first data having a first data type;

a second data source that generates a second data signal comprising second data having a second data type, wherein the second data type is different from the first data type;

a processor configured to:

receive the first data signal from the first data source;

receive the second data signal from the second data source;

process the first data signal and the second data signal through an artificial intelligence unit, wherein the artificial intelligence unit generates a third data signal comprising third data;

control, based on the third data, the regulatable component to alter the current state of the sewing machine.

94. The sewing machine of claim 93, wherein the first data source is a camera.

95. The sewing machine of claim 93 or claim 94, wherein the artificial intelligence unit is a neural network.

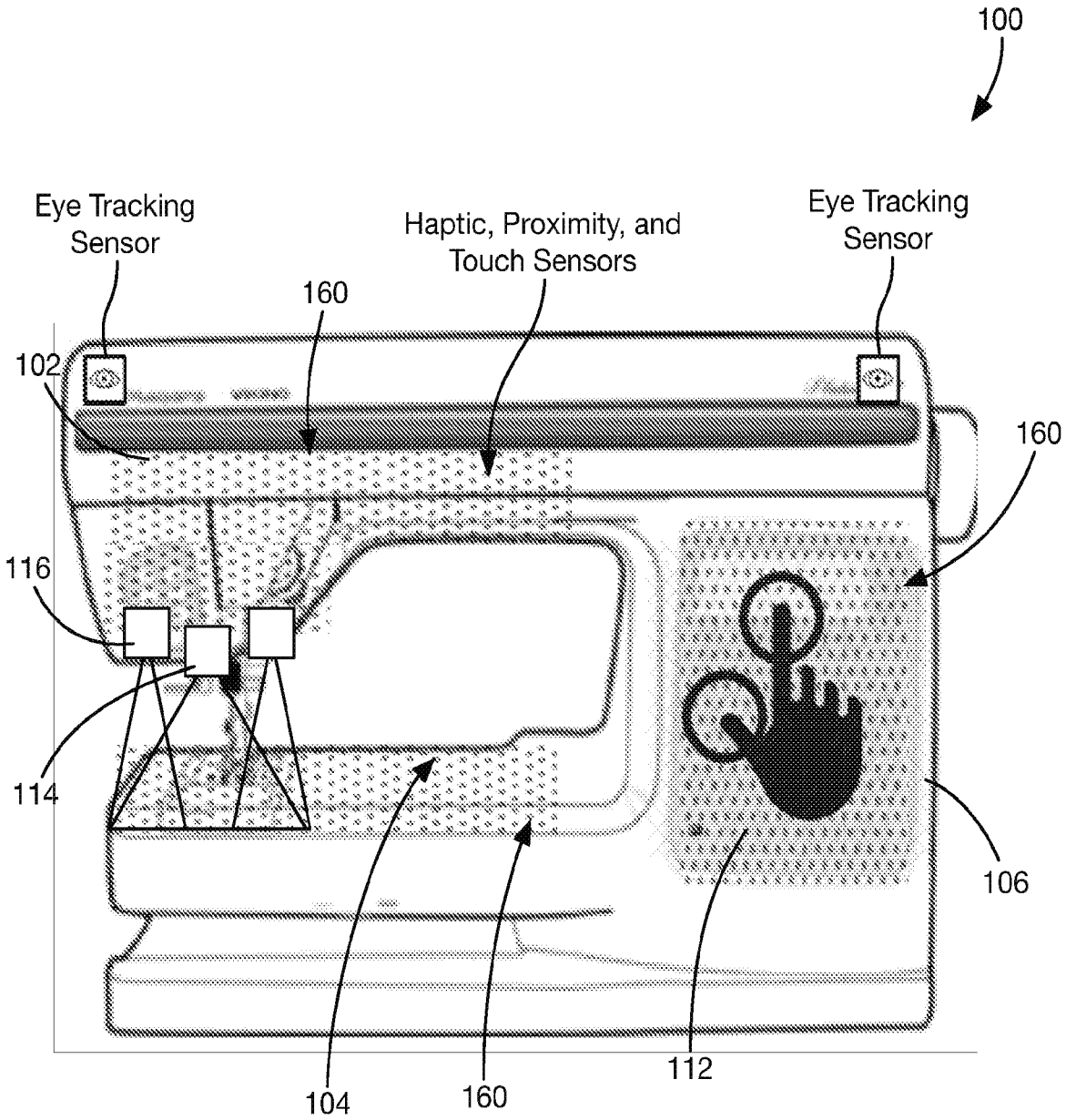

100
Eye Tracking Sensor
Haptic, Proximity, and Touch Sensors
Eye Tracking Sensor
160
102
160
116
114
106
104
160
112

FIG. 1

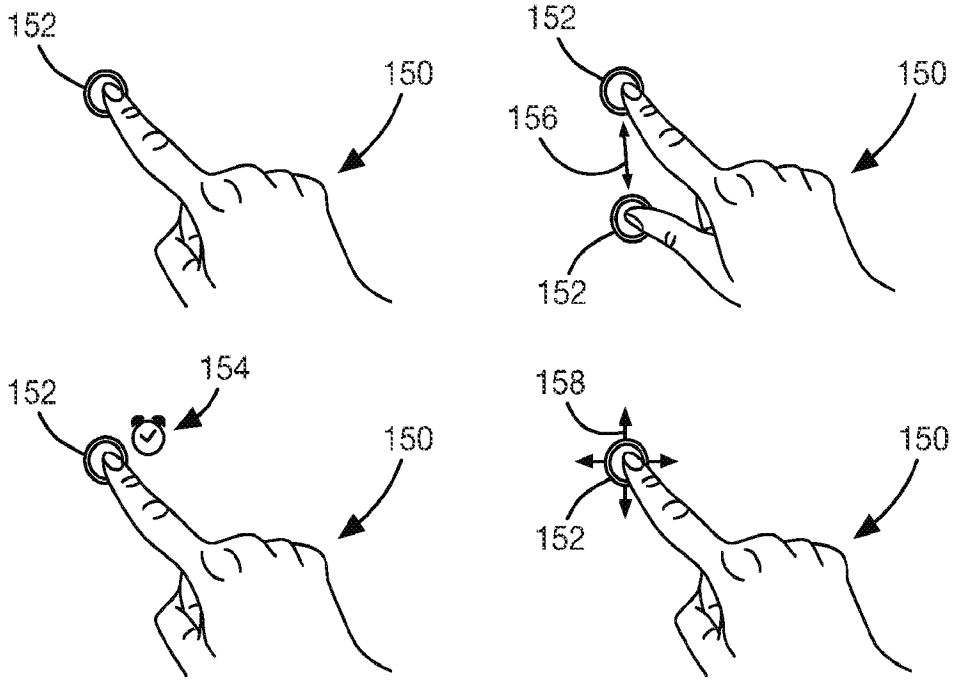


FIG. 2

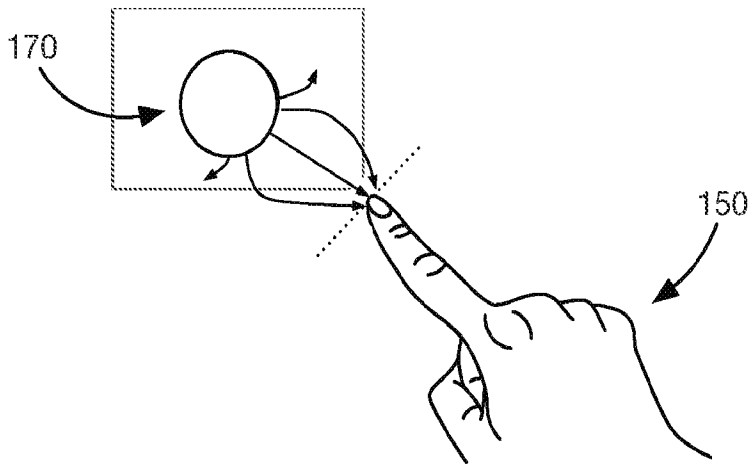


FIG. 3

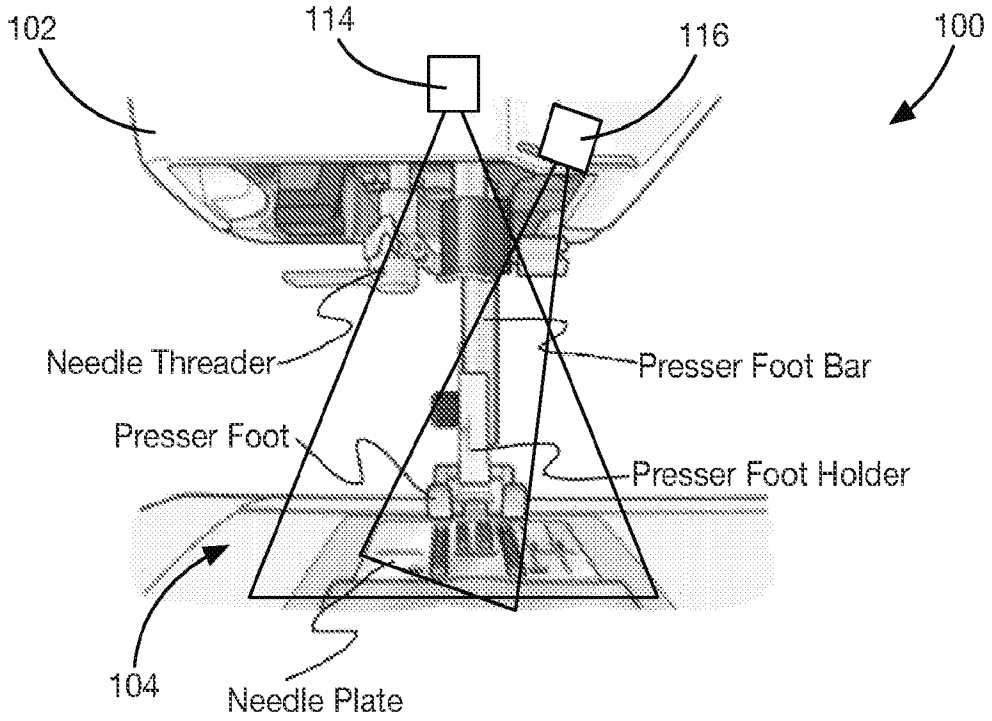

102
114
116
100
Needle Threader
Presser Foot Bar
Presser Foot
Presser Foot Holder
104
Needle Plate

FIG. 4

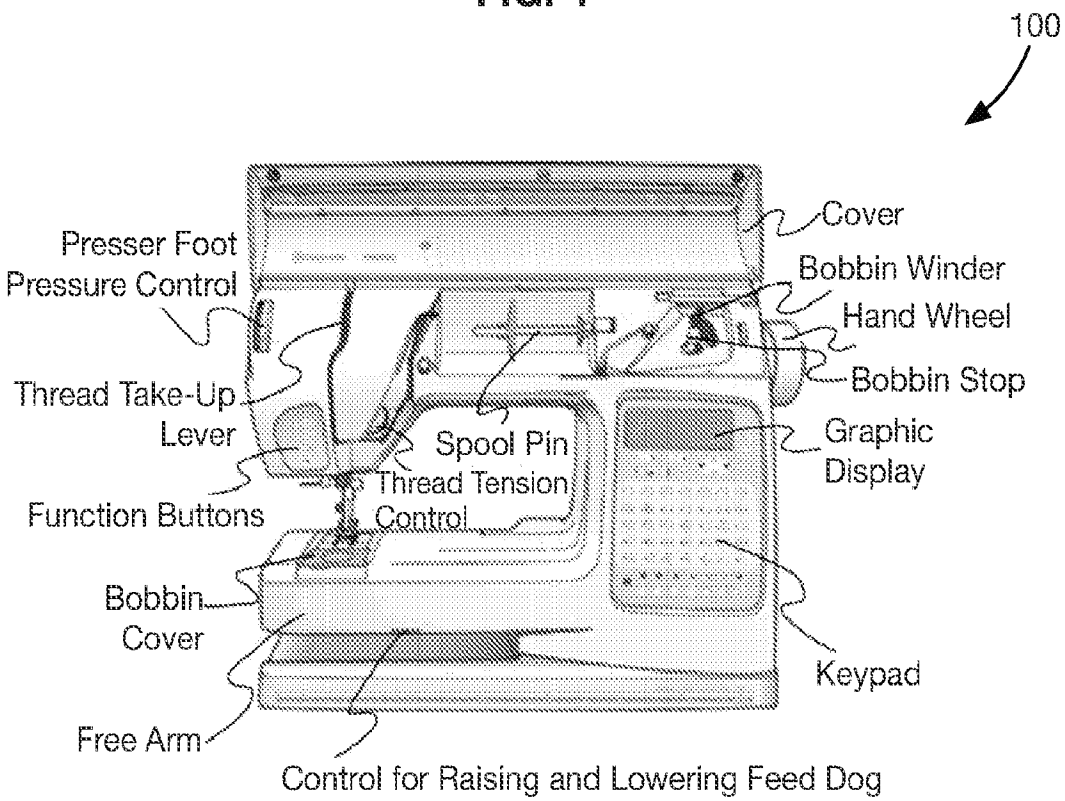

100
Cover
Presser Foot
Pressure Control
Bobbin Winder
Hand Wheel
Bobbin Stop
Thread Take-Up
Lever
Spool Pin
Thread Tension
Control
Graphic
Display
Function Buttons
Bobbin
Cover
Keypad
Free Arm
Control for Raising and Lowering Feed Dog

FIG. 5

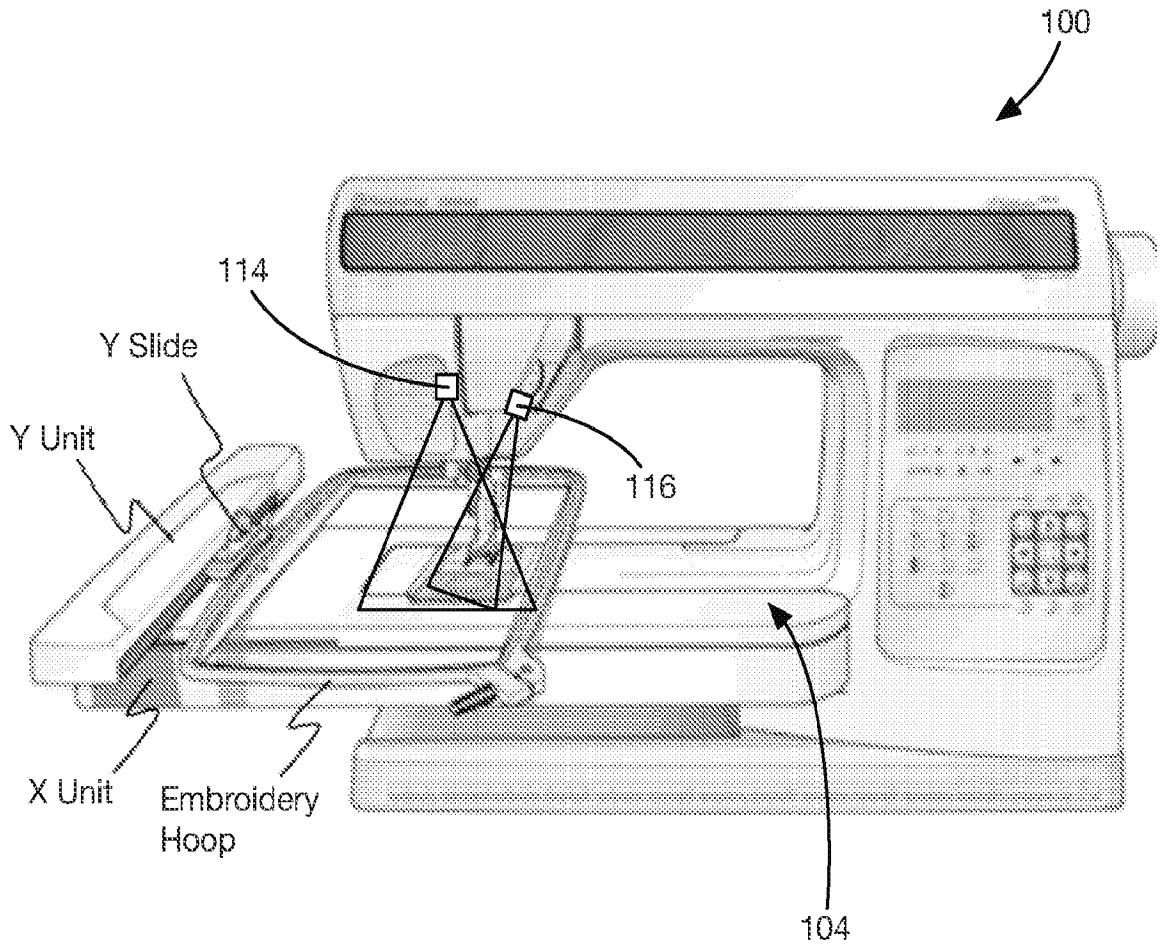


FIG. 6

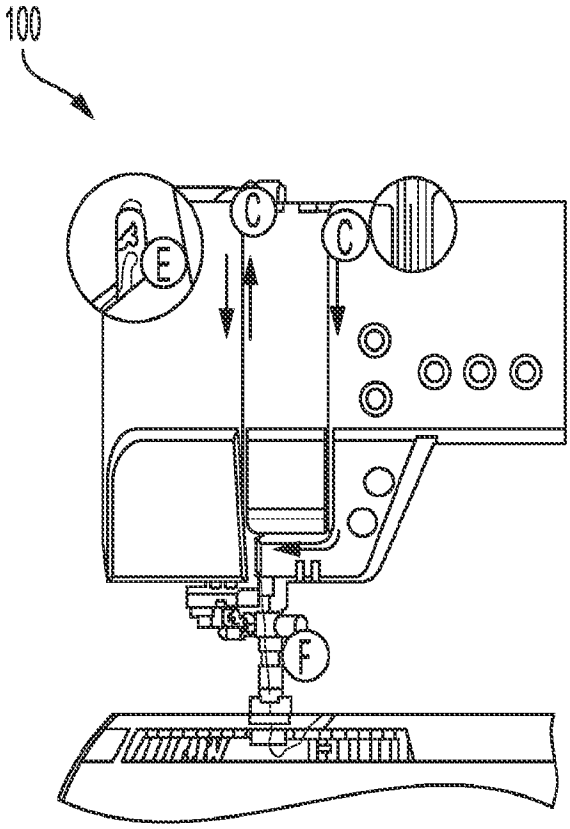


FIG. 7

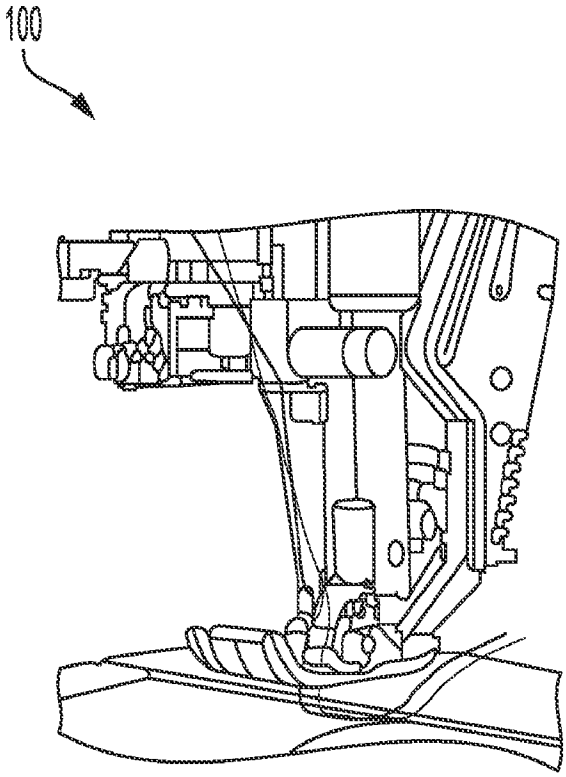


FIG. 8

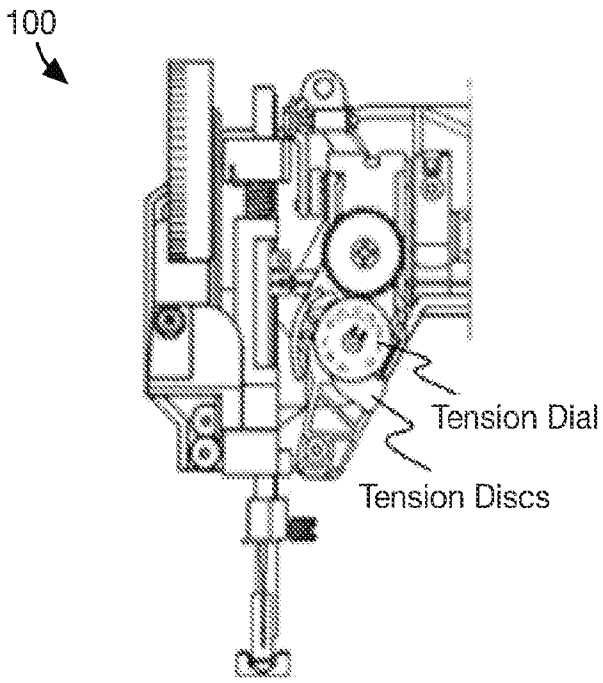


FIG. 9

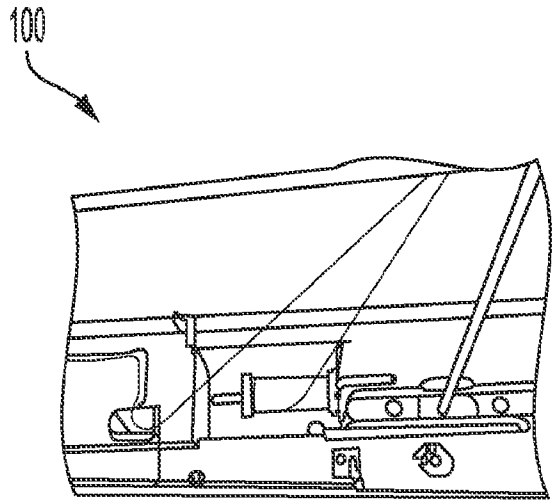


FIG. 10

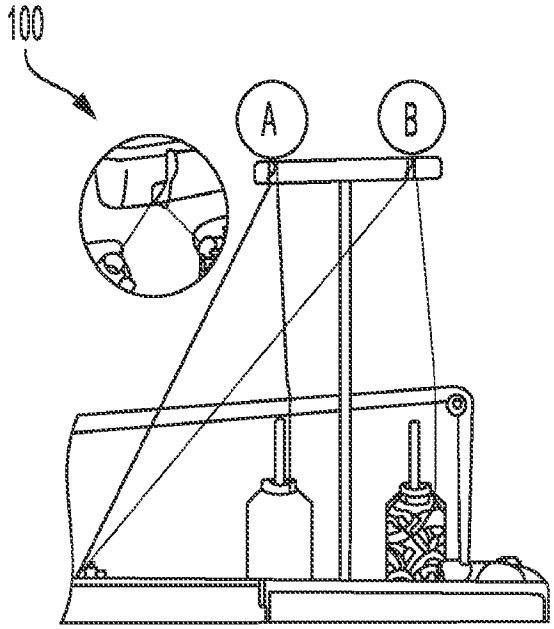


FIG. 11

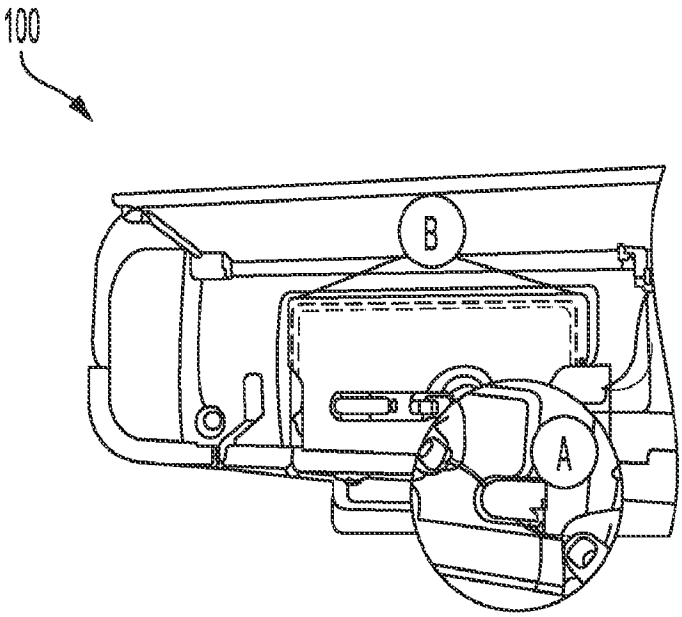


FIG. 12

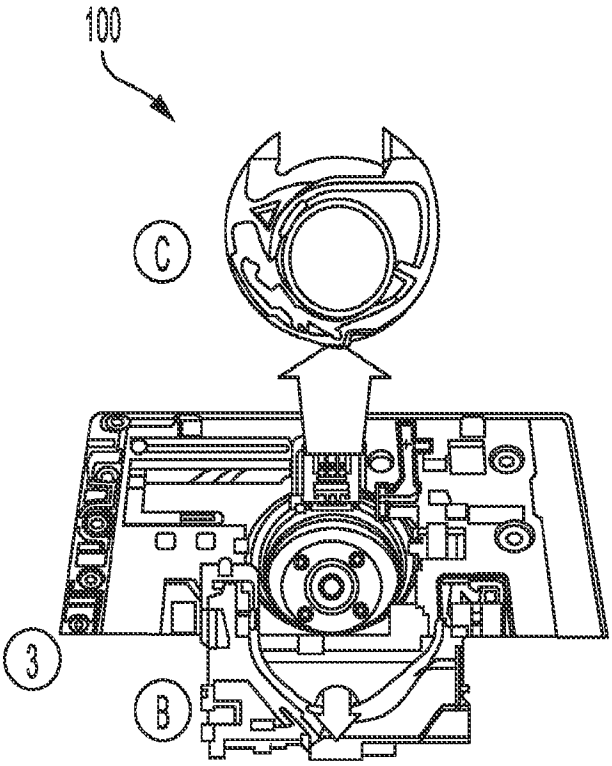


FIG. 13

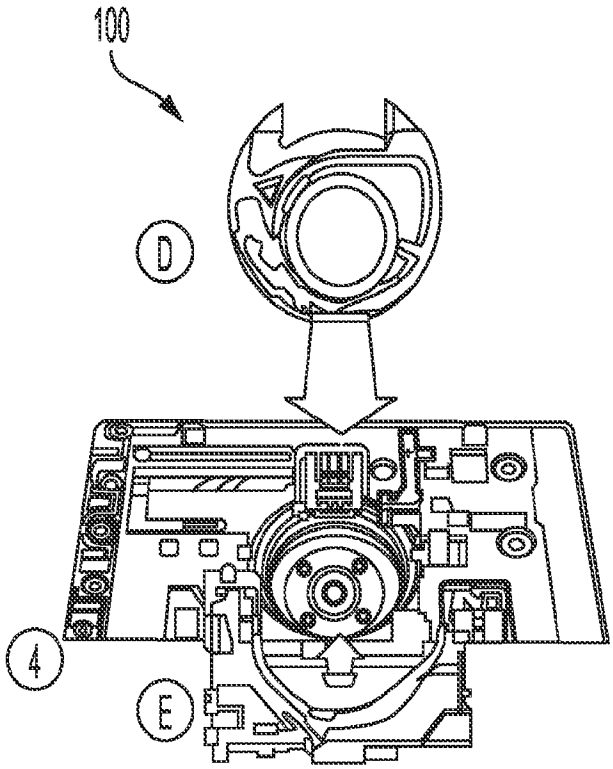


FIG. 14

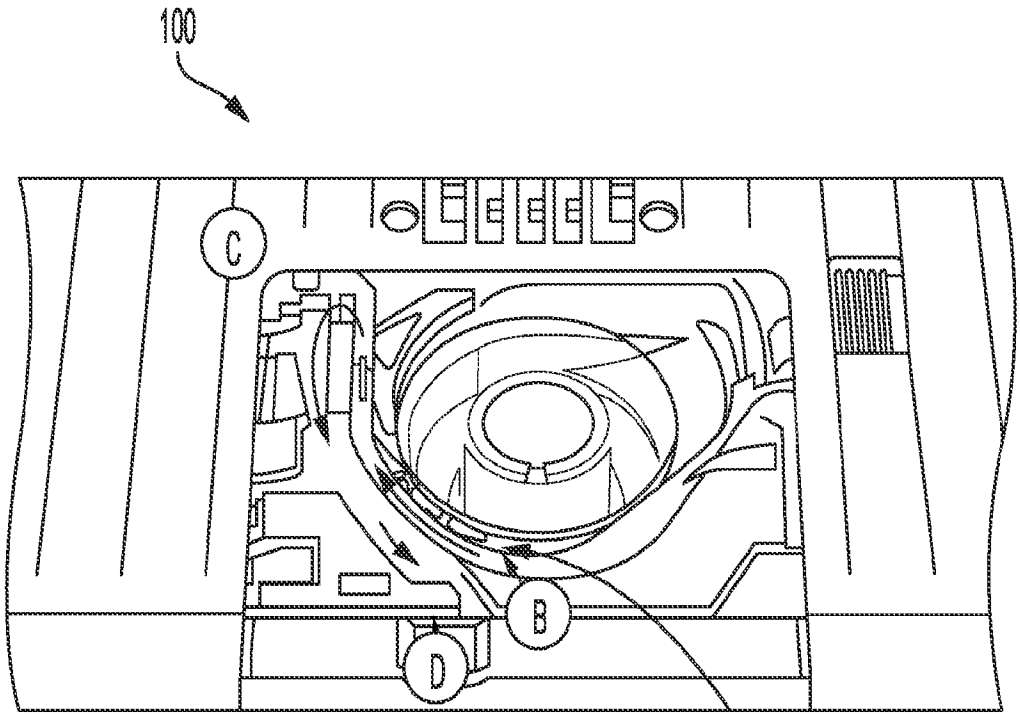


FIG. 15

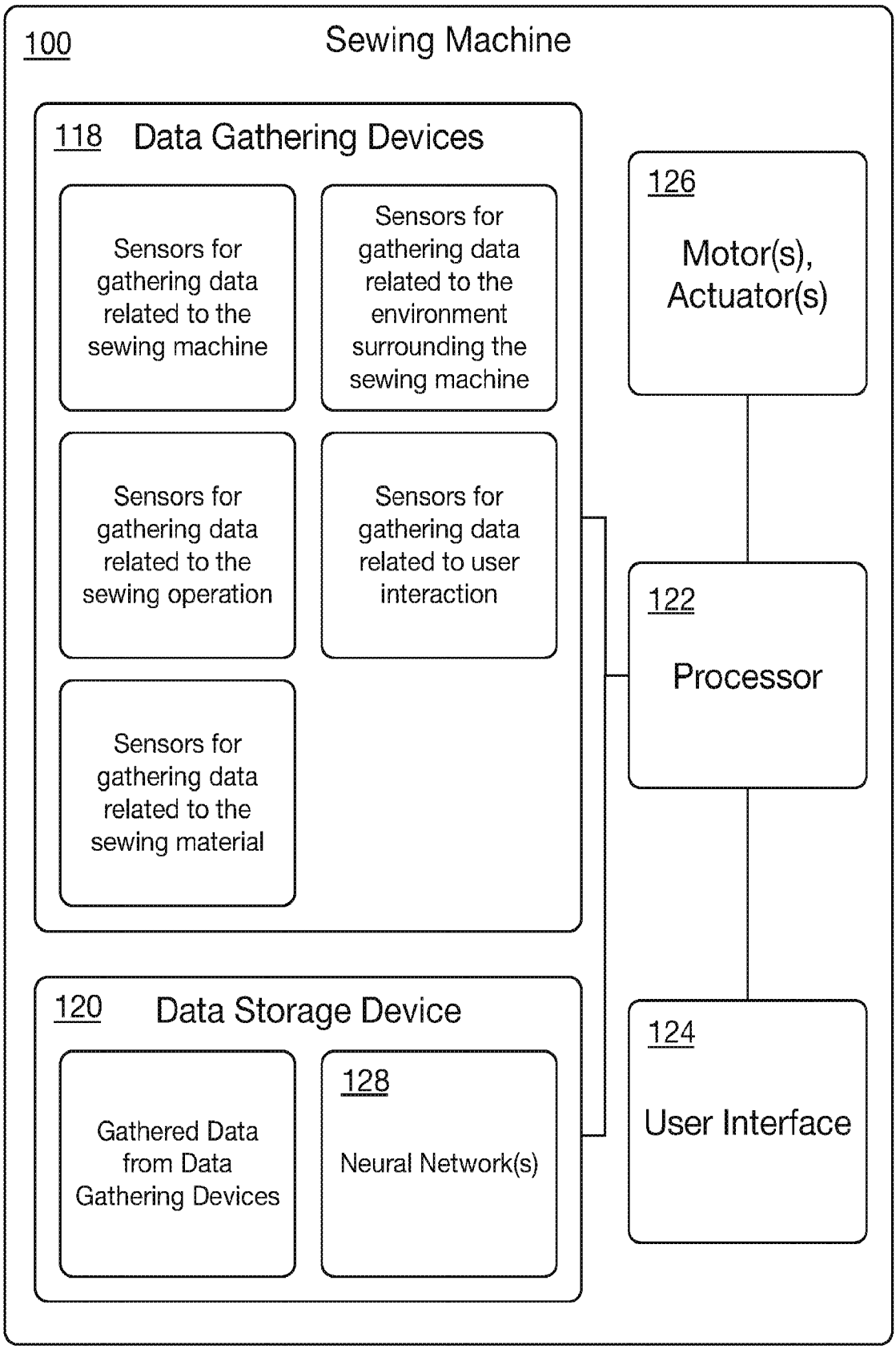

100
Sewing Machine
118 Data Gathering Devices
Sensors for gathering data related to the sewing machine
Sensors for gathering data related to the environment surrounding the sewing machine
Sensors for gathering data related to the sewing operation
Sensors for gathering data related to user interaction
Sensors for gathering data related to the sewing material
126
Motor(s), Actuator(s)
122
Processor
120 Data Storage Device
Gathered Data from Data Gathering Devices
128
Neural Network(s)
124
User Interface

FIG. 16

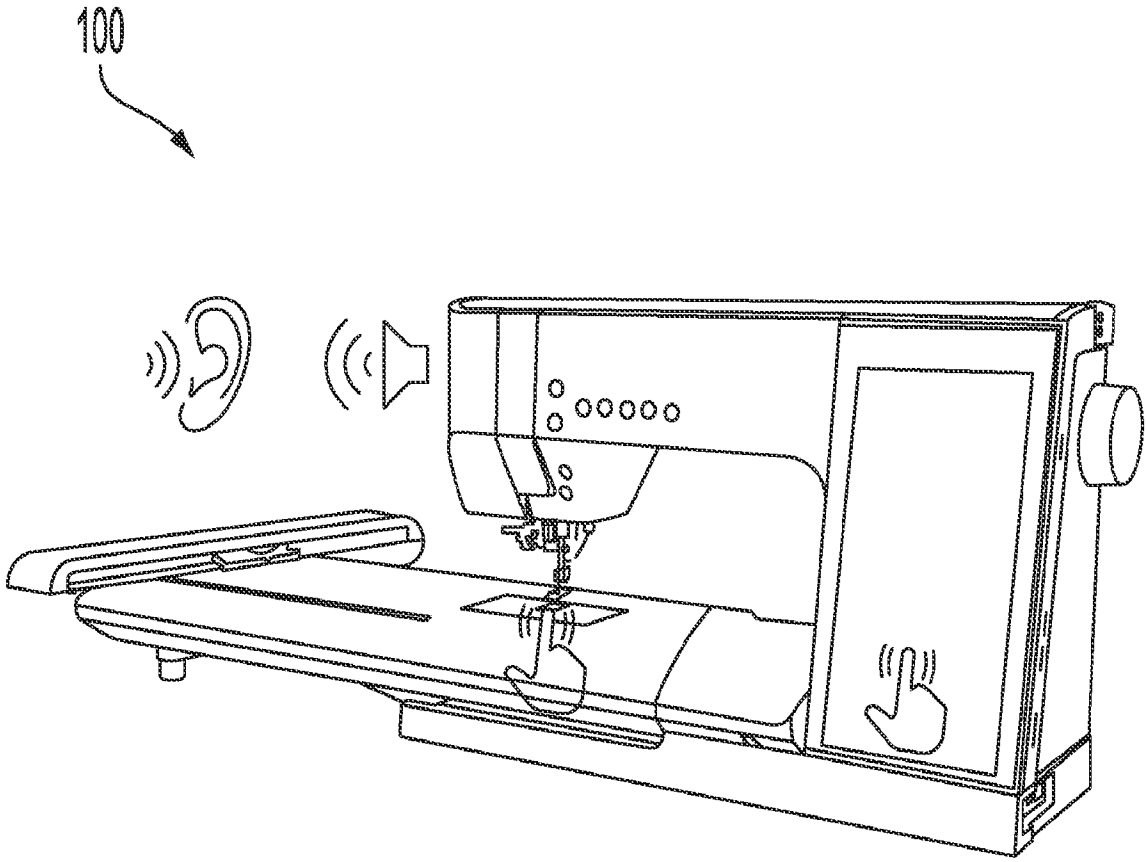


FIG. 17

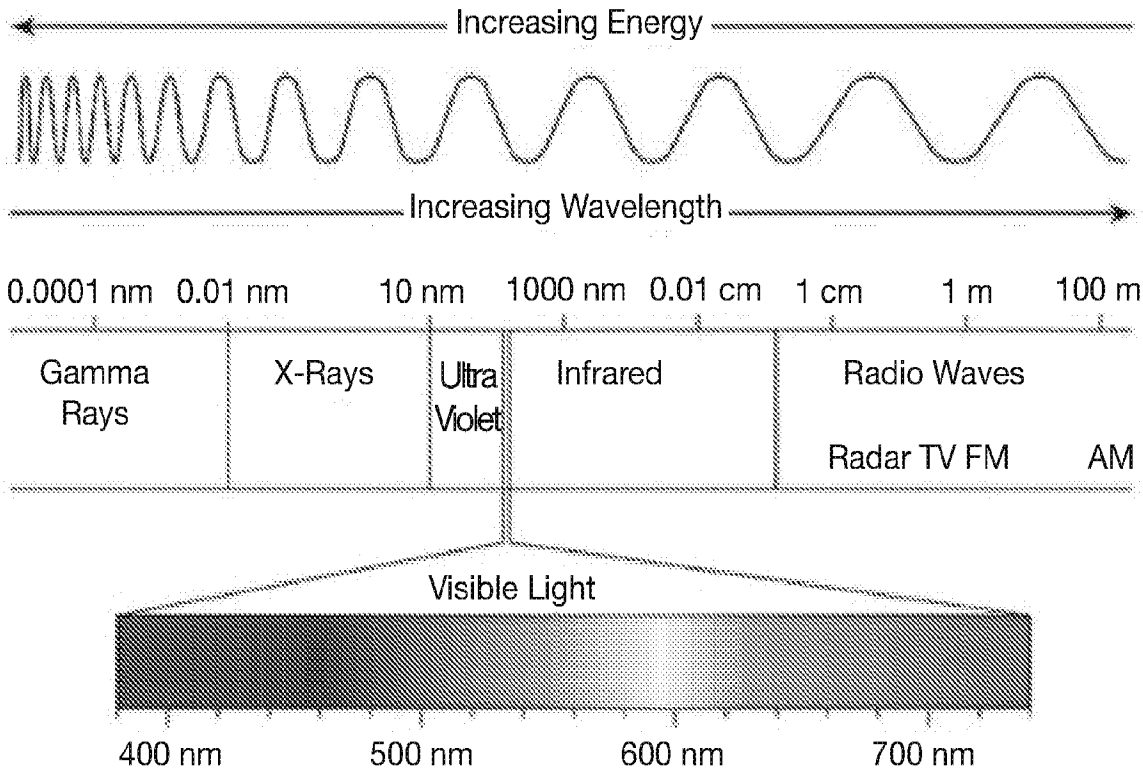

Increasing Energy
Increasing Wavelength
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
Gamma Rays
X-Rays
Ultra Violet
Infrared
Radio Waves
Radar TV FM
AM
Visible Light
400 nm
500 nm
600 nm
700 nm

FIG. 18

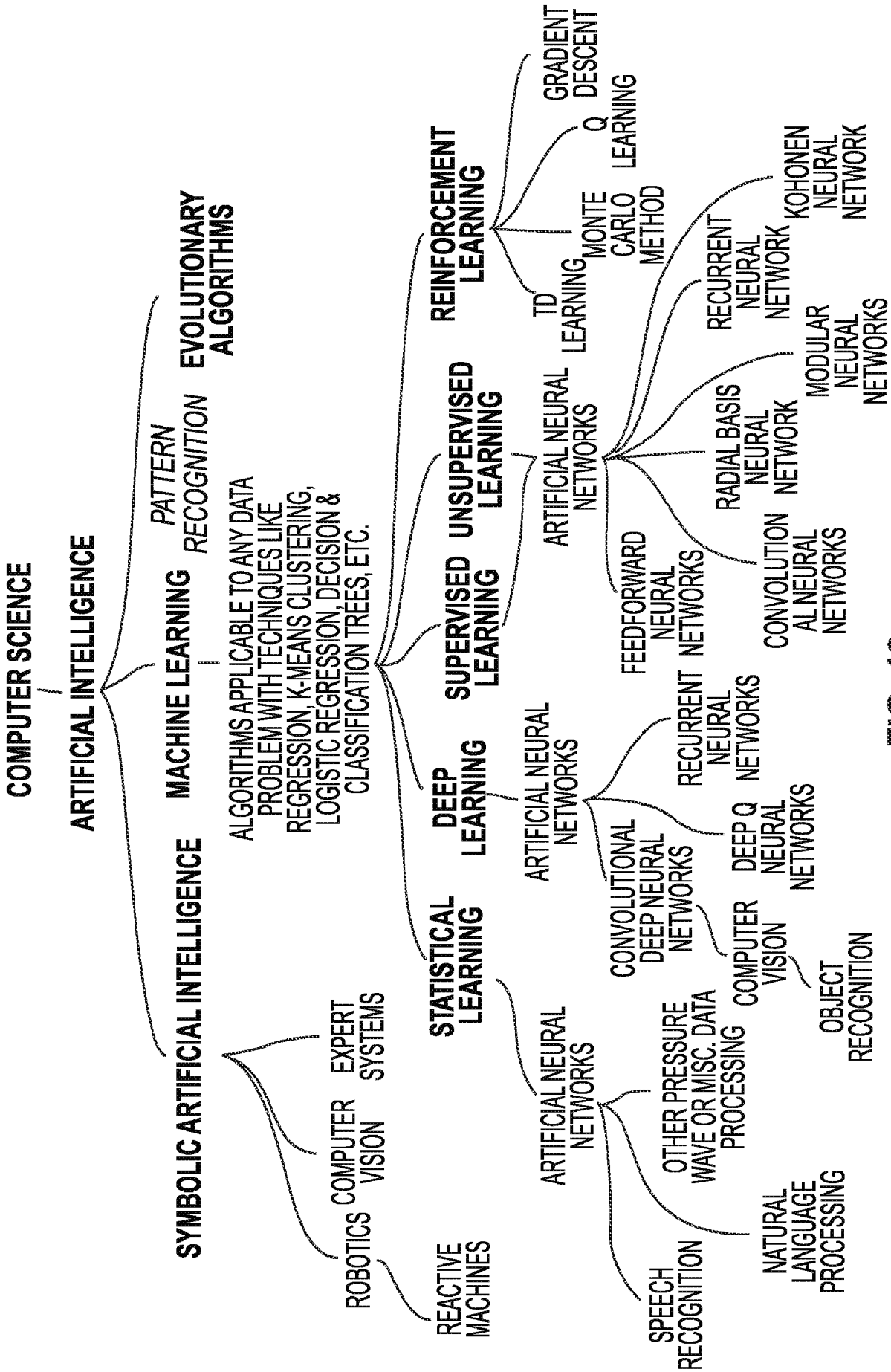

COMPUTER SCIENCE
ARTIFICIAL INTELLIGENCE
SYMBOLIC ARTIFICIAL INTELLIGENCE
EXPERT SYSTEMS
COMPUTER VISION
ROBOTICS
REACTIVE MACHINES
MACHINE LEARNING
ALGORITHMS APPLICABLE TO ANY DATA PROBLEM WITH TECHNIQUES LIKE REGRESSION, K-MEANS CLUSTERING, LOGISTIC REGRESSION, DECISION & CLASSIFICATION TREES, ETC.
PATTERN RECOGNITION
EVOLUTIONARY ALGORITHMS
STATISTICAL LEARNING
DEEP LEARNING
SUPERVISED LEARNING
UNSUPERVISED LEARNING
REINFORCEMENT LEARNING
ARTIFICIAL NEURAL NETWORKS
OTHER PRESSURE WAVE OR MISC. DATA PROCESSING
SPEECH RECOGNITION
NATURAL LANGUAGE PROCESSING
CONVOLUTIONAL DEEP NEURAL NETWORKS
RECURRENT NEURAL NETWORKS
DEEP Q NEURAL NETWORKS
COMPUTER VISION
OBJECT RECOGNITION
ARTIFICIAL NEURAL NETWORKS
FEEDFORWARD NEURAL NETWORKS
RADIAL BASIS NEURAL NETWORK
CONVOLUTIONAL NEURAL NETWORKS
MODULAR NEURAL NETWORKS
RECURRENT NEURAL NETWORK
KOHONEN NEURAL NETWORK
TD LEARNING
MONTE CARLO METHOD
Q LEARNING
GRADIENT DESCENT

FIG. 19

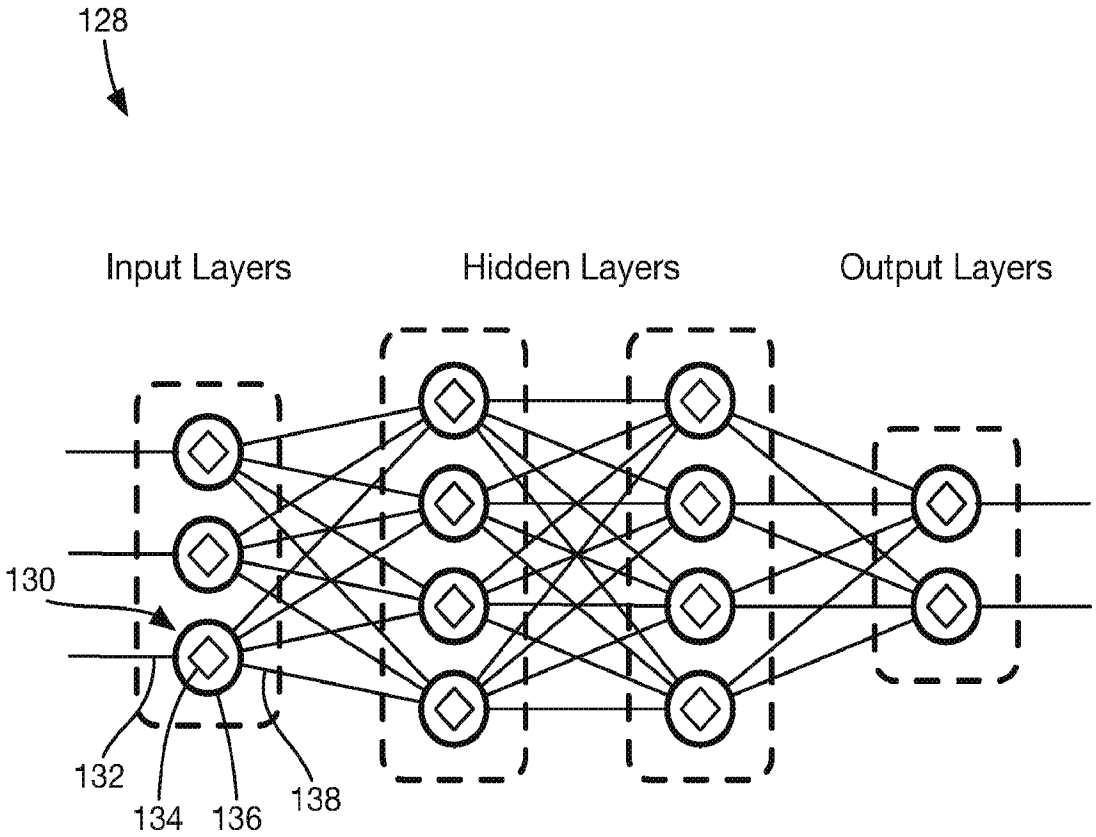

128
Input Layers
Hidden Layers
Output Layers
130
132
134
136
138

FIG. 20

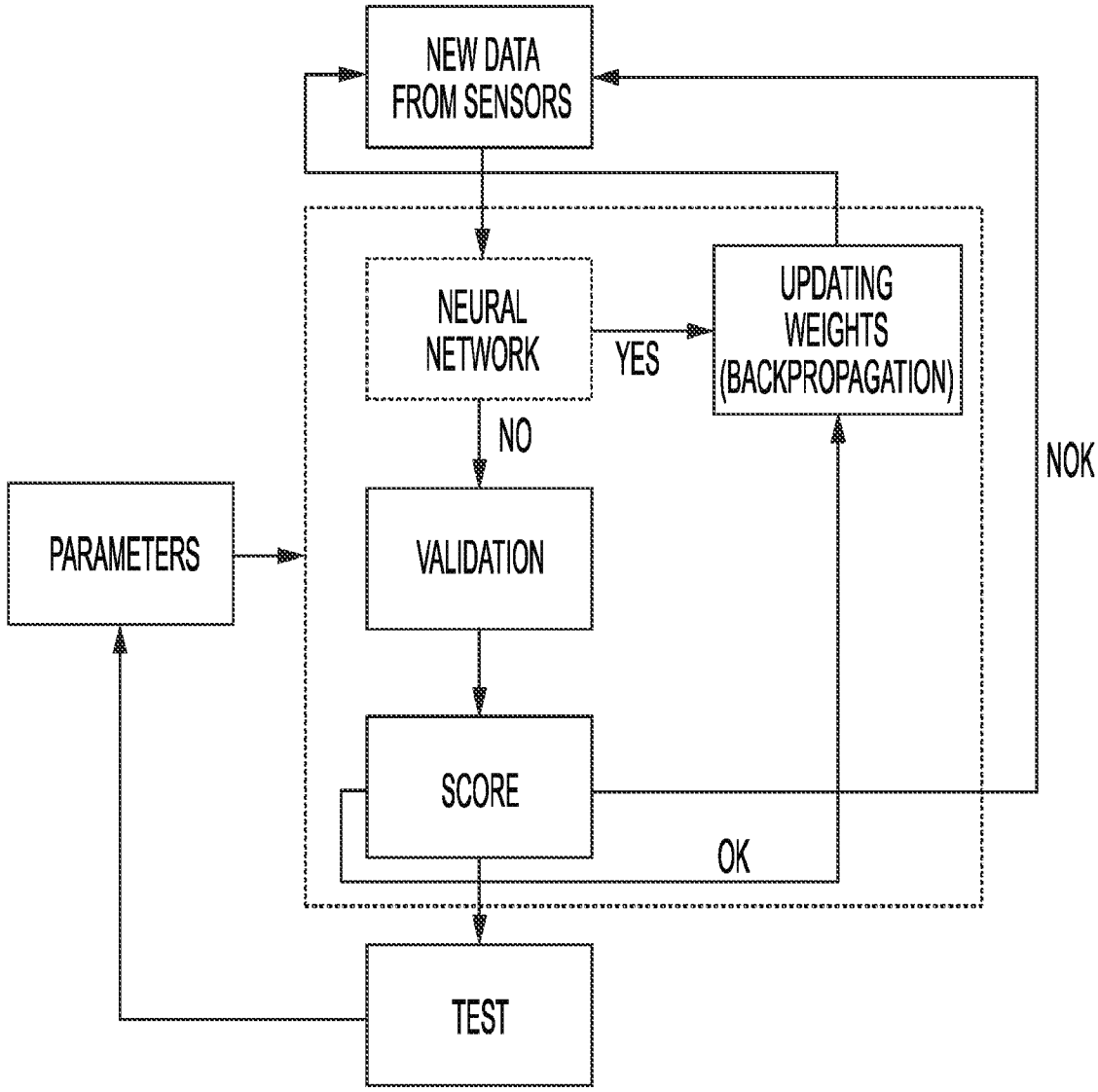

NEW DATA FROM SENSORS
NEURAL NETWORK
YES
UPDATING WEIGHTS (BACKPROPAGATION)
NO
NOK
PARAMETERS
VALIDATION
SCORE
OK
TEST

FIG. 21

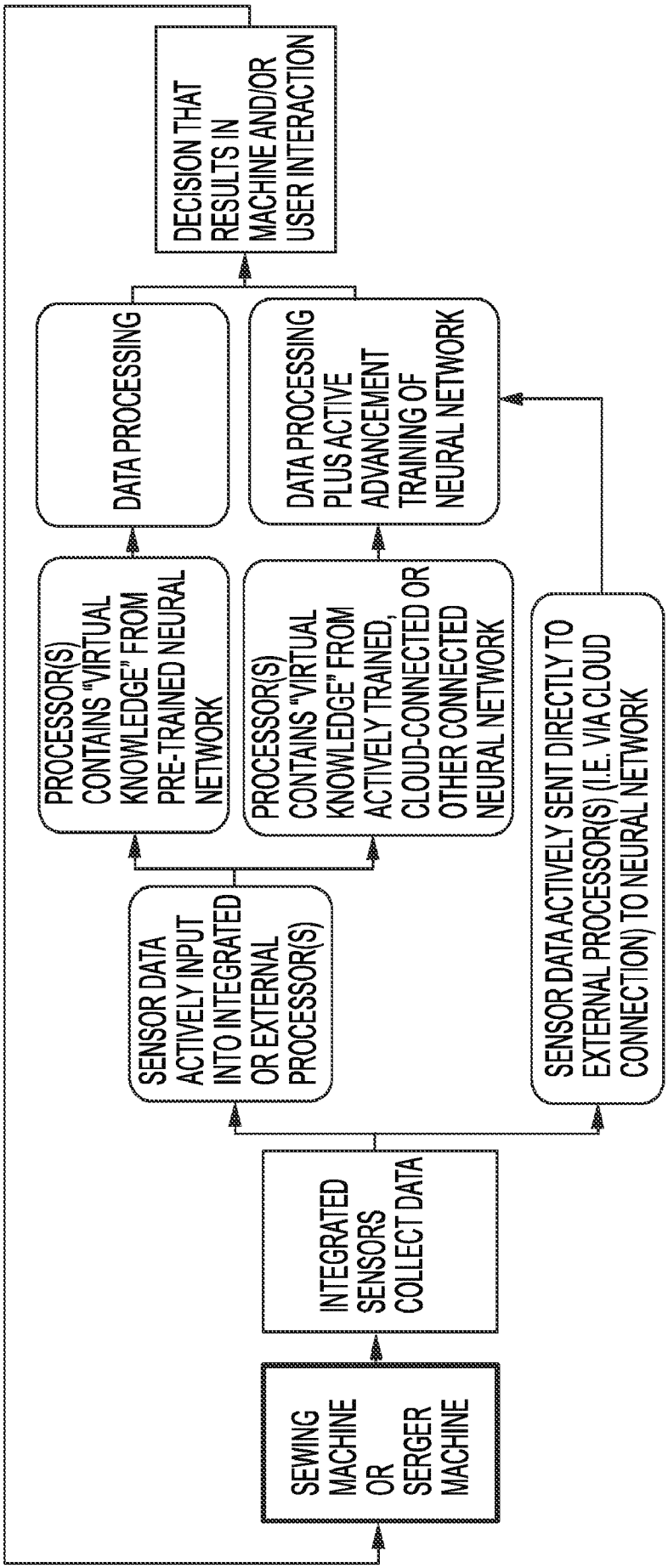

SEWING MACHINE OR SERGER MACHINE
INTEGRATED SENSORS COLLECT DATA
SENSOR DATA ACTIVELY INPUT INTO INTEGRATED OR EXTERNAL PROCESSOR(S)
SENSOR DATA ACTIVELY SENT DIRECTLY TO EXTERNAL PROCESSOR(S) (I.E. VIA CLOUD CONNECTION) TO NEURAL NETWORK
PROCESSOR(S) CONTAINS "VIRTUAL KNOWLEDGE" FROM PRE-TRAINED NEURAL NETWORK
PROCESSOR(S) CONTAINS "VIRTUAL KNOWLEDGE" FROM ACTIVELY TRAINED, CLOUD-CONNECTED OR OTHER CONNECTED NEURAL NETWORK
DATA PROCESSING
DATA PROCESSING PLUS ACTIVE ADVANCEMENT TRAINING OF NEURAL NETWORK
DECISION THAT RESULTS IN MACHINE AND/OR USER INTERACTION

FIG. 22

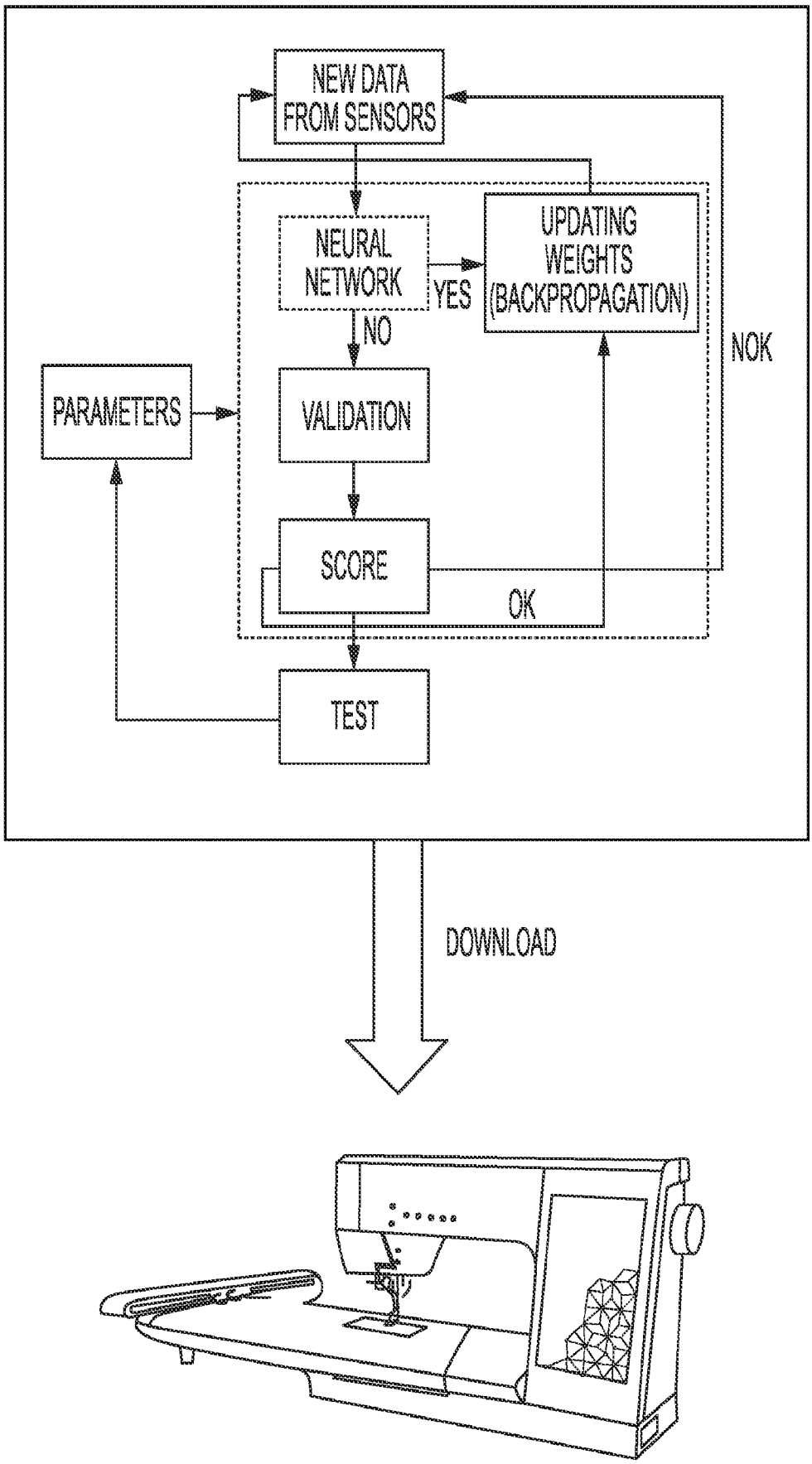

NEW DATA FROM SENSORS
NEURAL NETWORK
YES
UPDATING WEIGHTS (BACKPROPAGATION)
NO
NOK
PARAMETERS
VALIDATION
SCORE
OK
TEST
DOWNLOAD

FIG. 23

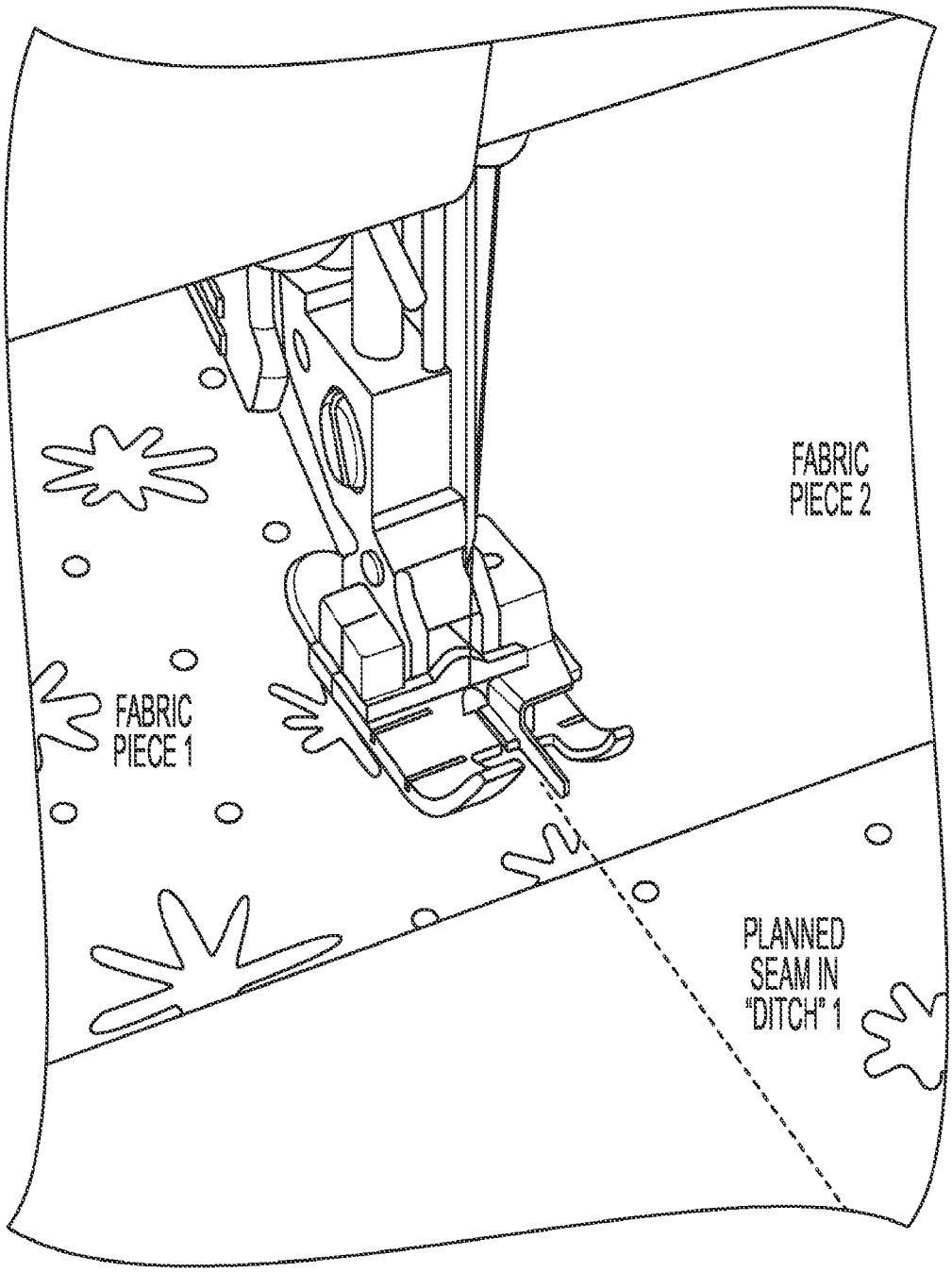


FIG. 24

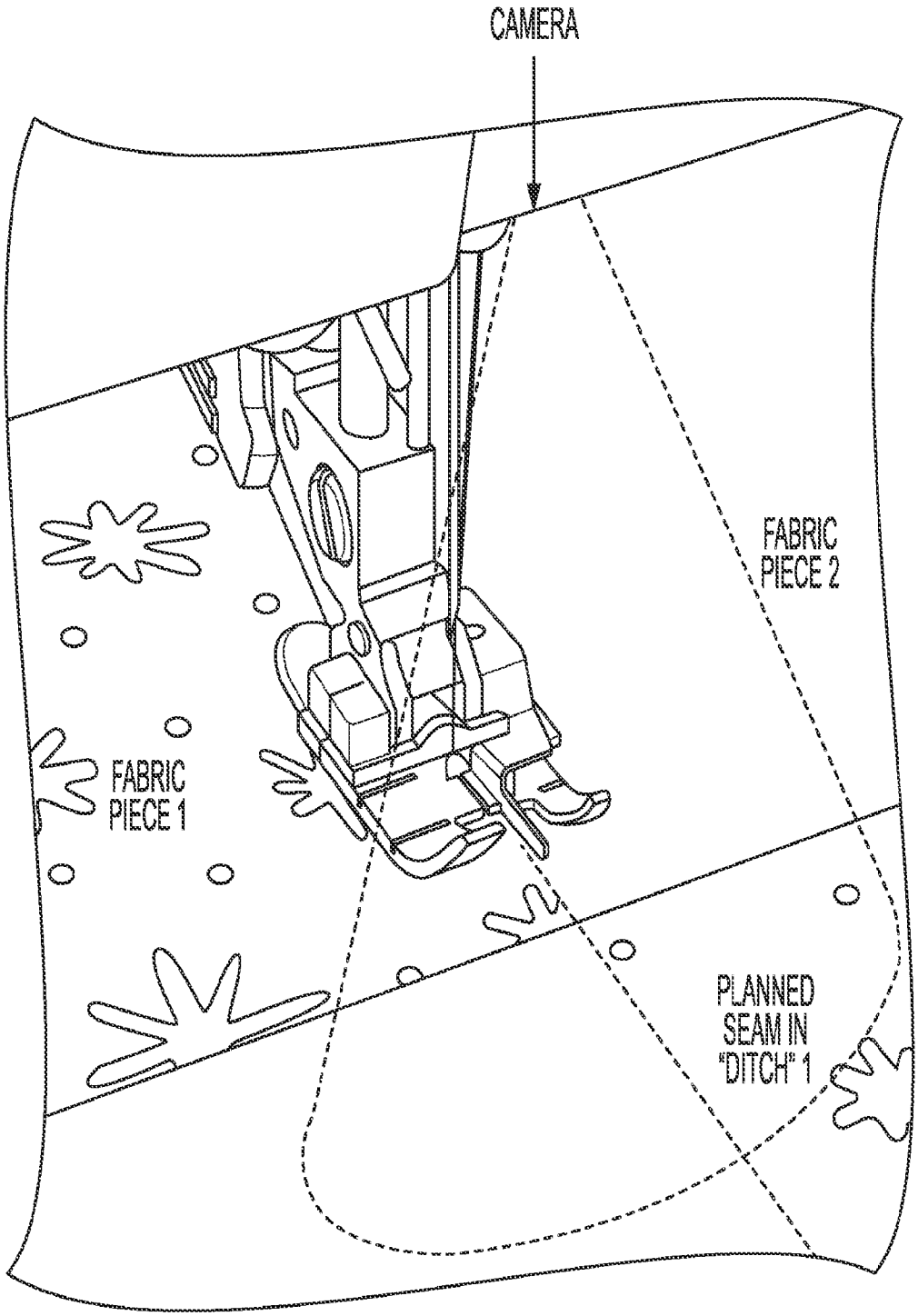


FIG. 25

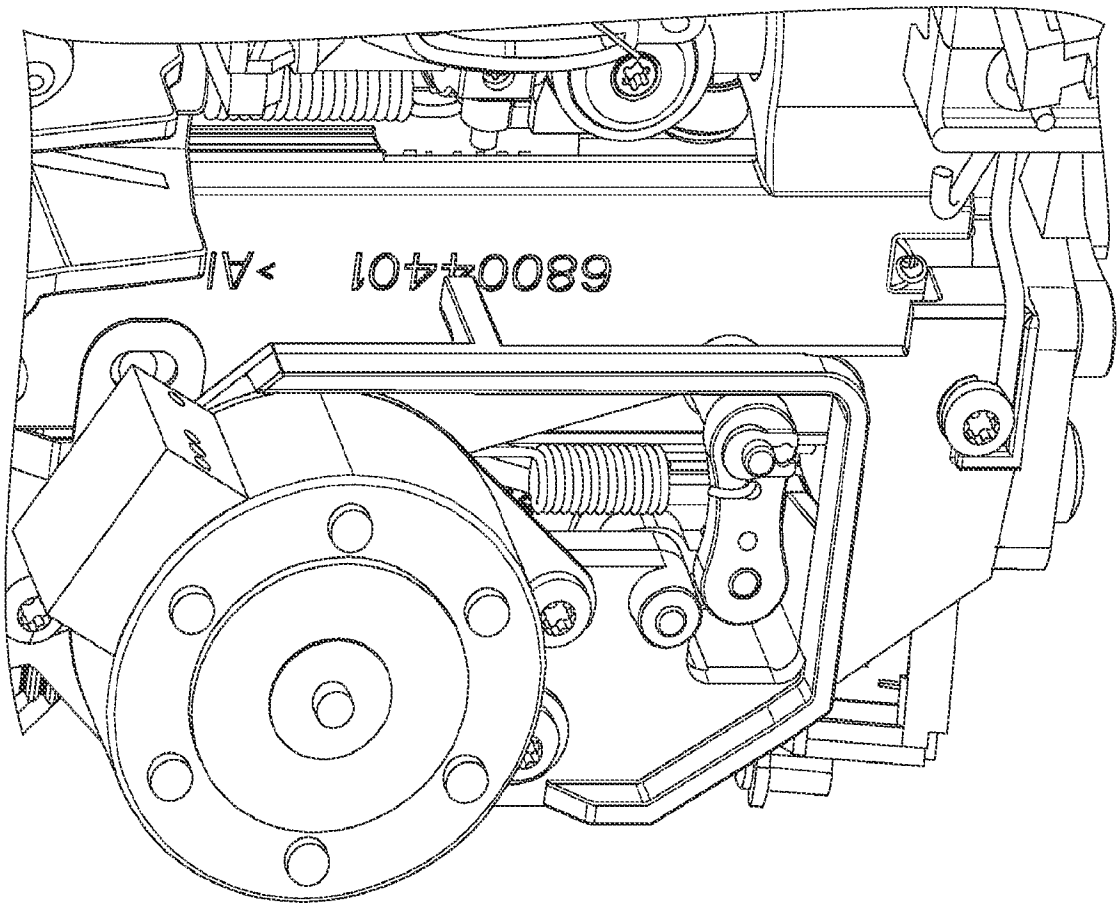


FIG. 27

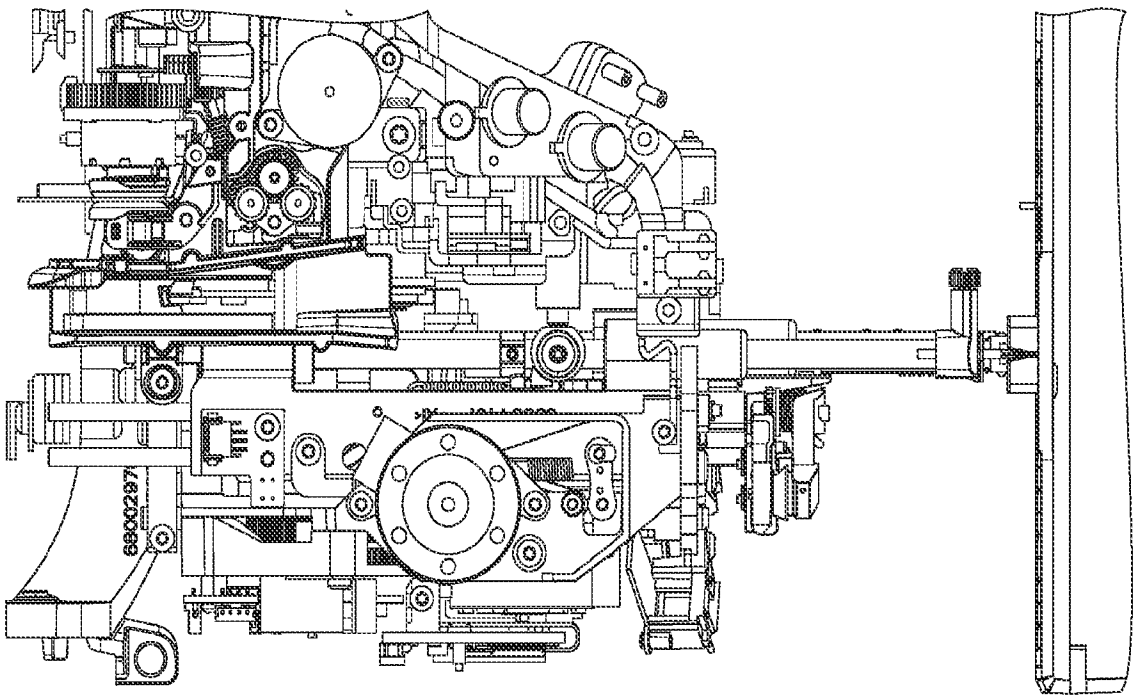


FIG. 26

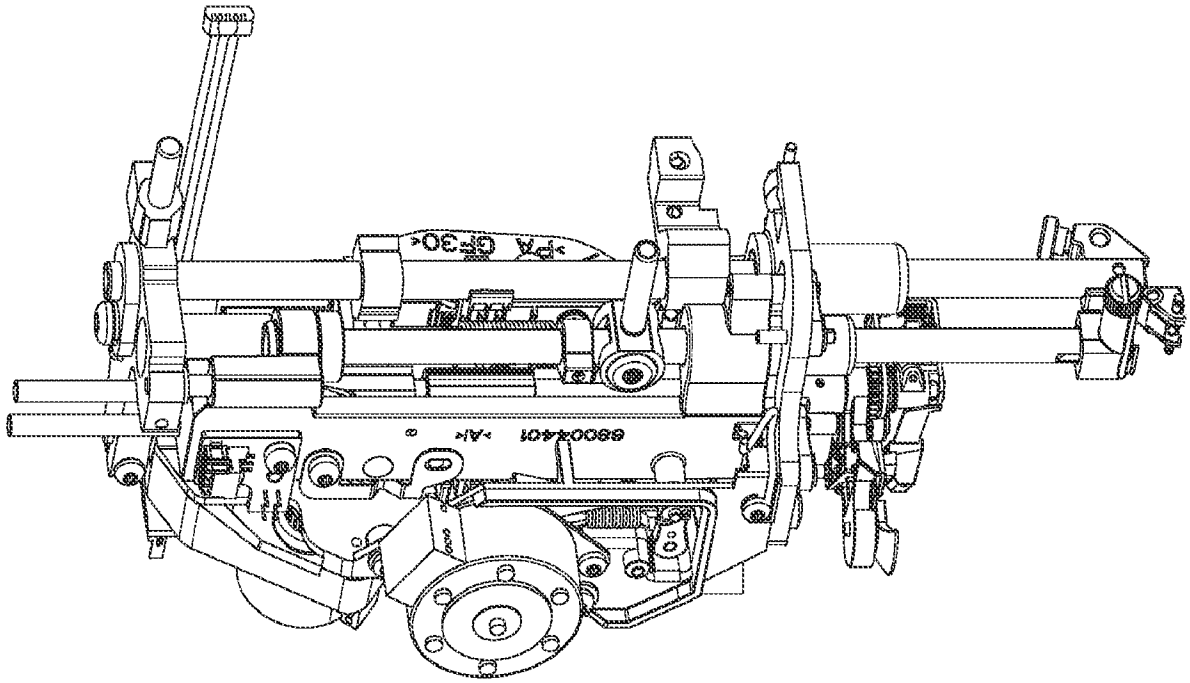


FIG. 29

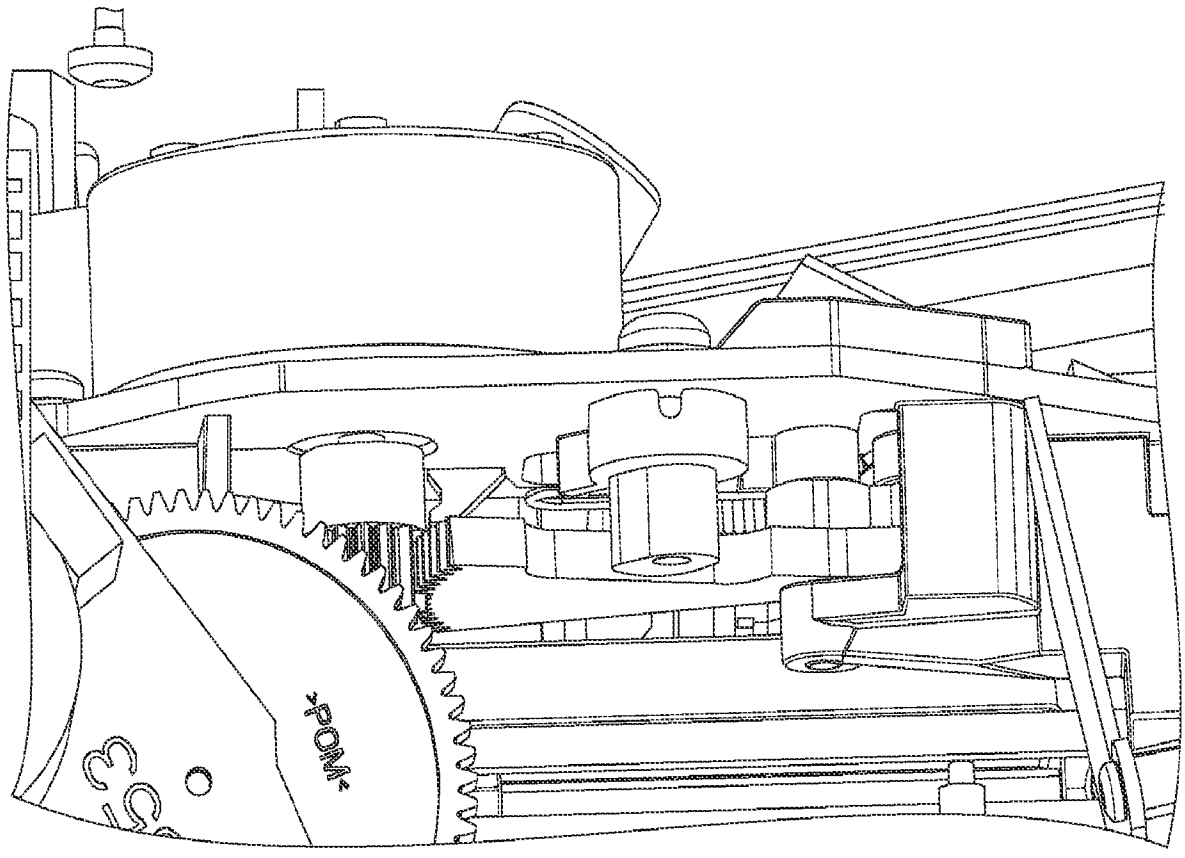


FIG. 28

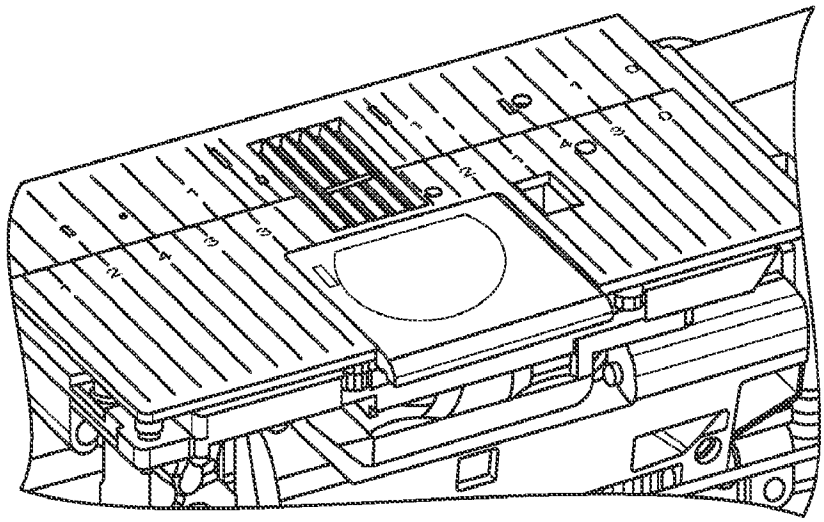


FIG. 30

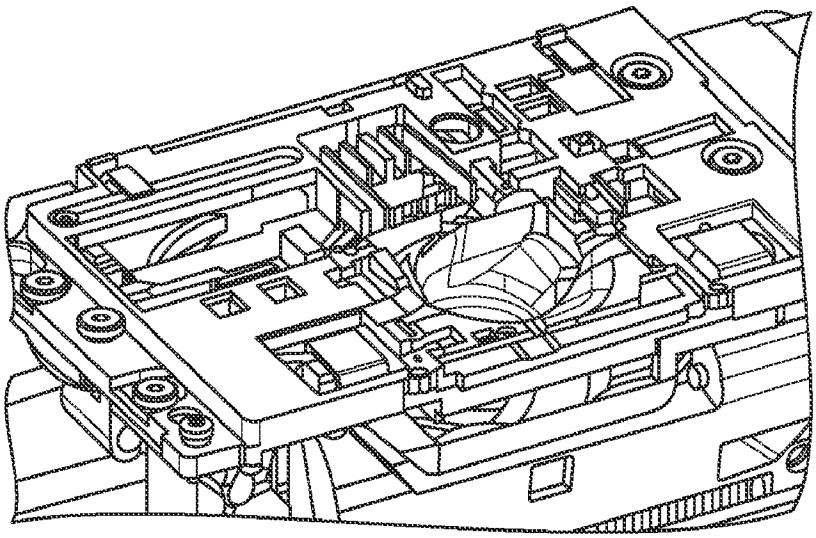


FIG. 31

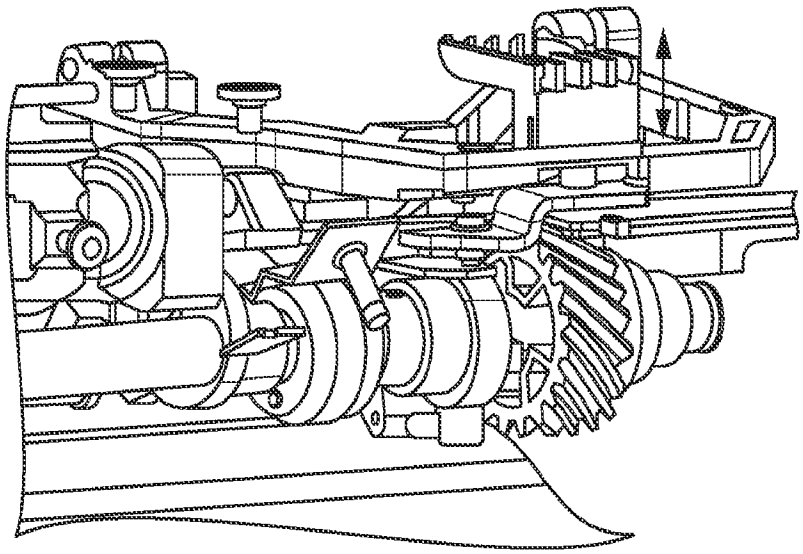


FIG. 32

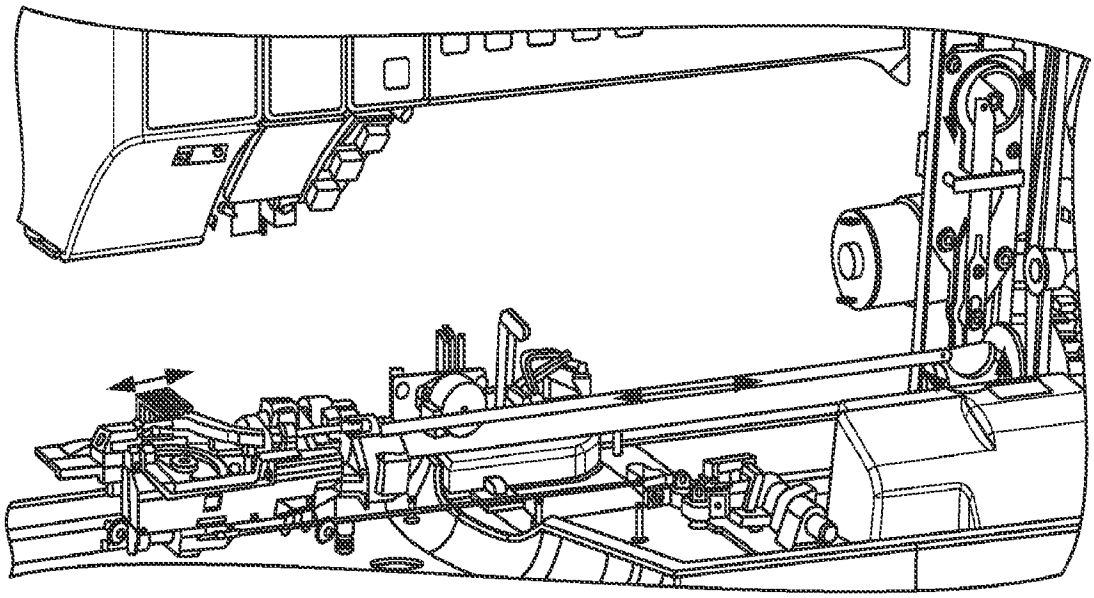


FIG. 33

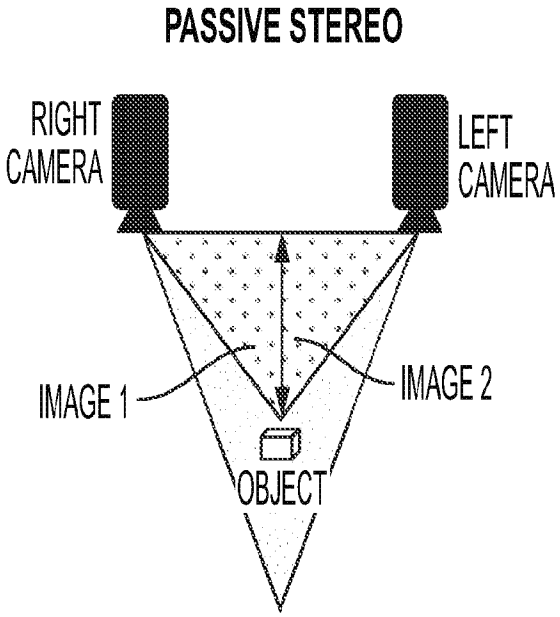


FIG. 34

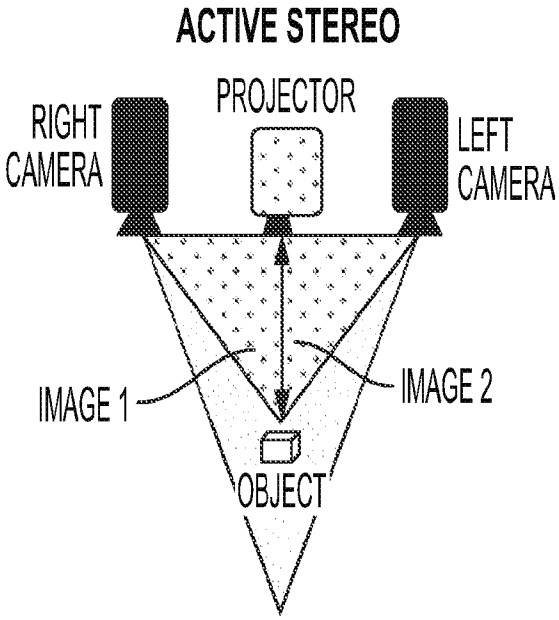


FIG. 35

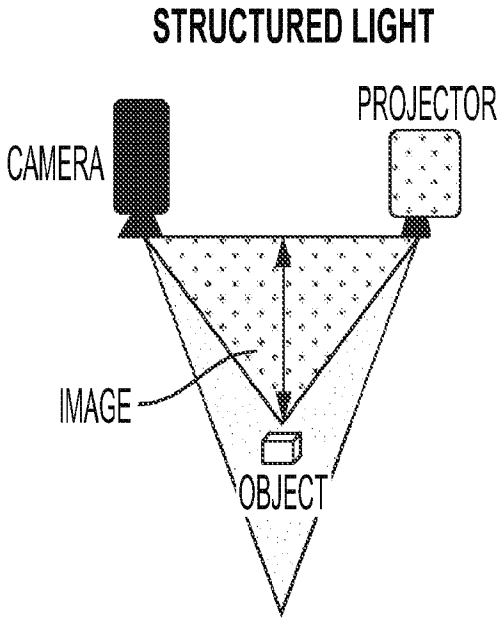


FIG. 36

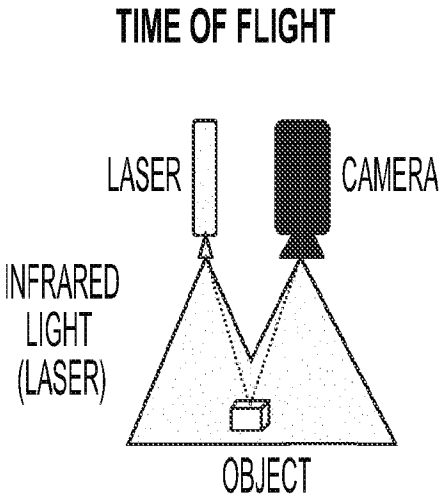


FIG. 37

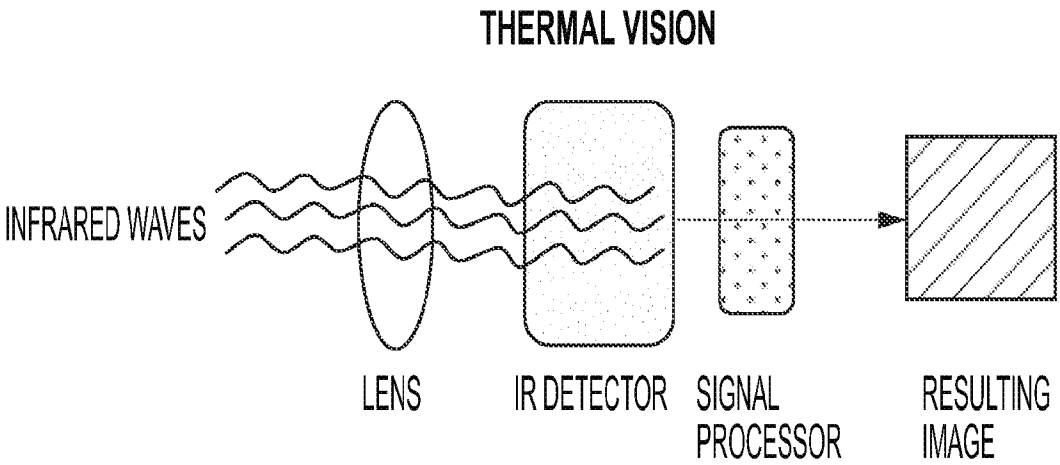

THERMAL VISION
INFRARED WAVES
LENS
IR DETECTOR
SIGNAL PROCESSOR
RESULTING IMAGE

FIG. 38

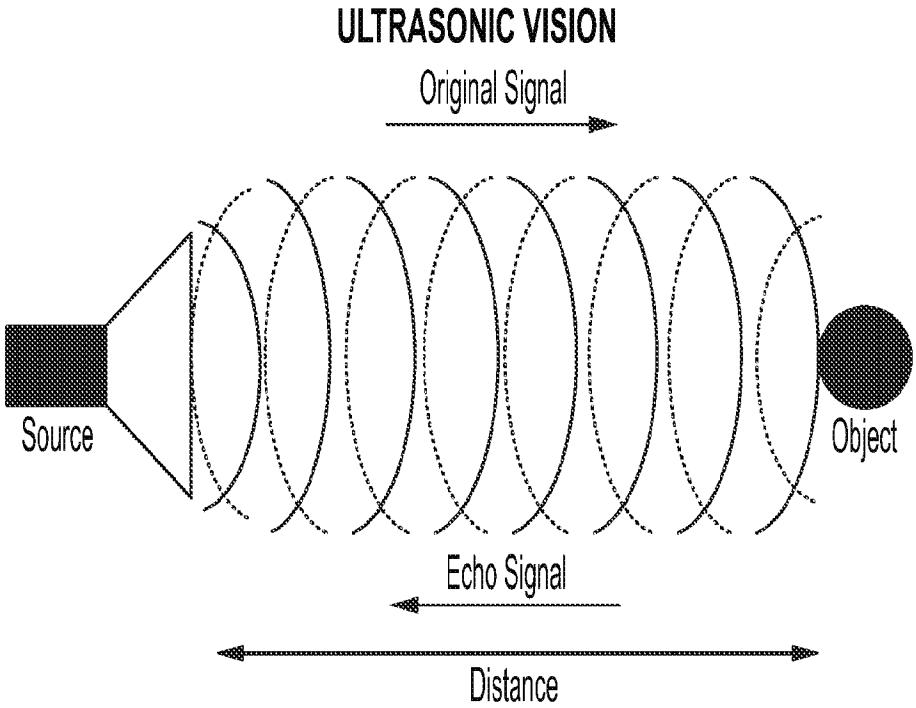
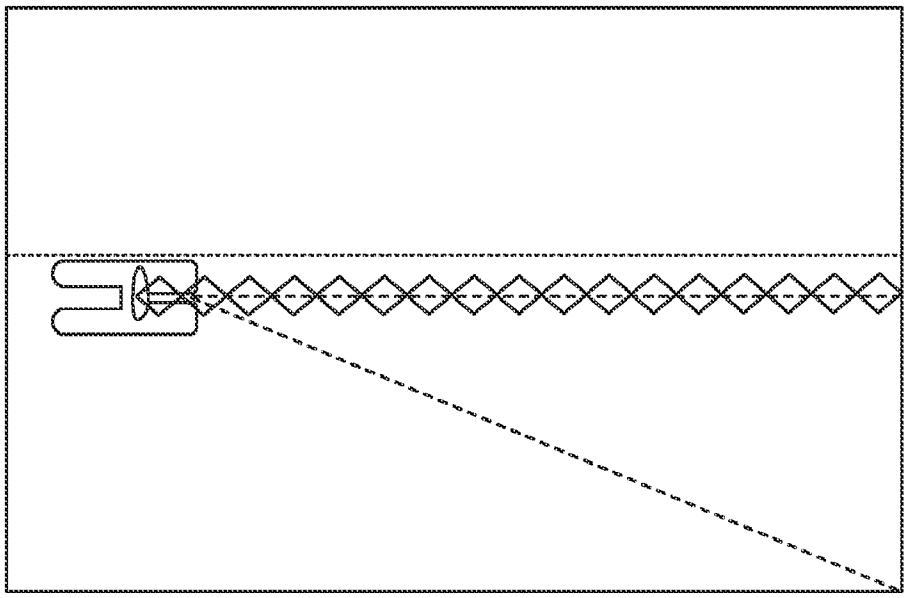
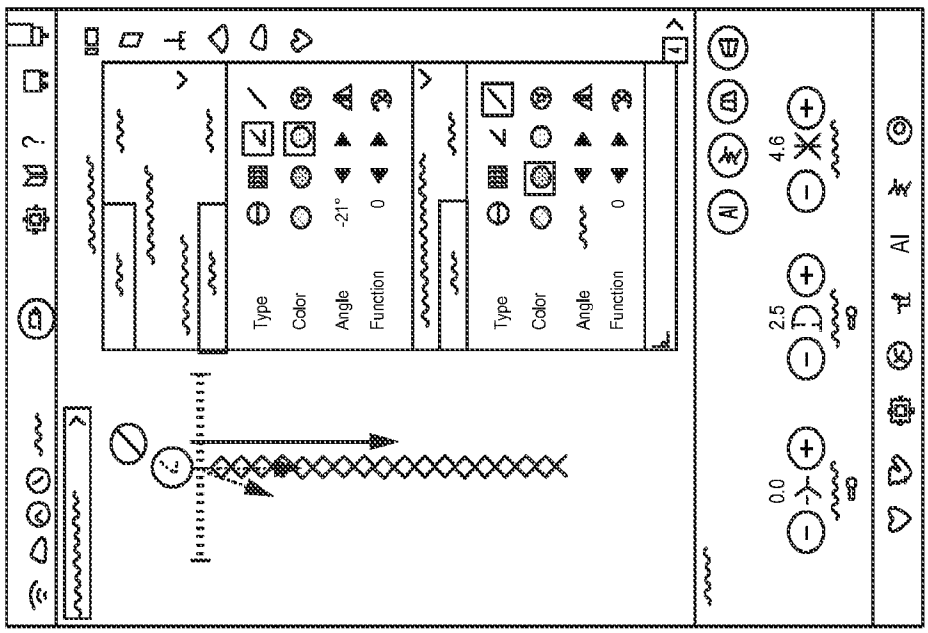

ULTRASONIC VISION
Original Signal
Source
Object
Echo Signal
Distance

FIG. 39



Projected onto fabric

FIG. 41



Selections made in GUI

FIG. 40

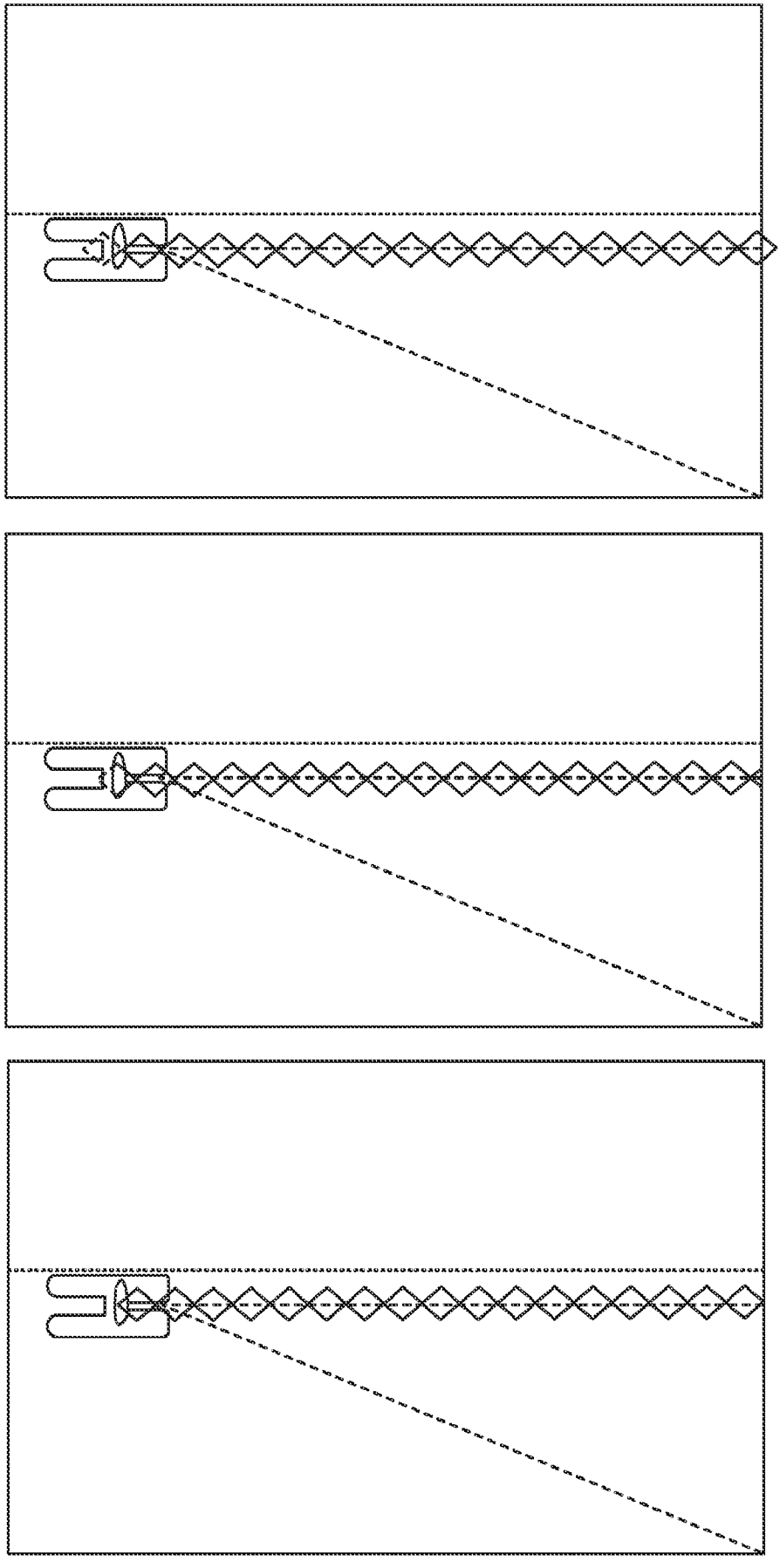


FIG. 42

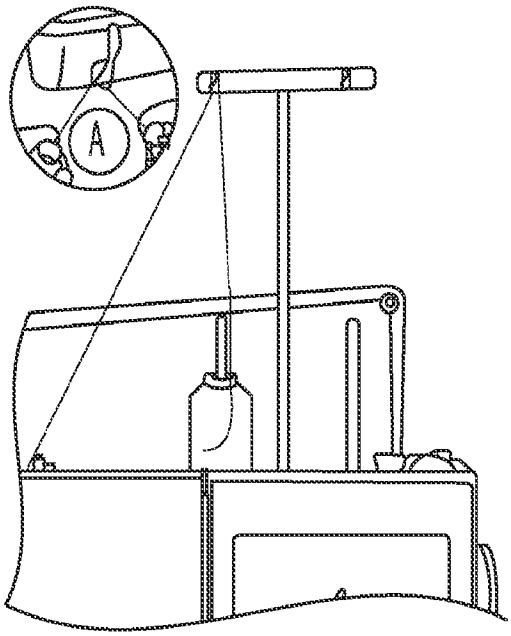


FIG. 43

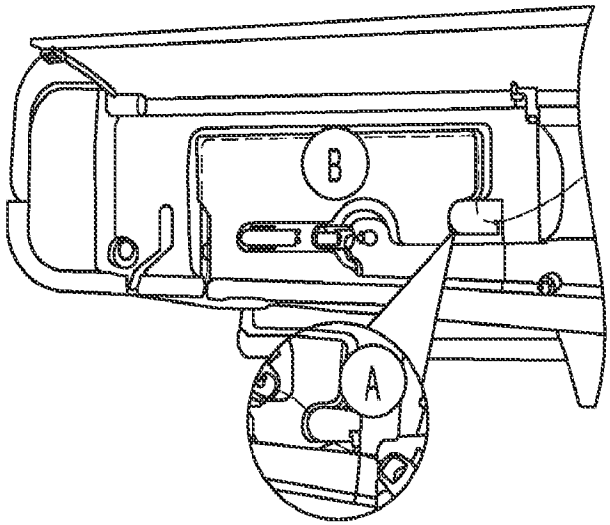


FIG. 44

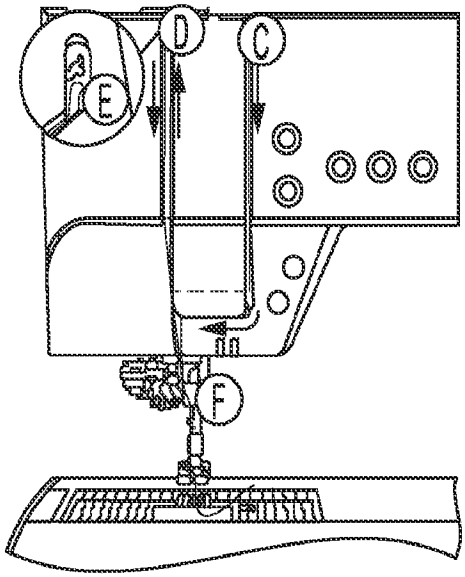


FIG. 45

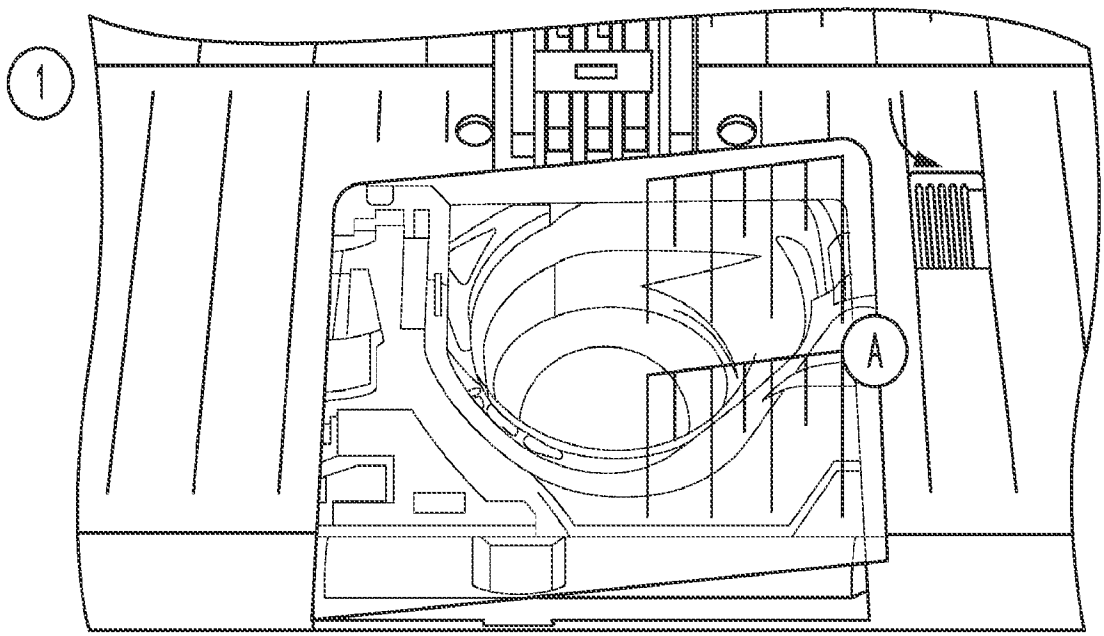


FIG. 46

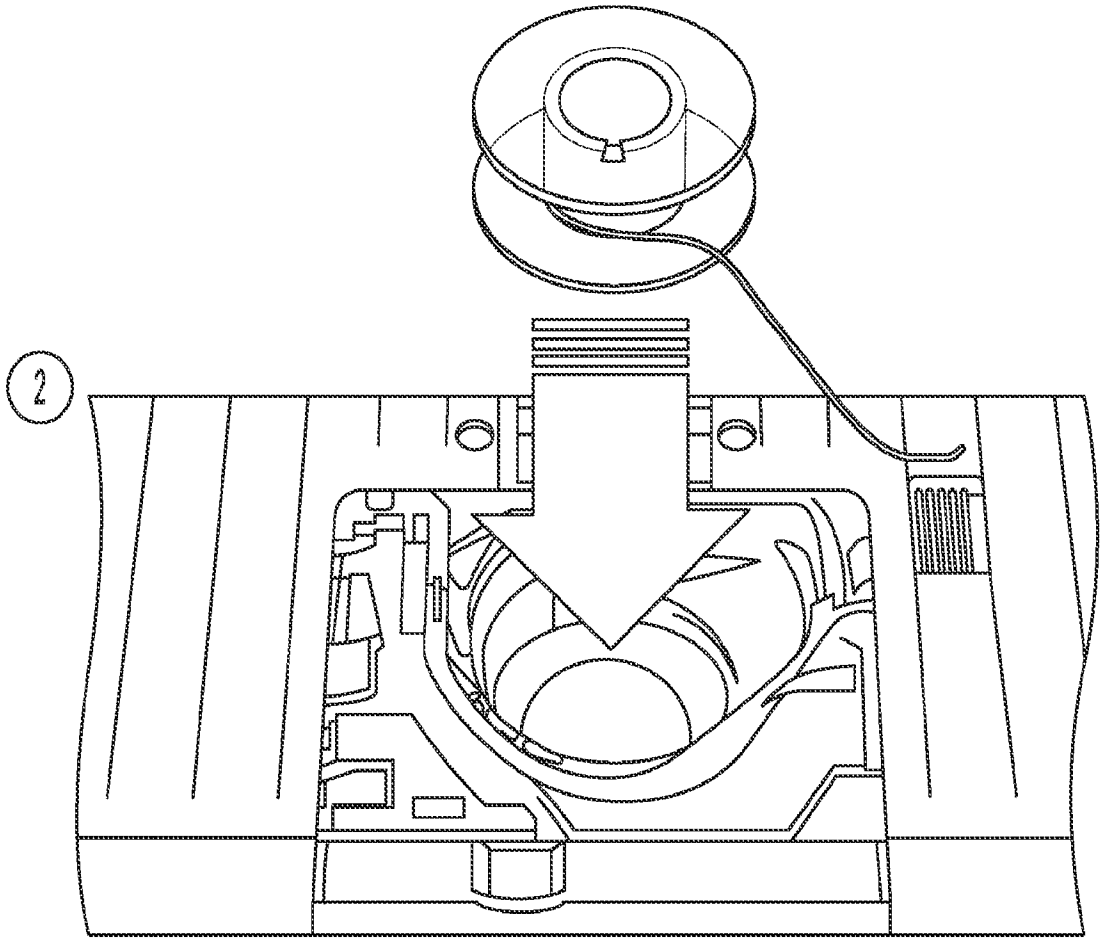


FIG. 47

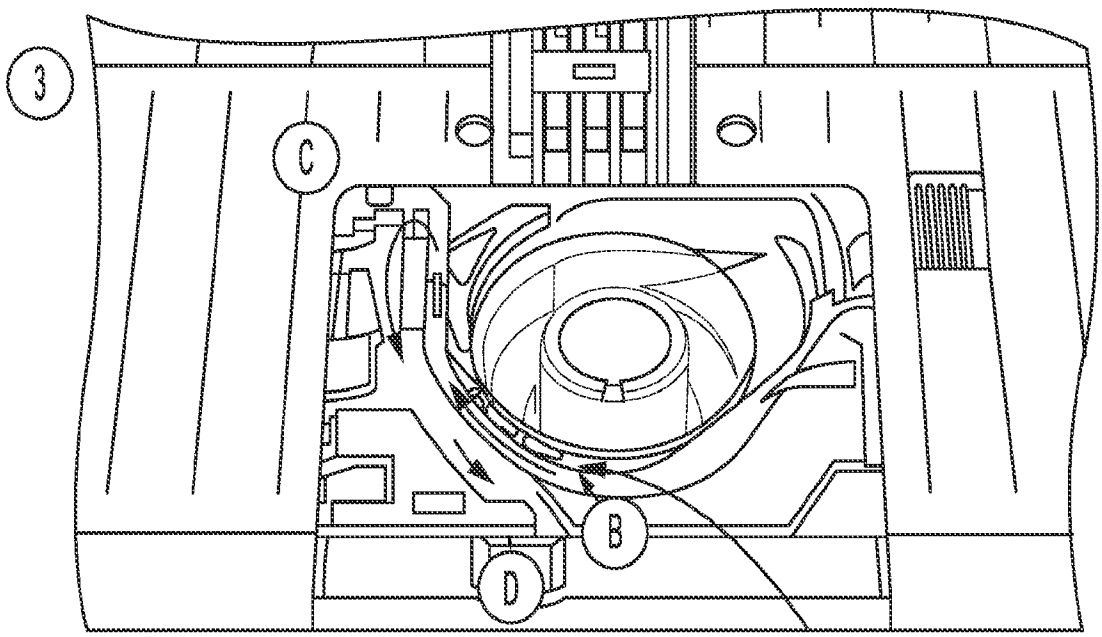


FIG. 48

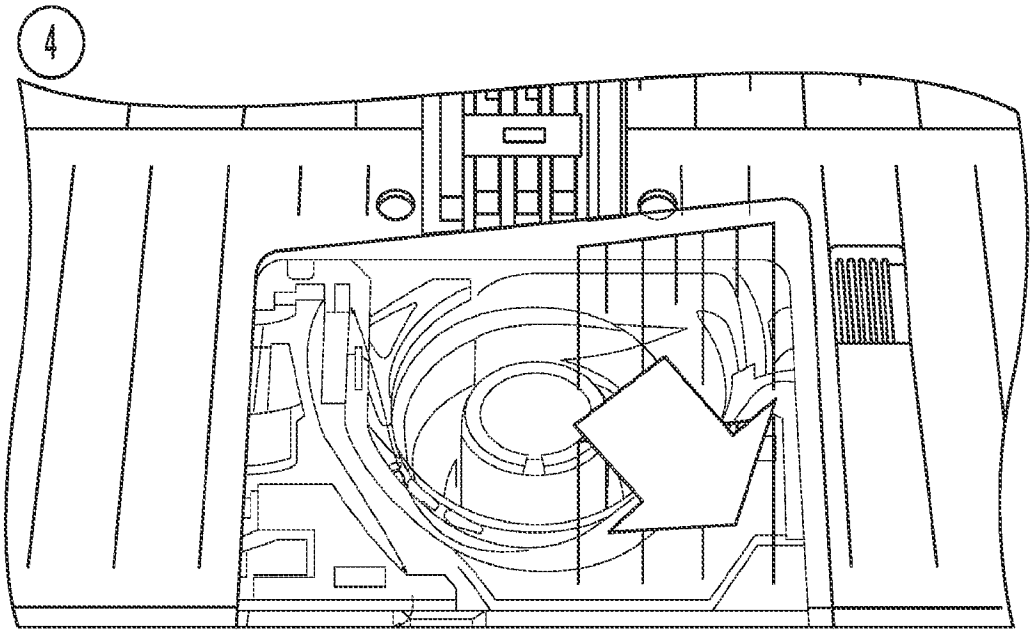


FIG. 49

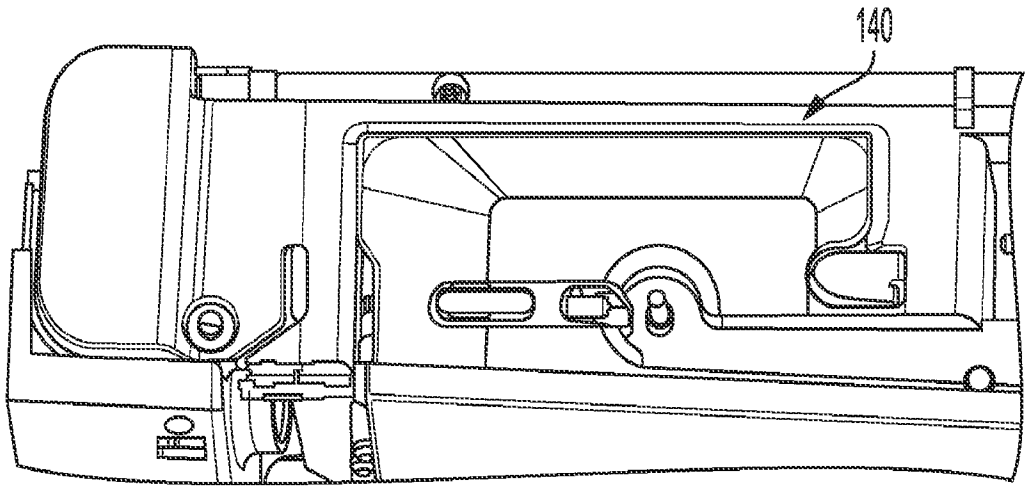


FIG. 50

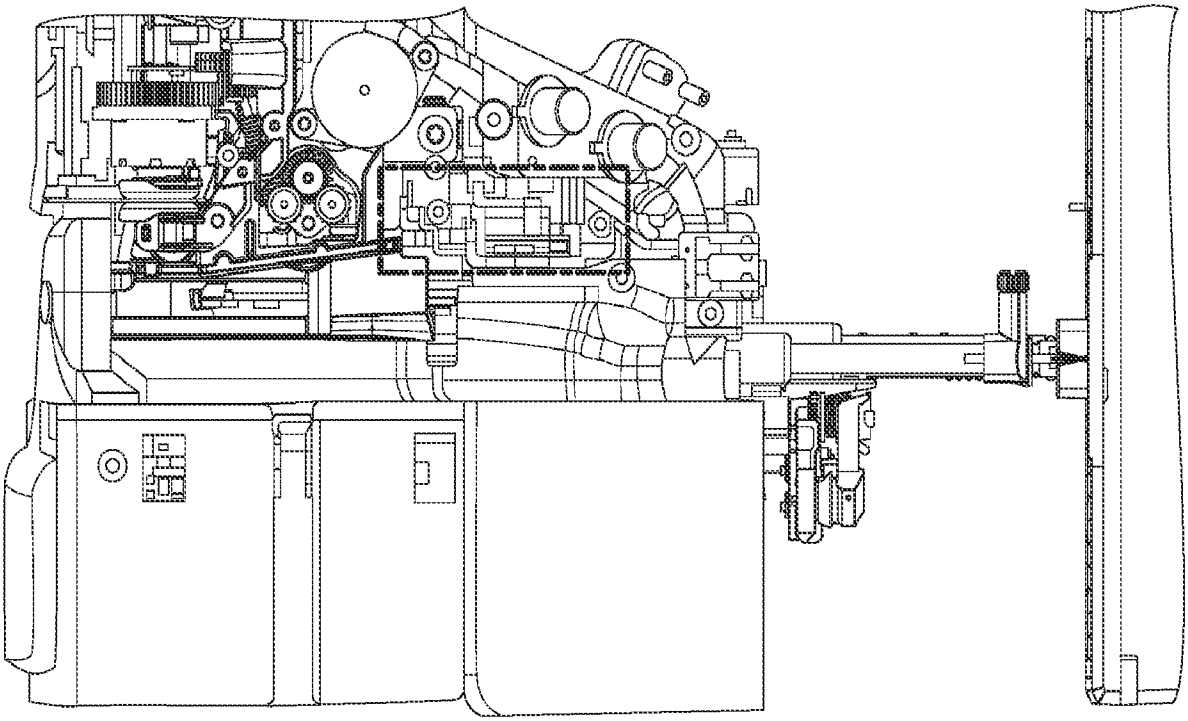


FIG. 52

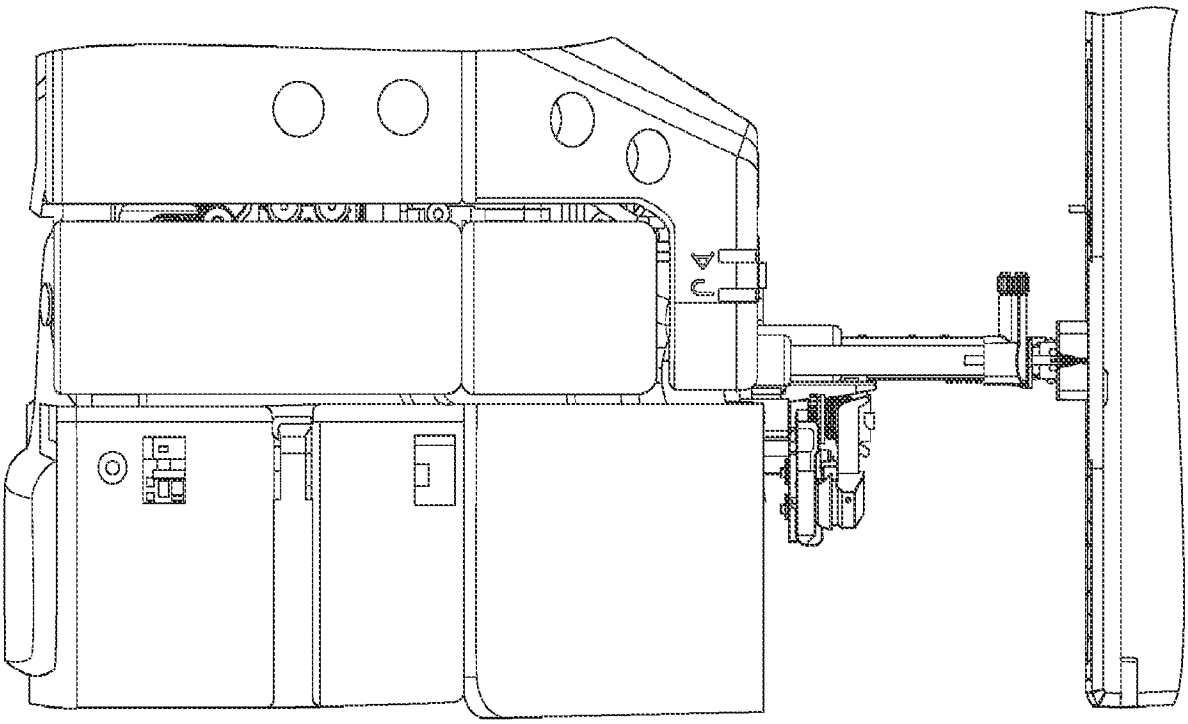


FIG. 51

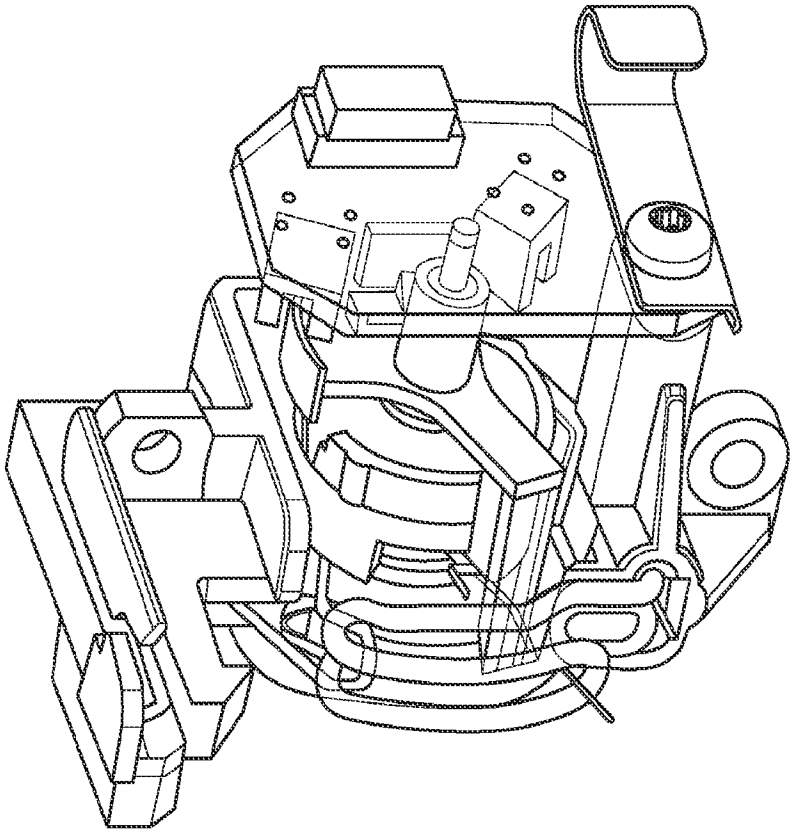


FIG. 54

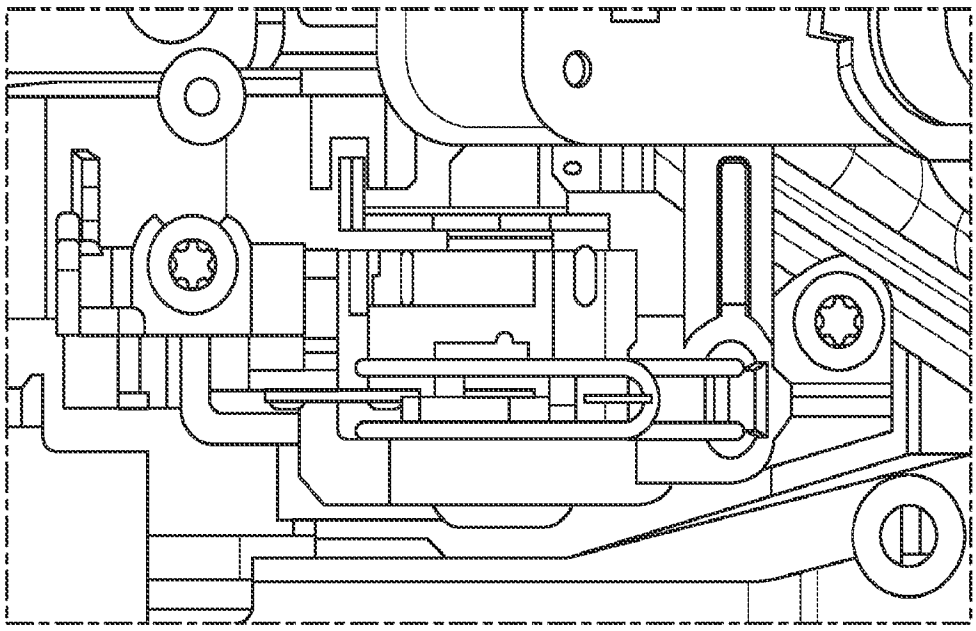


FIG. 53

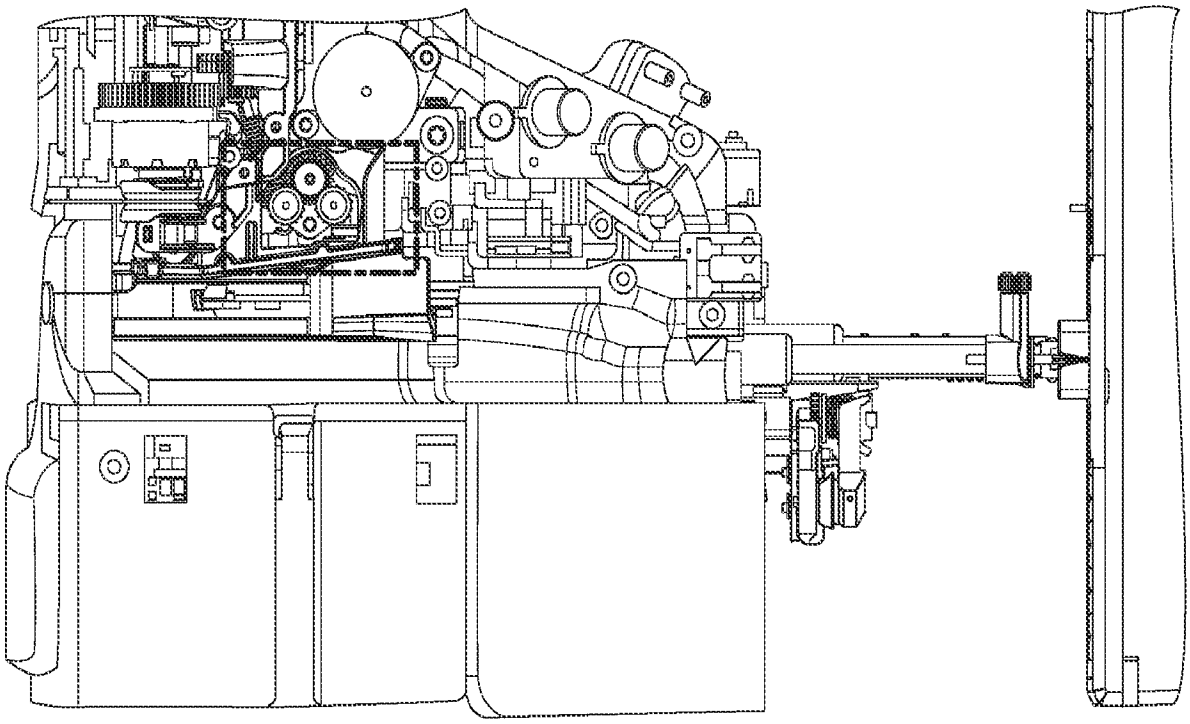


FIG. 56

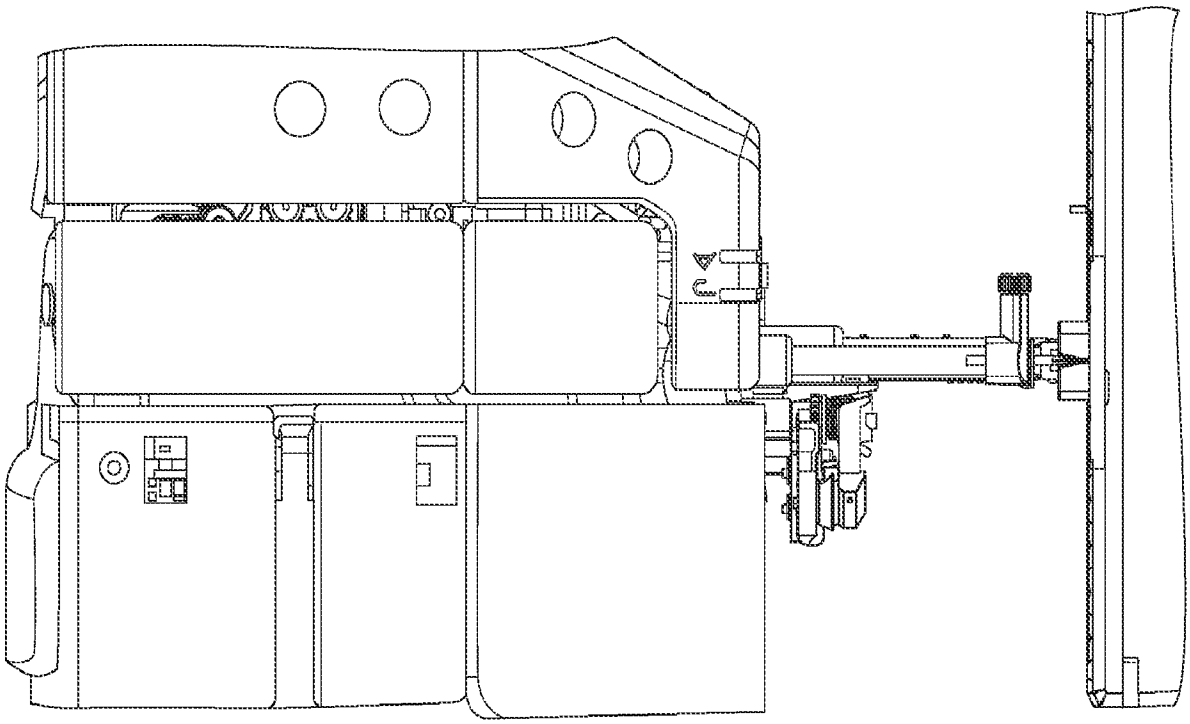


FIG. 55

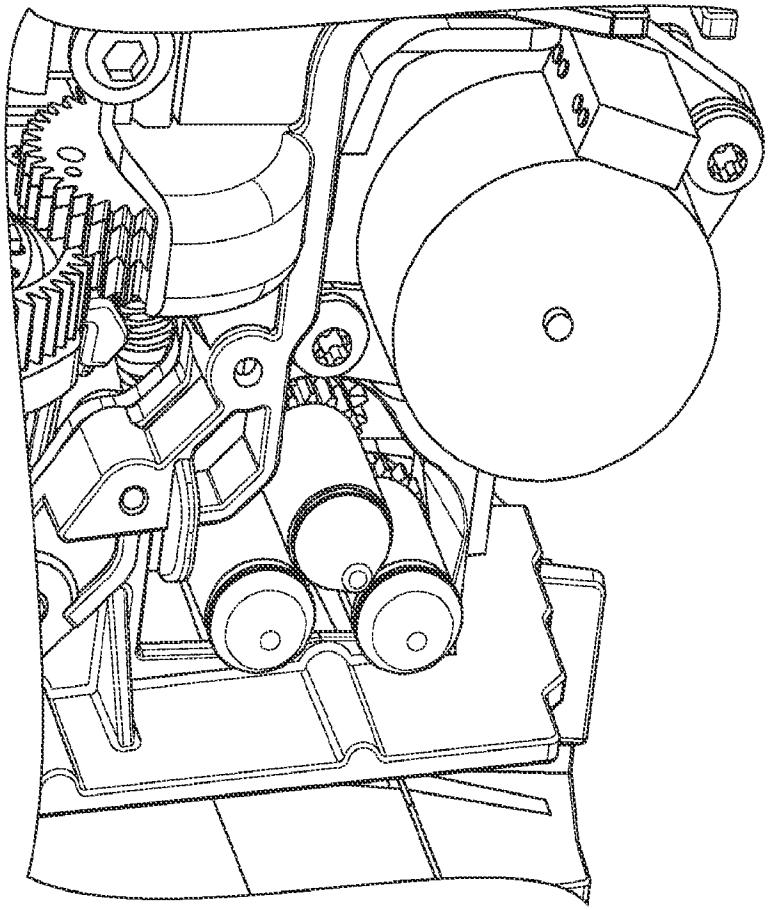


FIG. 58

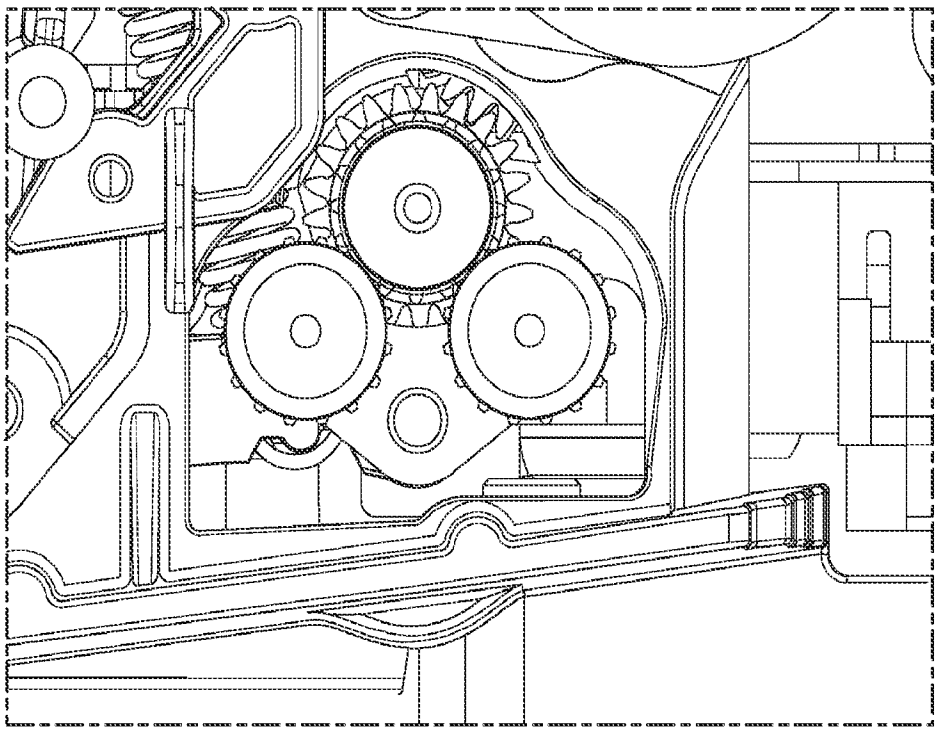


FIG. 57

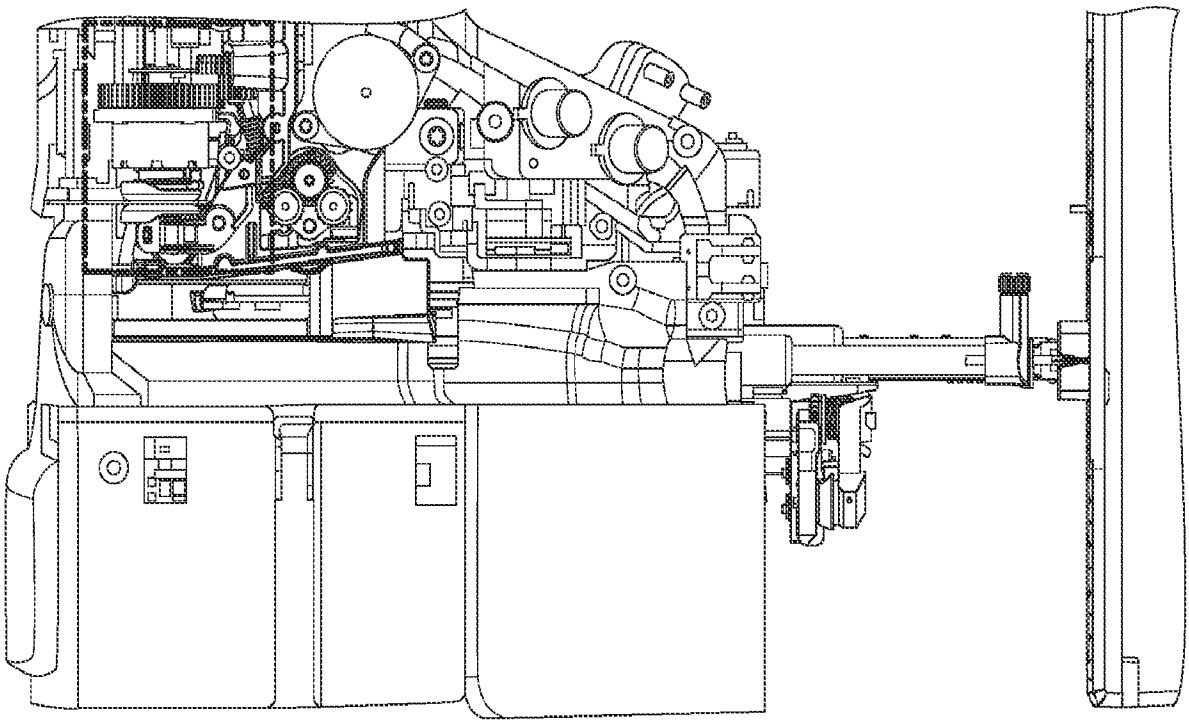


FIG. 60

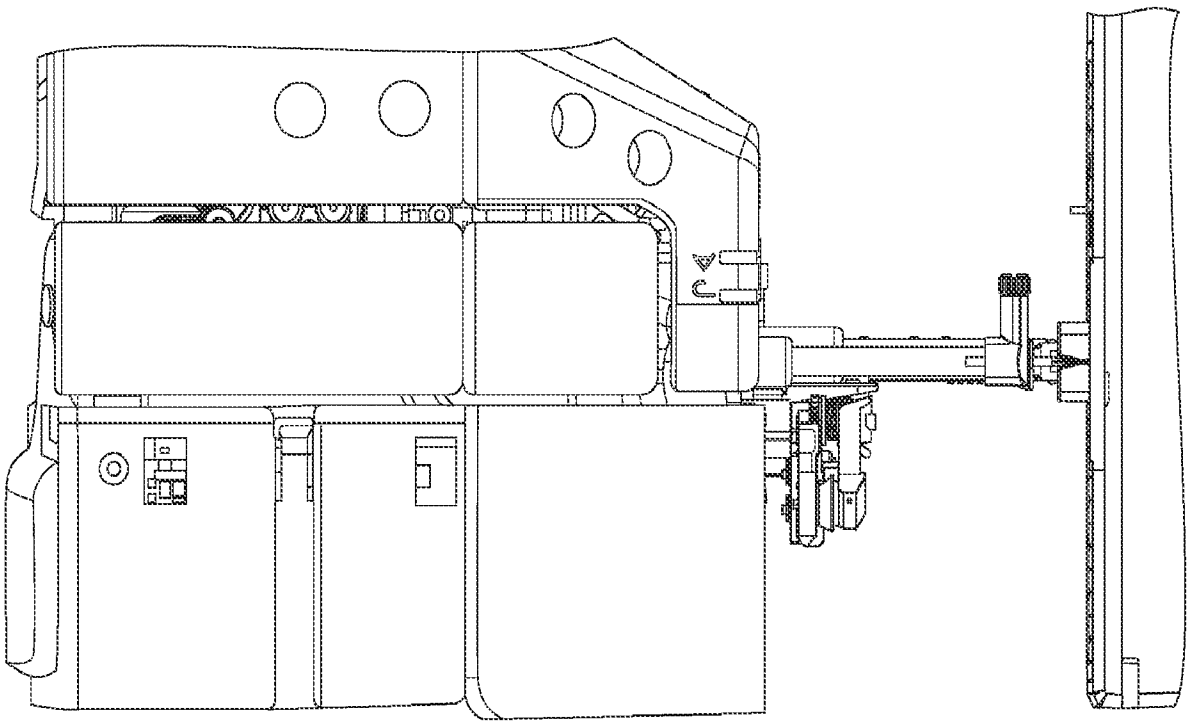


FIG. 59

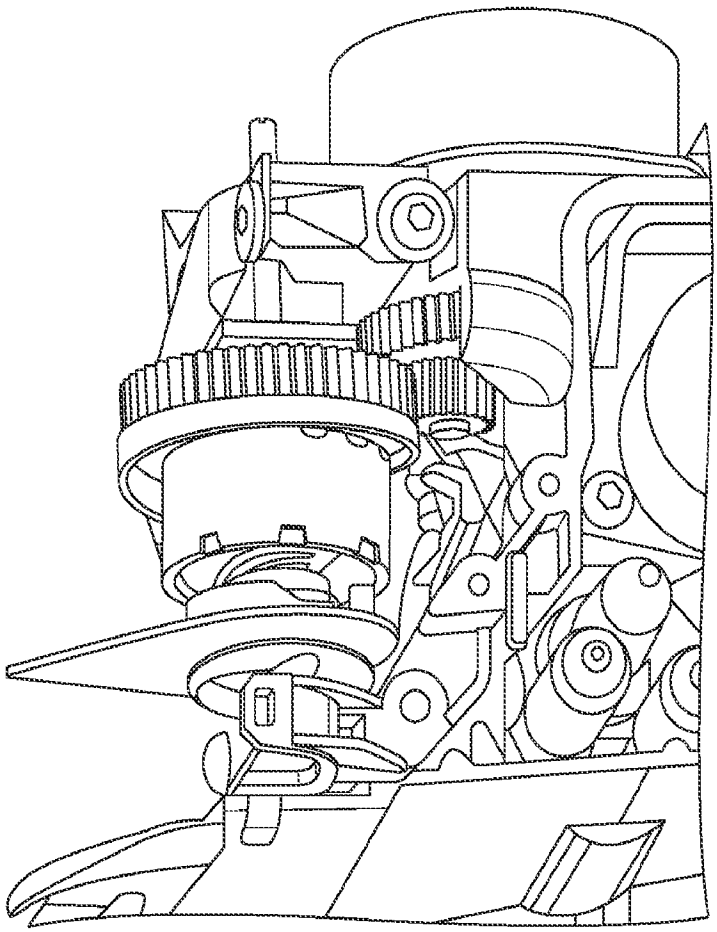


FIG. 62

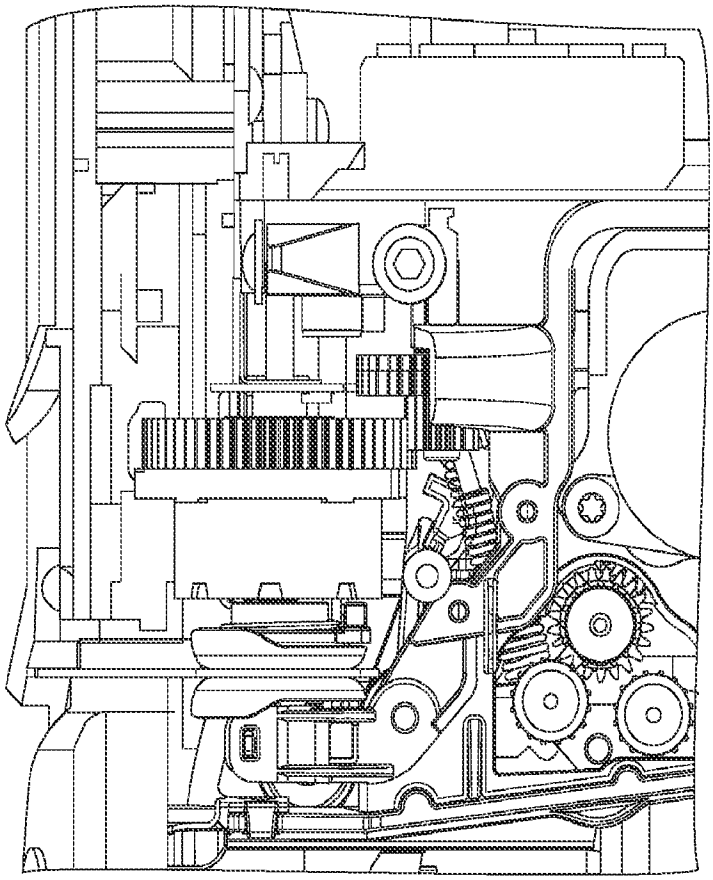


FIG. 61

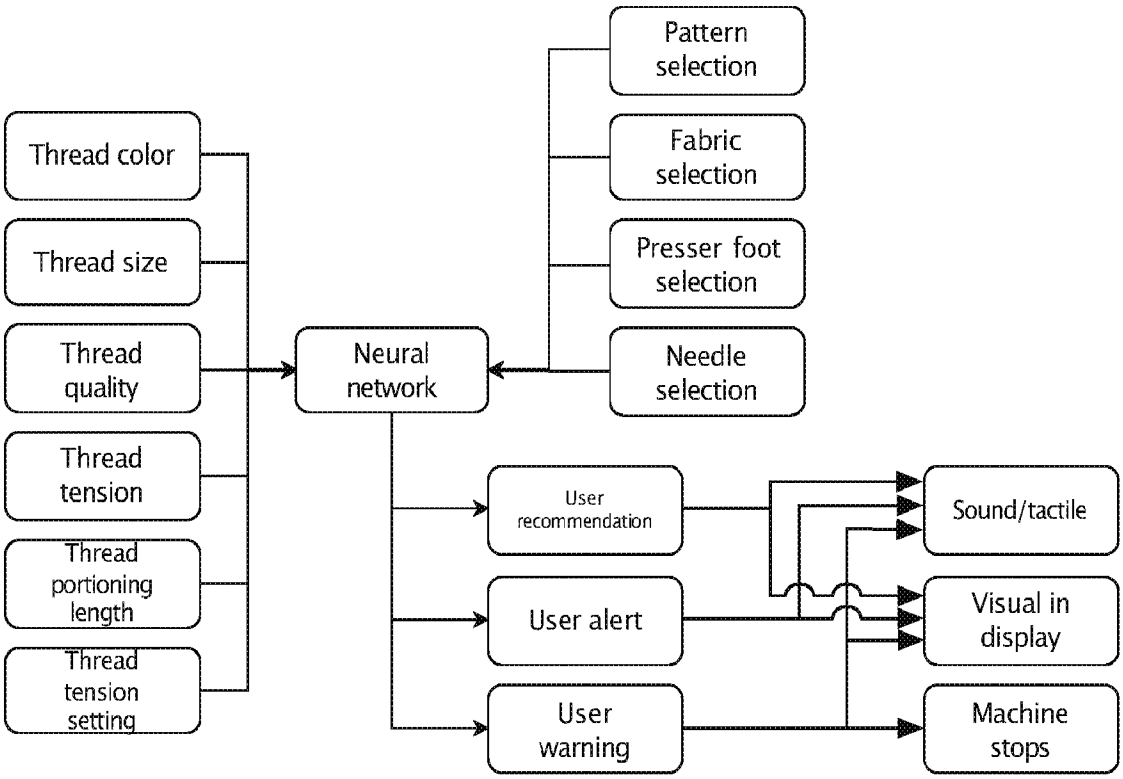

Pattern selection
Fabric selection
Presser foot selection
Needle selection
Thread color
Thread size
Thread quality
Thread tension
Thread portioning length
Thread tension setting
Neural network
User recommendation
User alert
User warning
Sound/tactile
Visual in display
Machine stops

FIG. 63

USER SELECTIONS: FABRIC & THREAD WEIGHT*			
FABRIC	**THREAD**	**COMPATIBILITY FEEDBACK**	**OVERRIDE?**
HEAVY	HEAVY	OK	YES/NO
LIGHT	LIGHT	OK	YES/NO
HEAVY	LIGHT	NOK	YES/NO
LIGHT	HEAVY	NOK	YES/NO
*WEIGHT REFERS TO ALL PHYSICAL PROPERTIES PERTAINING TO GEOMETRY, DENSITY, STRENGTH, FRICTIONAL QUALITIES OR OTHER RELEVANT CRITERIA.			

FIG. 64

USER SELECTIONS: FABRIC & THREAD COLOR			
FABRIC	**THREAD**	**COMPATIBILITY FEEDBACK**	**OVERRIDE?**
COLOR X	COLOR X	OK	YES/NO
COLOR X	COLOR X	NOK	YES/NO

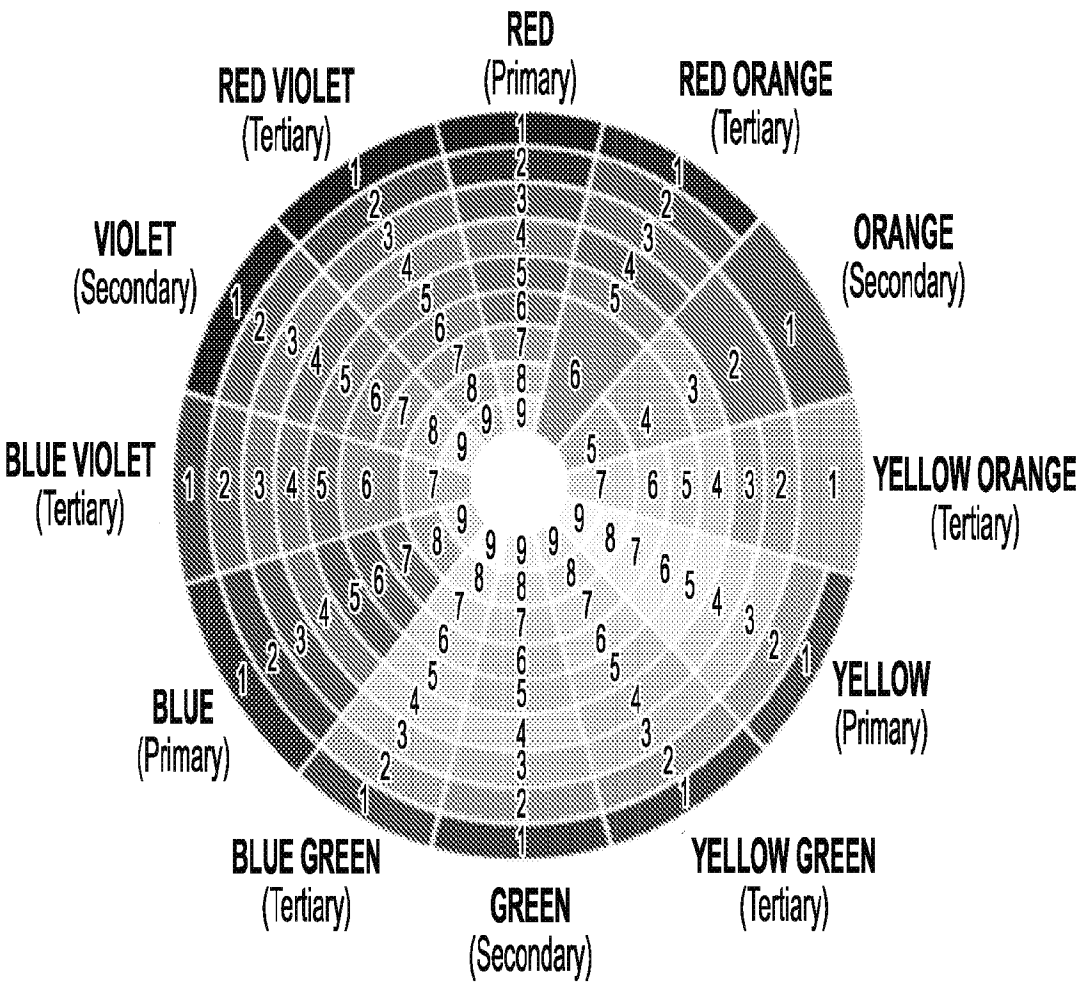


FIG. 65

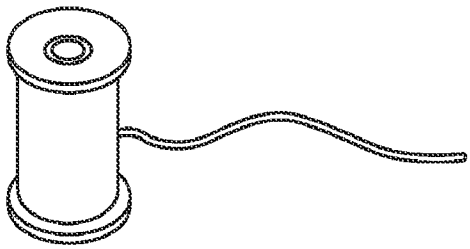


FIG. 66

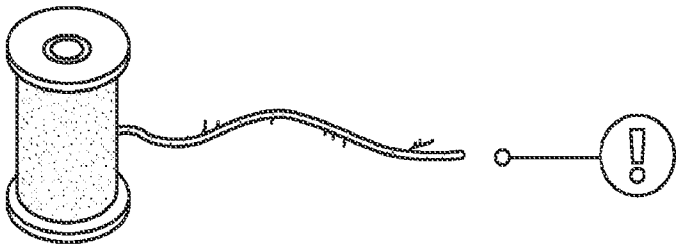


FIG. 67

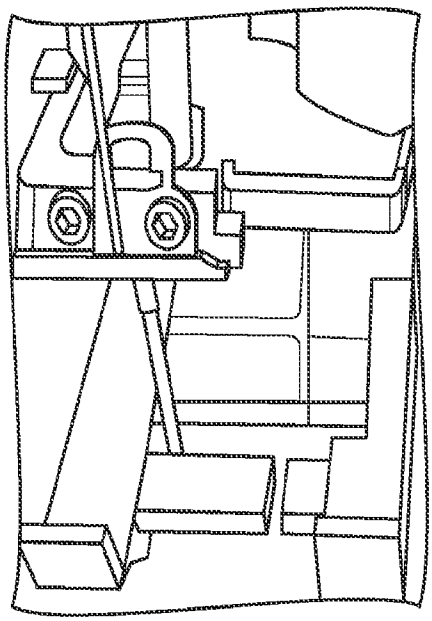


FIG. 68

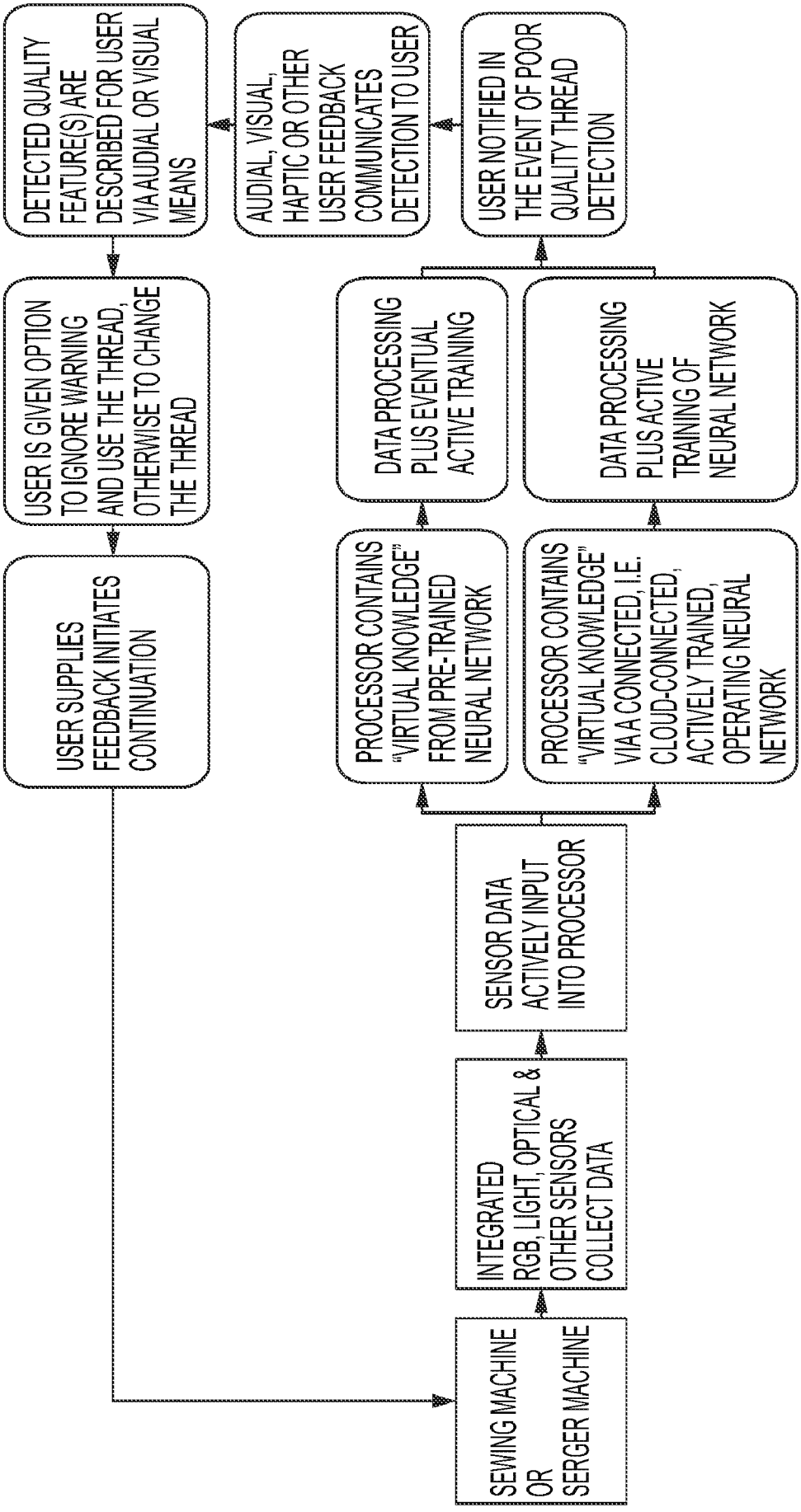

SEWING MACHINE OR SERGER MACHINE
INTEGRATED RGB, LIGHT, OPTICAL & OTHER SENSORS COLLECT DATA
SENSOR DATA ACTIVELY INPUT INTO PROCESSOR
PROCESSOR CONTAINS "VIRTUAL KNOWLEDGE" FROM PRE-TRAINED NEURAL NETWORK
PROCESSOR CONTAINS "VIRTUAL KNOWLEDGE" VIA A CONNECTED, I.E. CLOUD-CONNECTED, ACTIVELY TRAINED, OPERATING NEURAL NETWORK
DATA PROCESSING PLUS EVENTUAL ACTIVE TRAINING
DATA PROCESSING PLUS ACTIVE TRAINING OF NEURAL NETWORK
USER SUPPLIES FEEDBACK INITIATES CONTINUATION
USER IS GIVEN OPTION TO IGNORE WARNING AND USE THE THREAD, OTHERWISE TO CHANGE THE THREAD
DETECTED QUALITY FEATURE(S) ARE DESCRIBED FOR USER VIA AUDIAL OR VISUAL MEANS
AUDIAL, VISUAL, HAPTIC OR OTHER USER FEEDBACK COMMUNICATES DETECTION TO USER
USER NOTIFIED IN THE EVENT OF POOR QUALITY THREAD DETECTION

FIG. 69

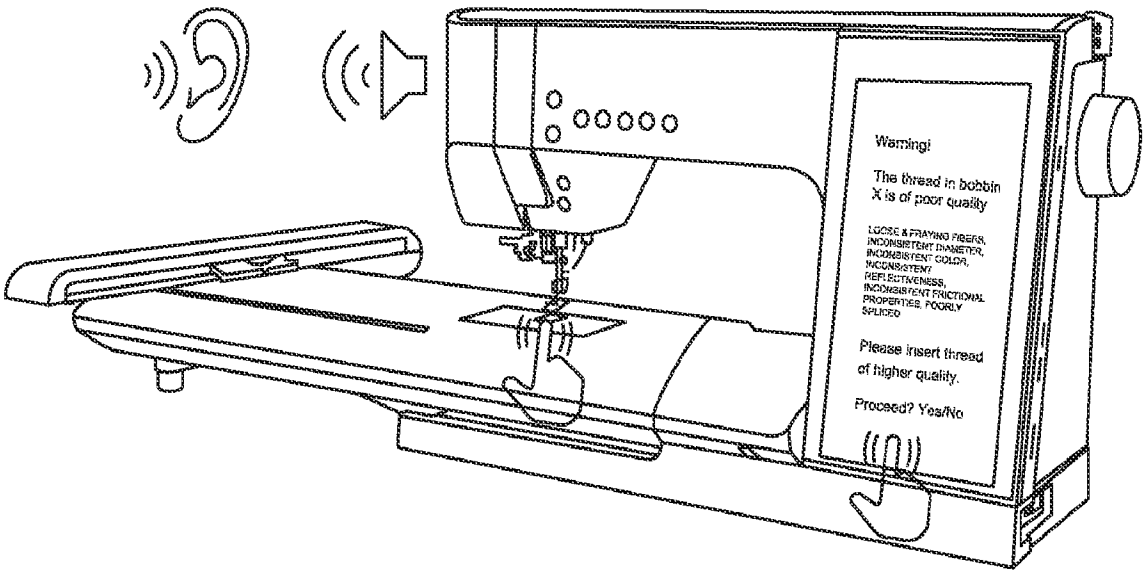

Warning!
The thread in bobbin X is of poor quality
LOOSE & FRAYING FIBERS, INCONSISTENT DIAMETER, INCONSISTENT COLOR, INCONSISTENT REFLECTIVENESS, INCONSISTENT FRICTIONAL PROPERTIES, POORLY SPLICED
Please insert thread of higher quality.
Proceed? Yes/No

FIG. 70

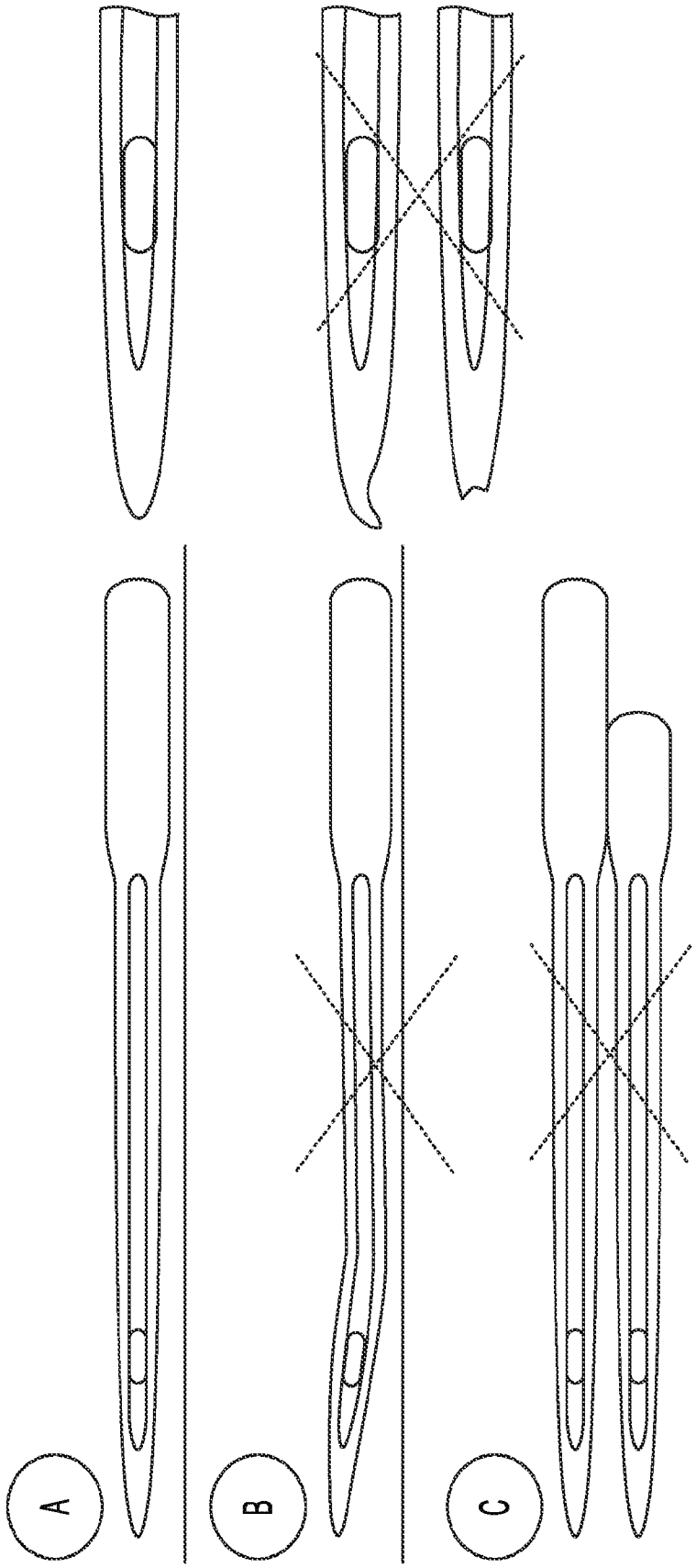


FIG. 71

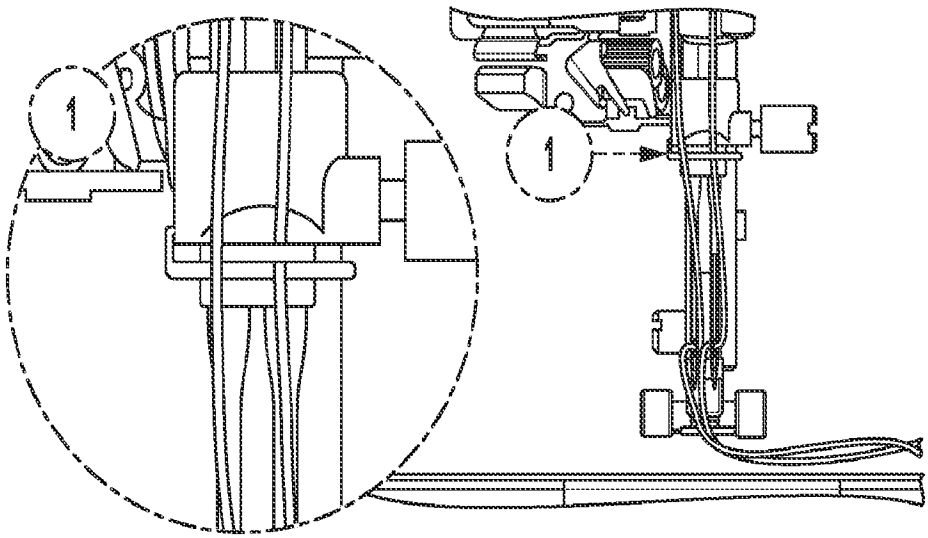


FIG. 72

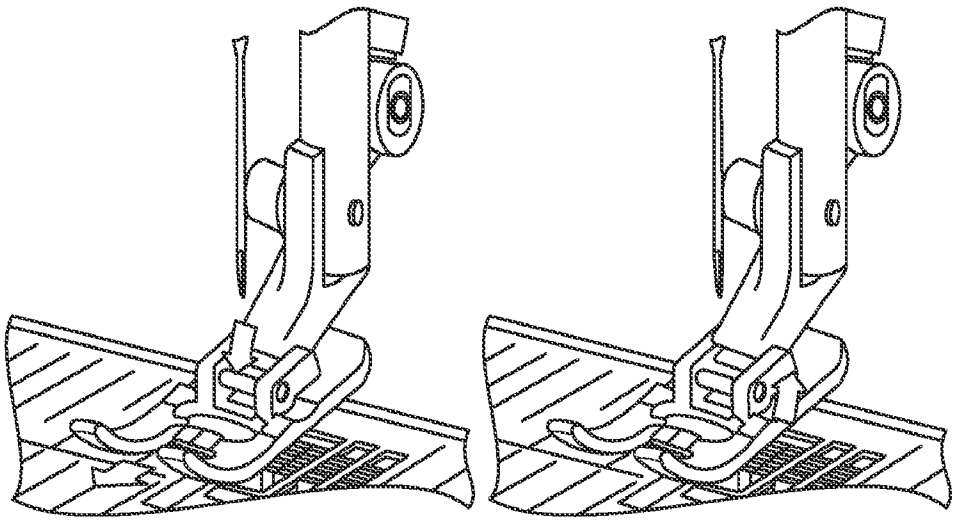


FIG. 73

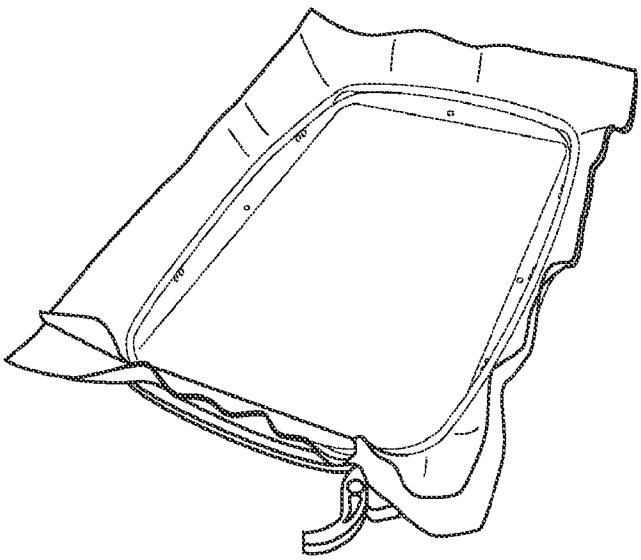


FIG. 74

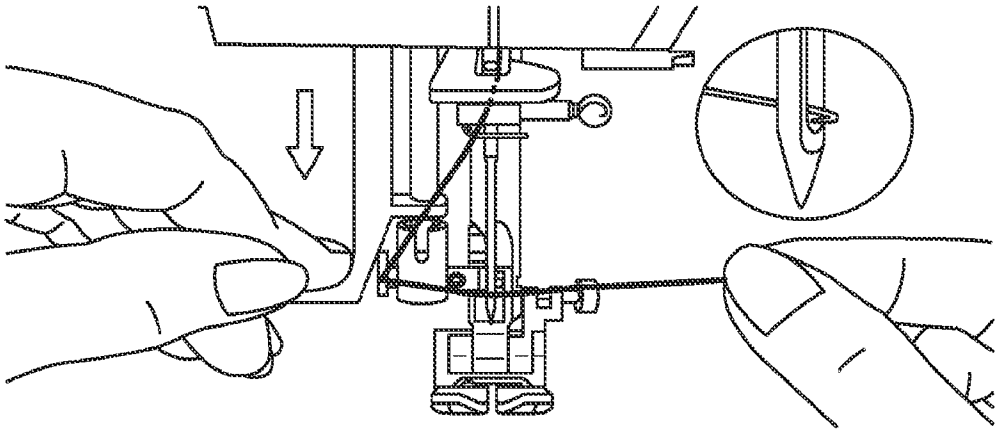


FIG. 75

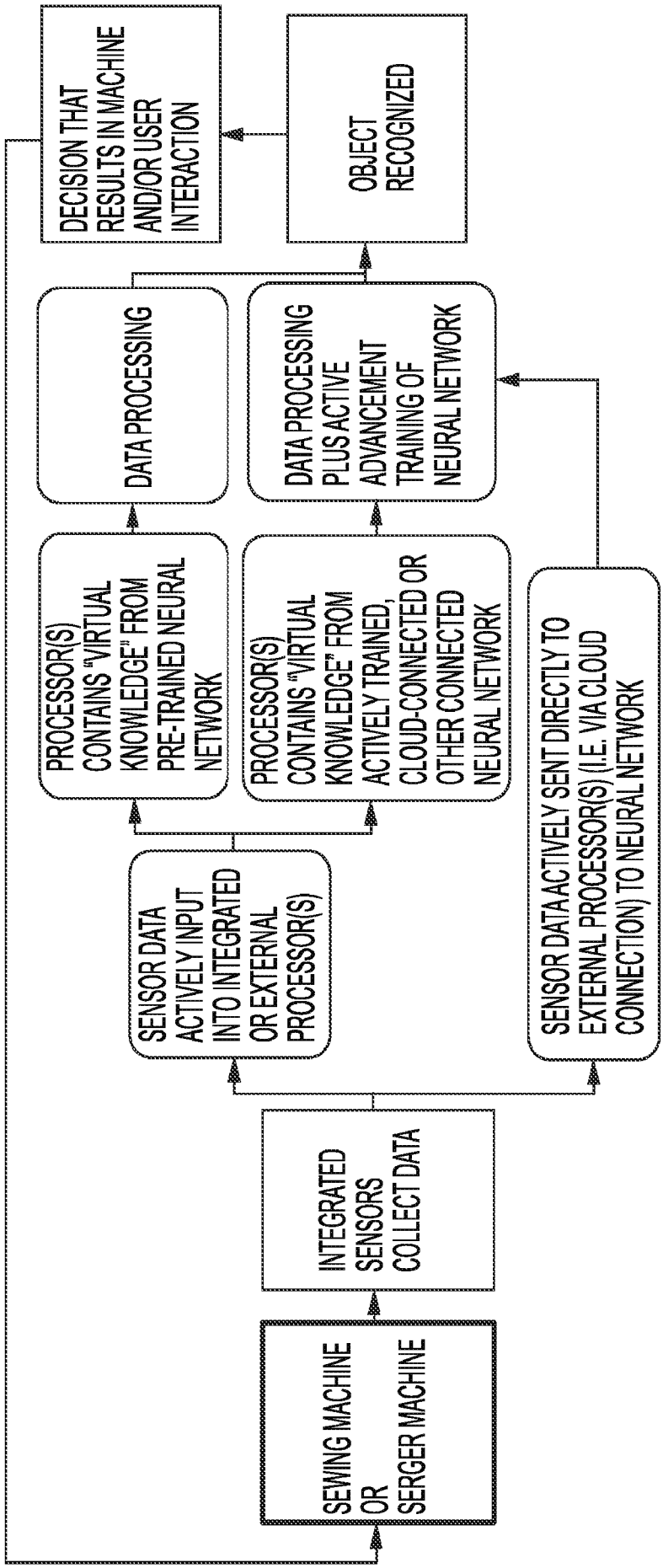

SEWING MACHINE OR SERGER MACHINE
INTEGRATED SENSORS COLLECT DATA
SENSOR DATA ACTIVELY INPUT INTO INTEGRATED OR EXTERNAL PROCESSOR(S)
SENSOR DATA ACTIVELY SENT DIRECTLY TO EXTERNAL PROCESSOR(S) (I.E. VIA CLOUD CONNECTION) TO NEURAL NETWORK
PROCESSOR(S) CONTAINS "VIRTUAL KNOWLEDGE" FROM PRE-TRAINED NEURAL NETWORK
PROCESSOR(S) CONTAINS "VIRTUAL KNOWLEDGE" FROM ACTIVELY TRAINED, CLOUD-CONNECTED OR OTHER CONNECTED NEURAL NETWORK
DATA PROCESSING
DATA PROCESSING PLUS ACTIVE ADVANCEMENT TRAINING OF NEURAL NETWORK
OBJECT RECOGNIZED
DECISION THAT RESULTS IN MACHINE AND/OR USER INTERACTION

FIG. 76

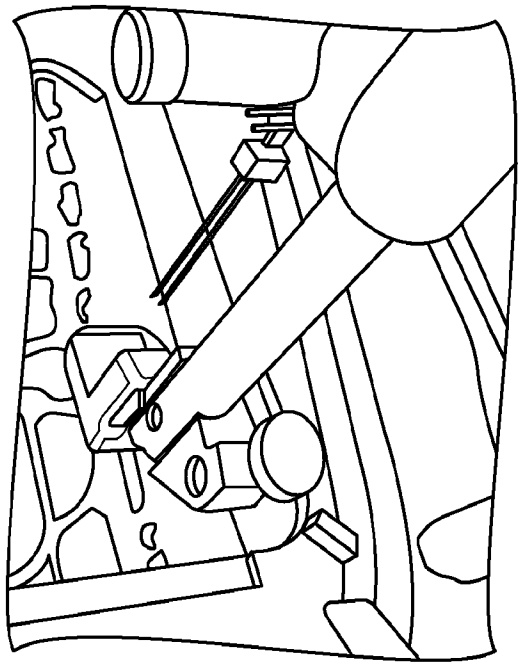


FIG. 77

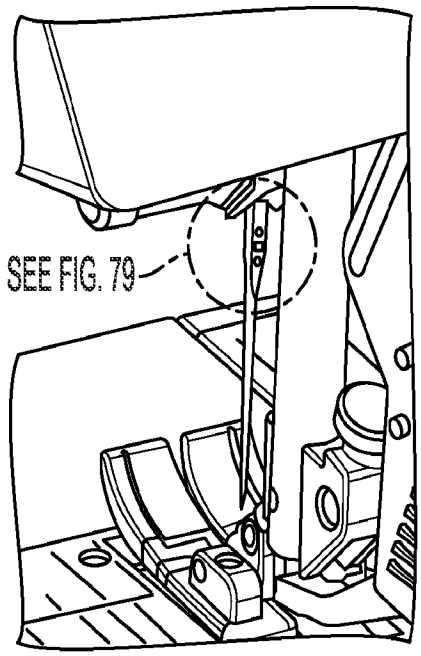


FIG. 78

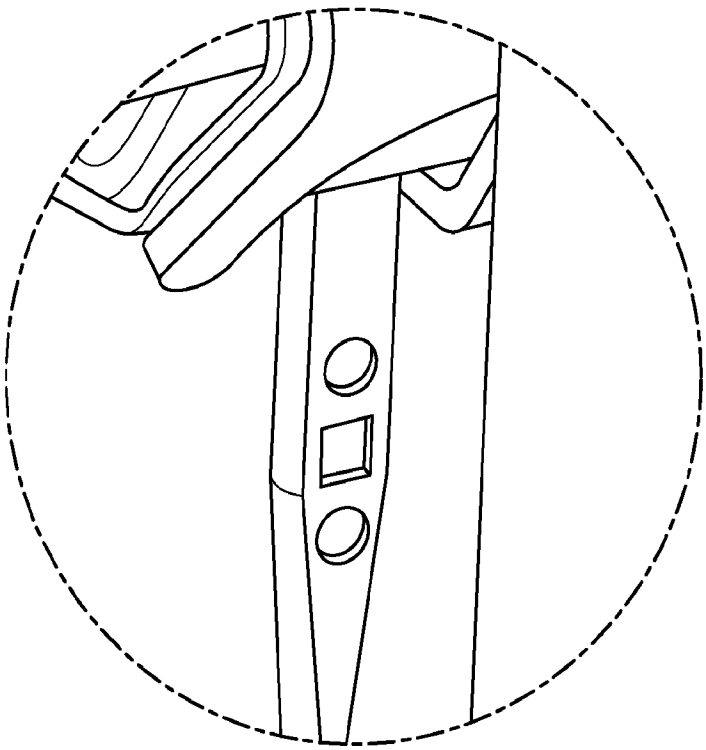


FIG. 79

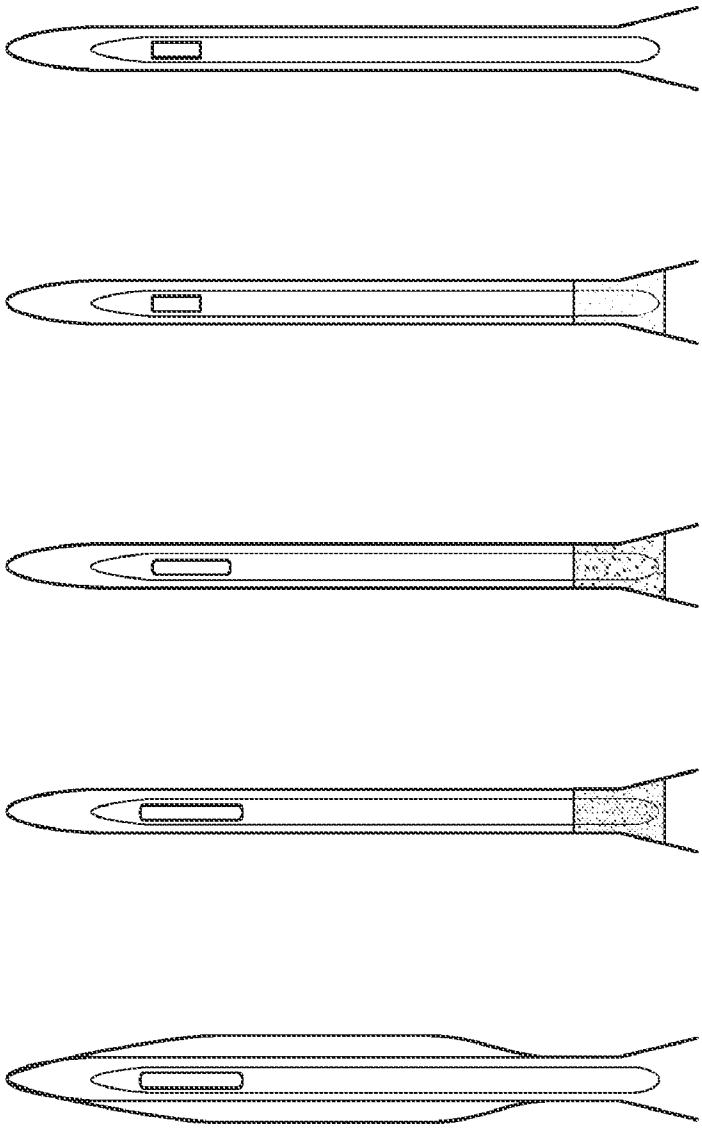


FIG. 80

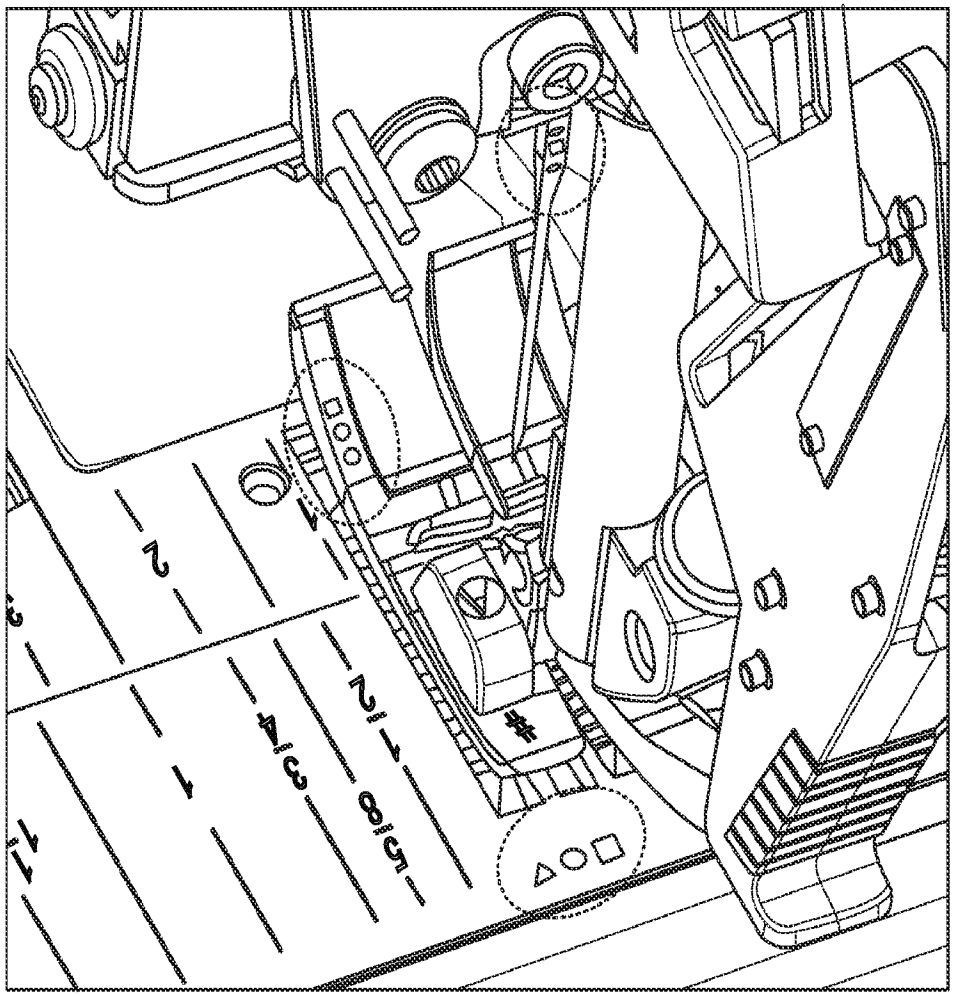


FIG. 81

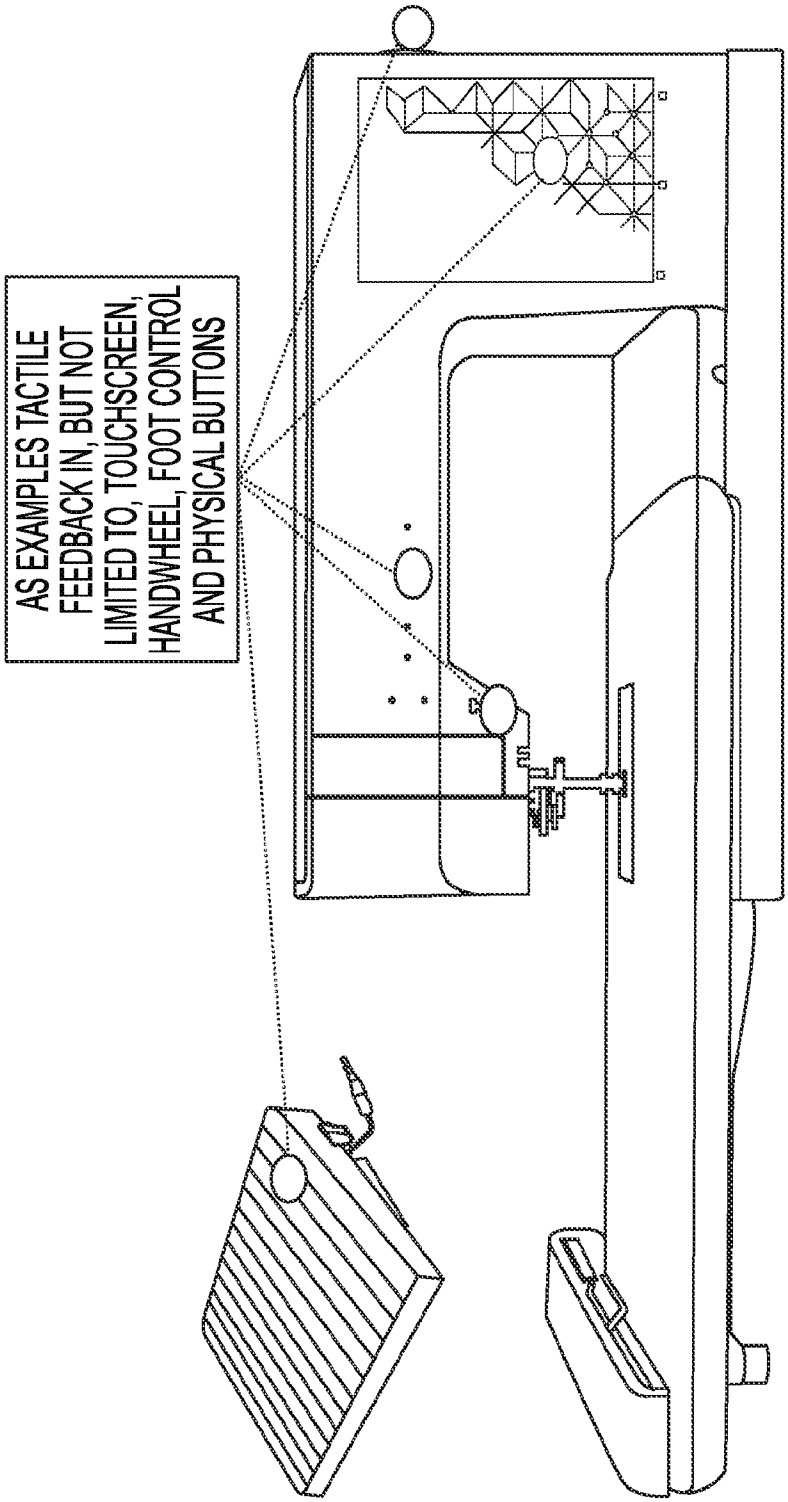

AS EXAMPLES TACTILE FEEDBACK IN, BUT NOT LIMITED TO, TOUCHSCREEN, HANDWHEEL, FOOT CONTROL AND PHYSICAL BUTTONS

FIG. 82

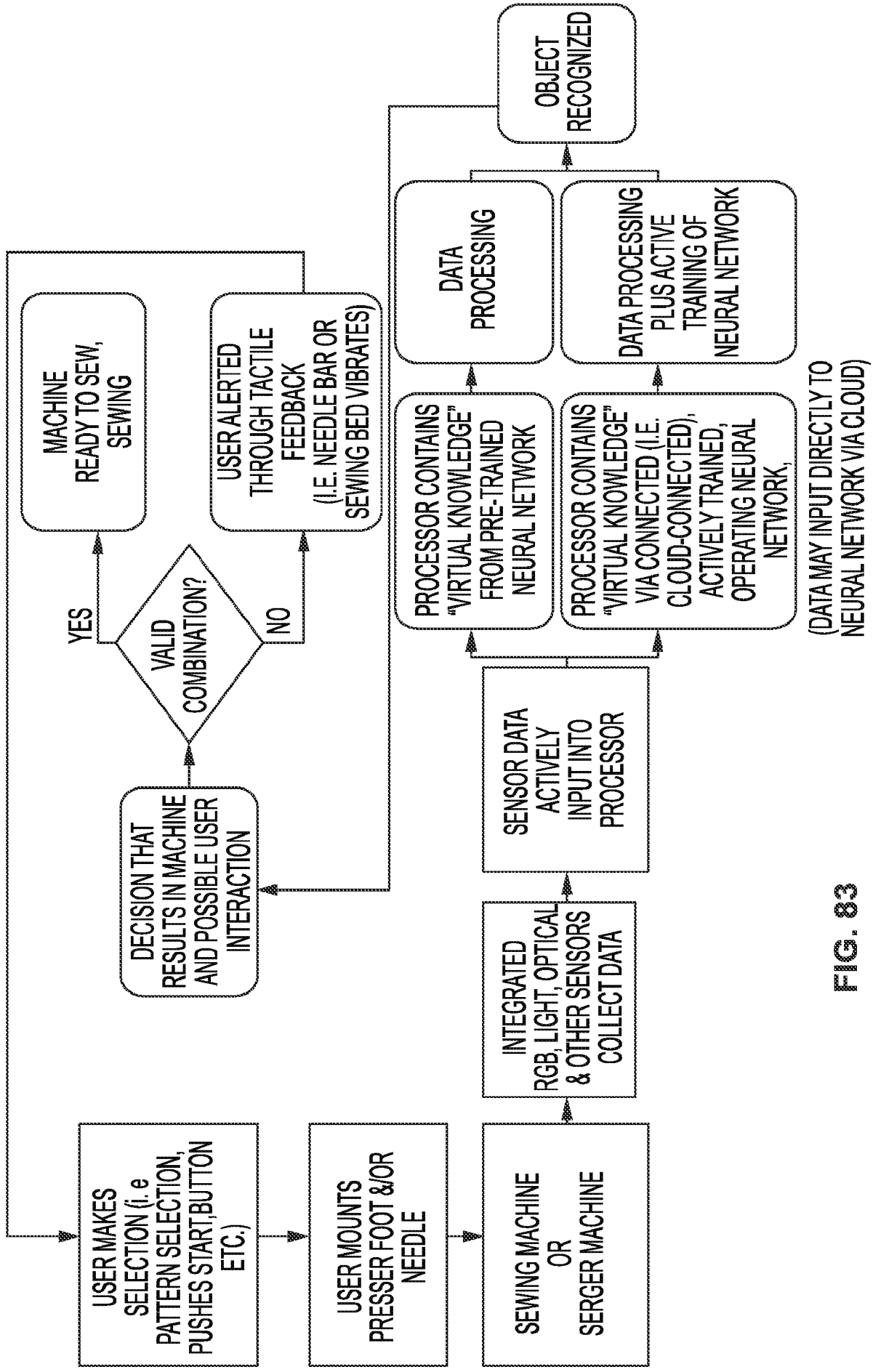

USER MAKES SELECTION (i. e PATTERN SELECTION, PUSHES START,BUTTON ETC.)
USER MOUNTS PRESSER FOOT &OR NEEDLE
SEWING MACHINE OR SERGER MACHINE
INTEGRATED RGB, LIGHT, OPTICAL & OTHER SENSORS COLLECT DATA
SENSOR DATA ACTIVELY INPUT INTO PROCESSOR
PROCESSOR CONTAINS "VIRTUAL KNOWLEDGE" FROM PRE-TRAINED NEURAL NETWORK
PROCESSOR CONTAINS "VIRTUAL KNOWLEDGE" VIA CONNECTED (I.E. CLOUD-CONNECTED), ACTIVELY TRAINED, OPERATING NEURAL NETWORK,
(DATA MAY INPUT DIRECTLY TO NEURAL NETWORK VIA CLOUD)
DATA PROCESSING
DATA PROCESSING PLUS ACTIVE TRAINING OF NEURAL NETWORK
OBJECT RECOGNIZED
DECISION THAT RESULTS IN MACHINE AND POSSIBLE USER INTERACTION
VALID COMBINATION?
YES
NO
MACHINE READY TO SEW, SEWING
USER ALERTED THROUGH TACTILE FEEDBACK (I.E. NEEDLE BAR OR SEWING BED VIBRATES)

FIG. 83

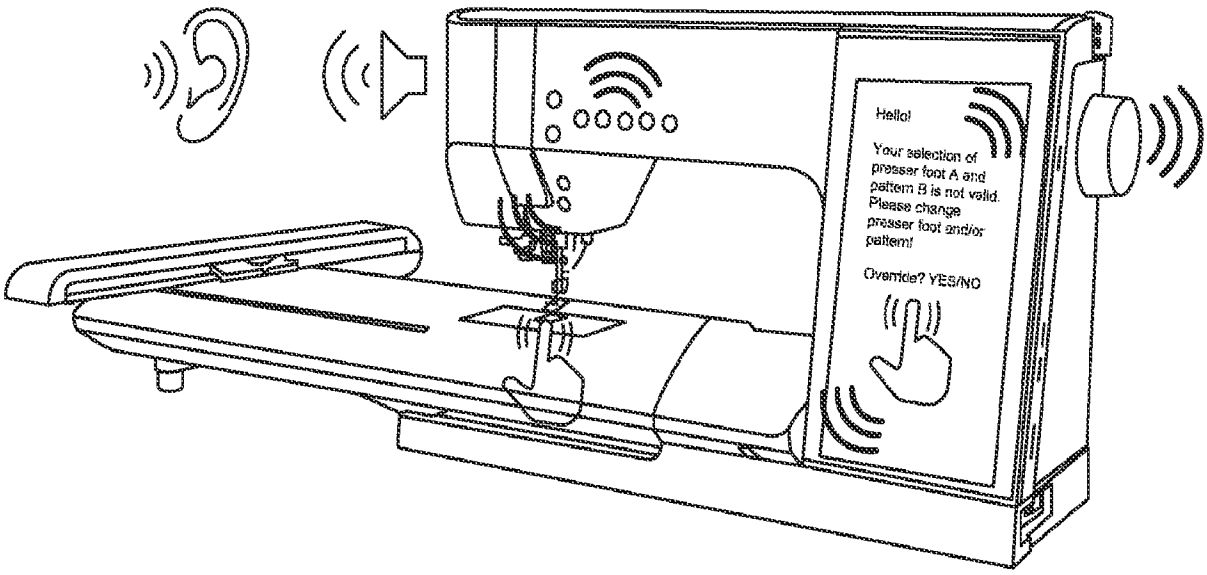

Hello!
Your selection of presser foot A and pattern B is not valid. Please change presser foot and/or pattern!
Override? YES/NO

FIG. 84

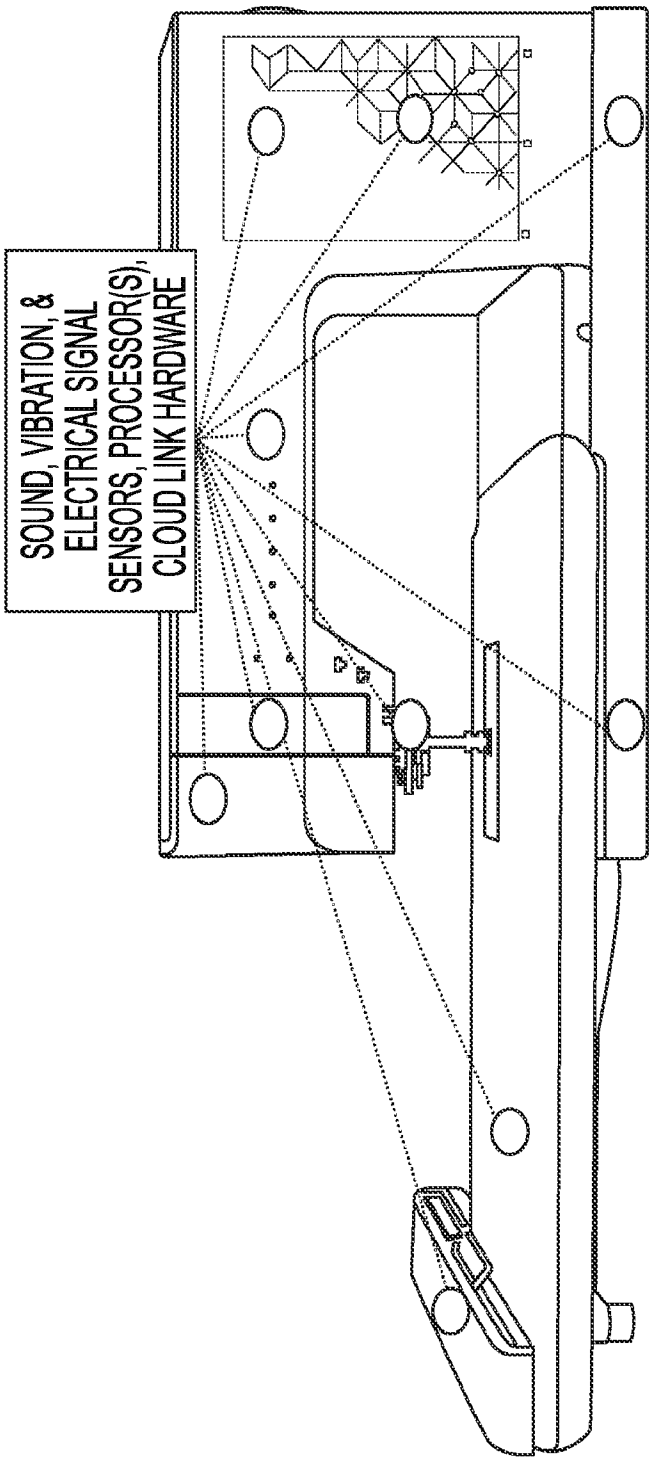

SOUND, VIBRATION, &
ELECTRICAL SIGNAL
SENSORS, PROCESSOR(S),
CLOUD LINK HARDWARE

FIG. 85

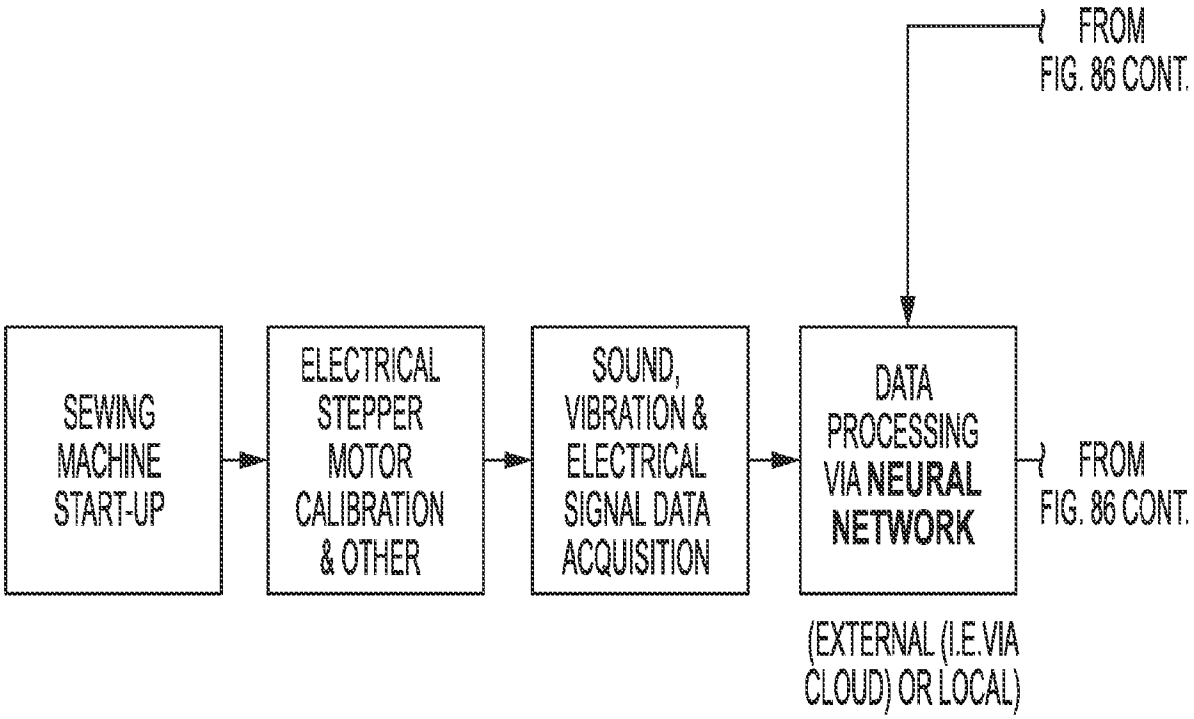

FROM FIG. 86 CONT.
SEWING MACHINE START-UP
ELECTRICAL STEPPER MOTOR CALIBRATION & OTHER
SOUND, VIBRATION & ELECTRICAL SIGNAL DATA ACQUISITION
DATA PROCESSING VIA NEURAL NETWORK
FROM FIG. 86 CONT.
(EXTERNAL (I.E.VIA CLOUD) OR LOCAL)

FIG. 86

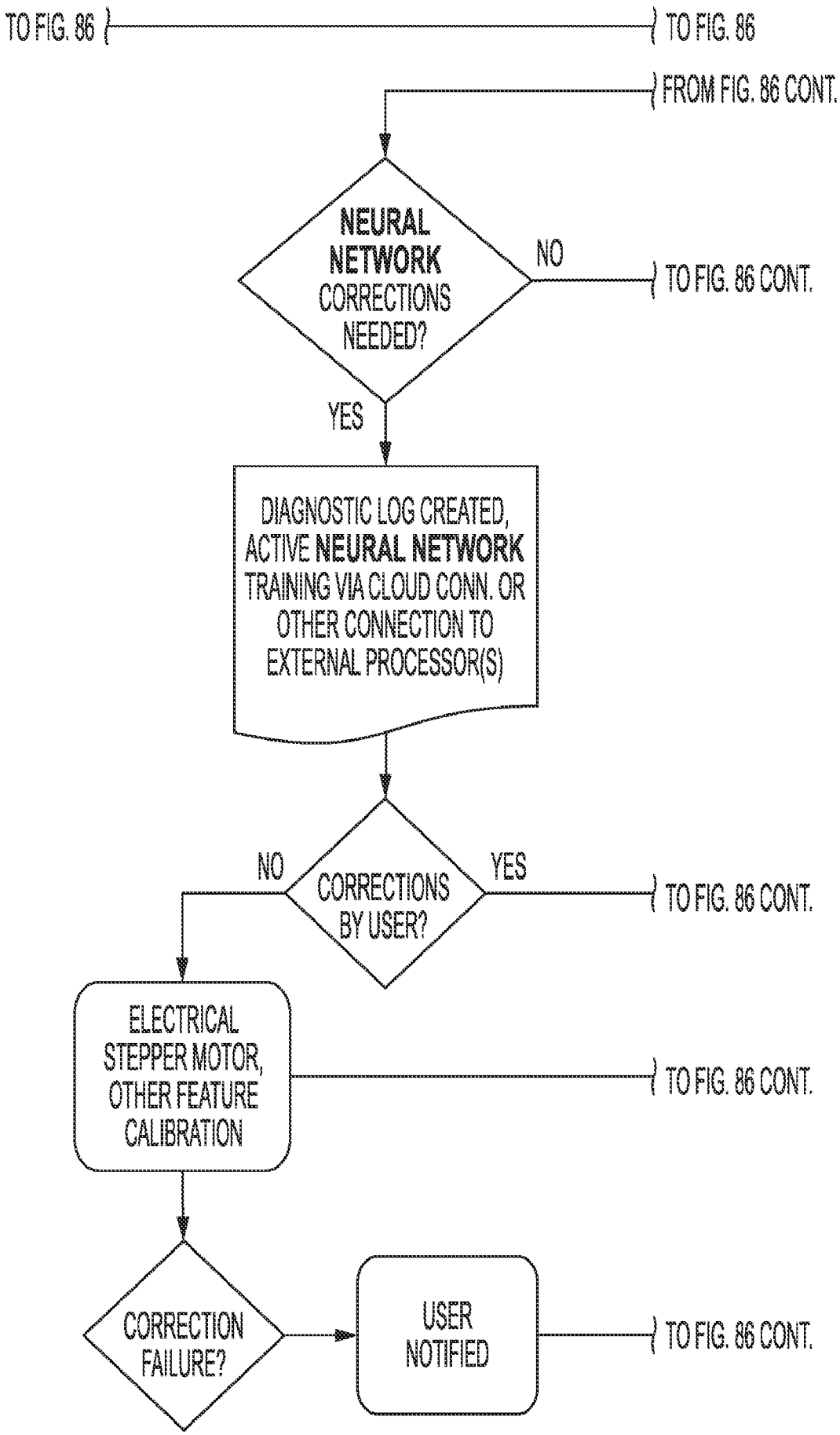

TO FIG. 86
TO FIG. 86
FROM FIG. 86 CONT.
NEURAL NETWORK CORRECTIONS NEEDED?
NO
TO FIG. 86 CONT.
YES
DIAGNOSTIC LOG CREATED, ACTIVE NEURAL NETWORK TRAINING VIA CLOUD CONN. OR OTHER CONNECTION TO EXTERNAL PROCESSOR(S)
NO
CORRECTIONS BY USER?
YES
TO FIG. 86 CONT.
ELECTRICAL STEPPER MOTOR, OTHER FEATURE CALIBRATION
TO FIG. 86 CONT.
CORRECTION FAILURE?
USER NOTIFIED
TO FIG. 86 CONT.

FIG. 86 CONT.

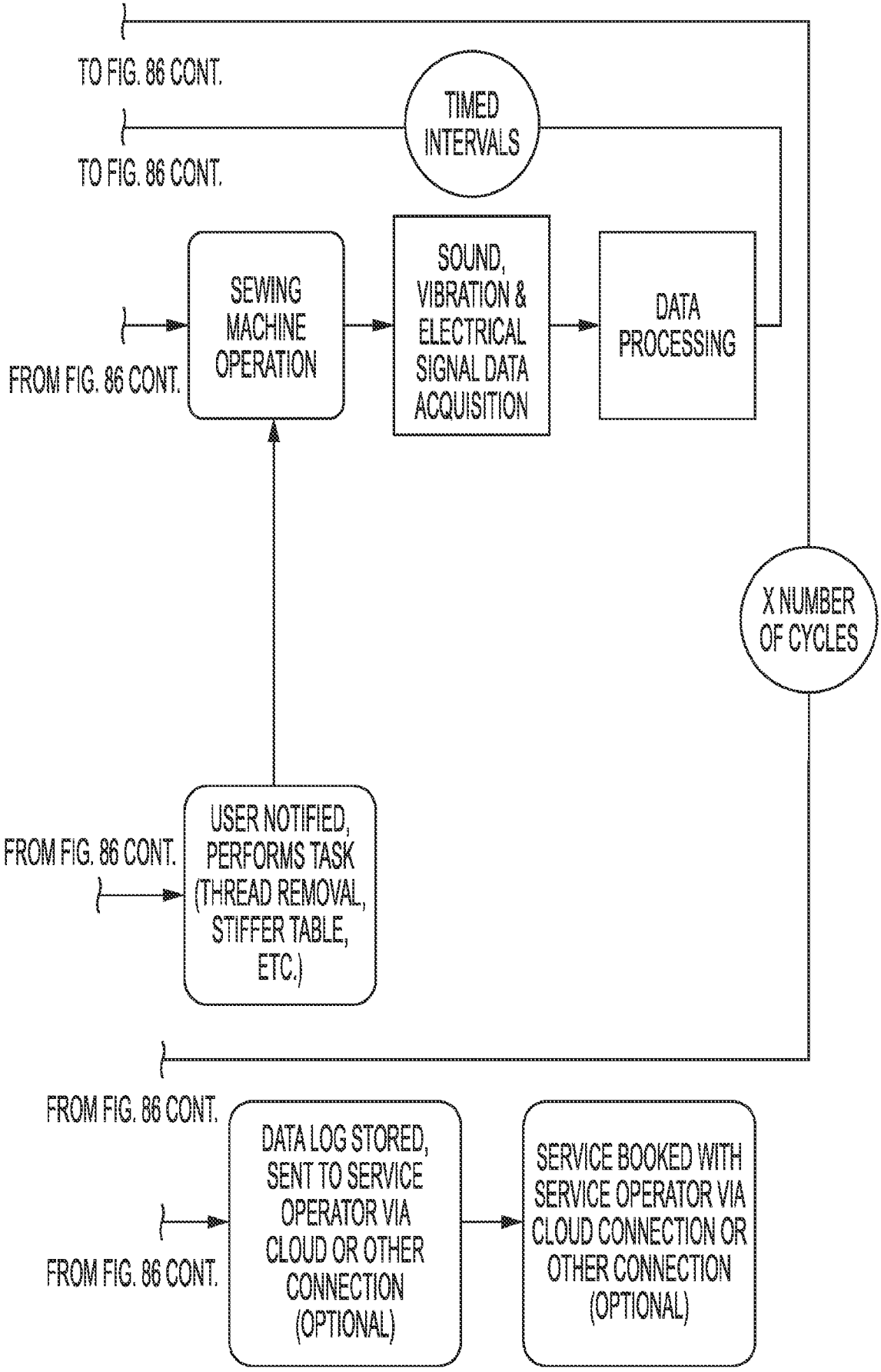

TO FIG. 86 CONT.
TO FIG. 86 CONT.
TIMED INTERVALS
SEWING MACHINE OPERATION
SOUND, VIBRATION & ELECTRICAL SIGNAL DATA ACQUISITION
DATA PROCESSING
FROM FIG. 86 CONT.
X NUMBER OF CYCLES
FROM FIG. 86 CONT.
USER NOTIFIED, PERFORMS TASK (THREAD REMOVAL, STIFFER TABLE, ETC.)
FROM FIG. 86 CONT.
FROM FIG. 86 CONT.
DATA LOG STORED, SENT TO SERVICE OPERATOR VIA CLOUD OR OTHER CONNECTION (OPTIONAL)
SERVICE BOOKED WITH SERVICE OPERATOR VIA CLOUD CONNECTION OR OTHER CONNECTION (OPTIONAL)

FIG. 86 CONT.

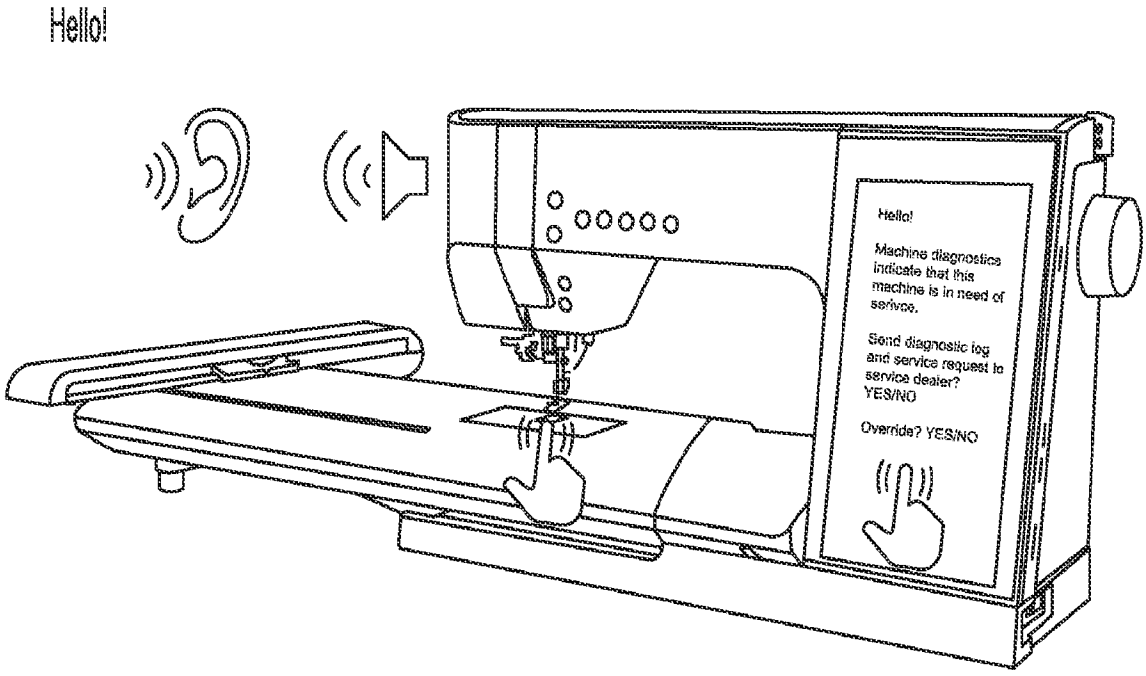

Hello!
Hello!
Machine diagnostics indicate that this machine is in need of service.
Send diagnostic log and service request to service dealer? YES/NO
Override? YES/NO

FIG. 87

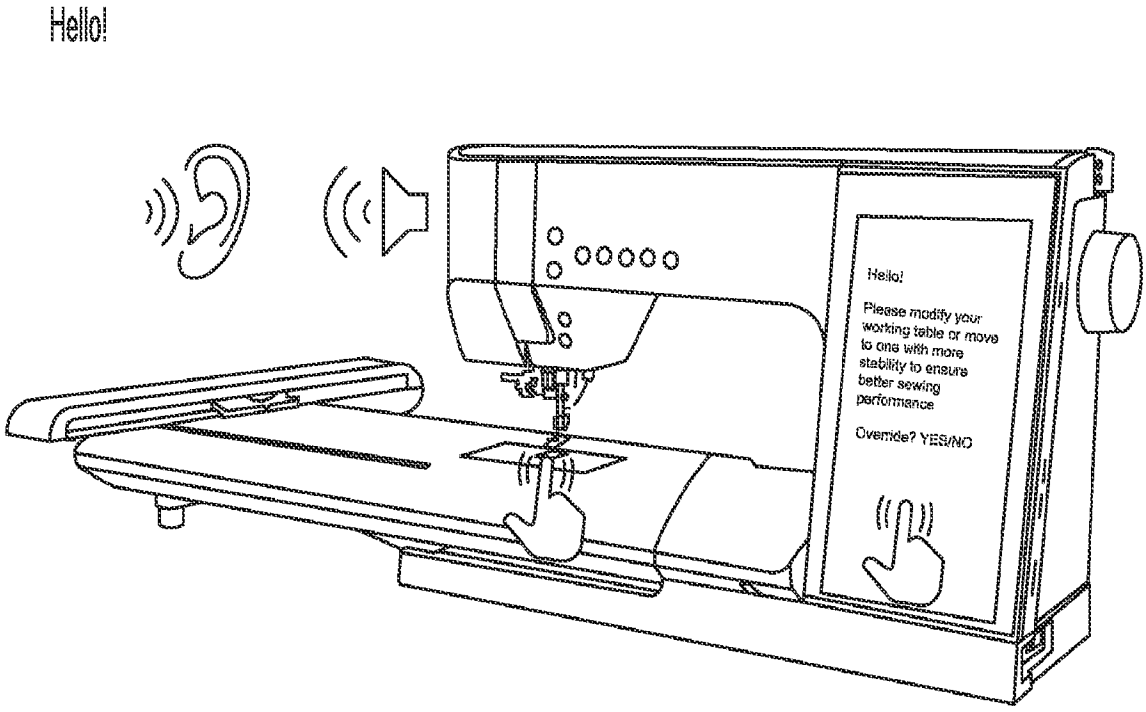

Hello!
Hello!
Please modify your working table or move to one with more stability to ensure better sewing performance
Override? YES/NO

FIG. 88

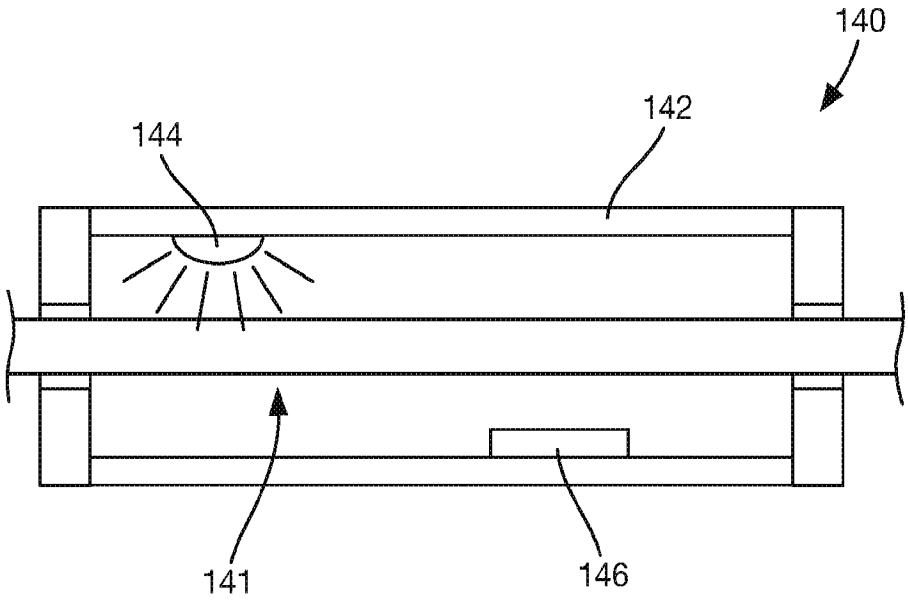


FIG. 89

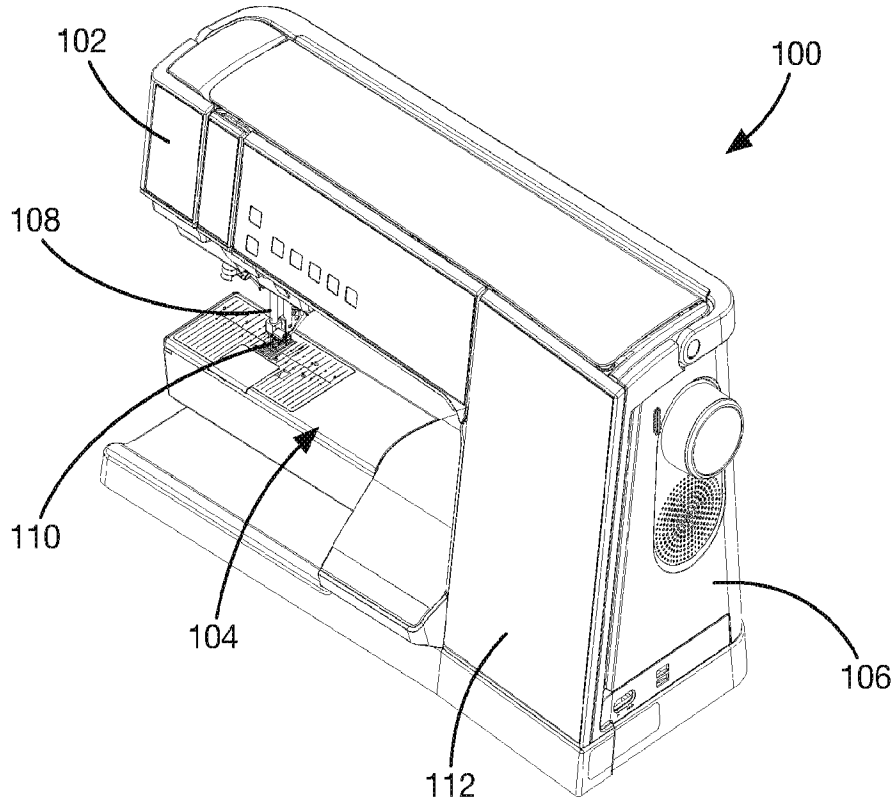


FIG. 90

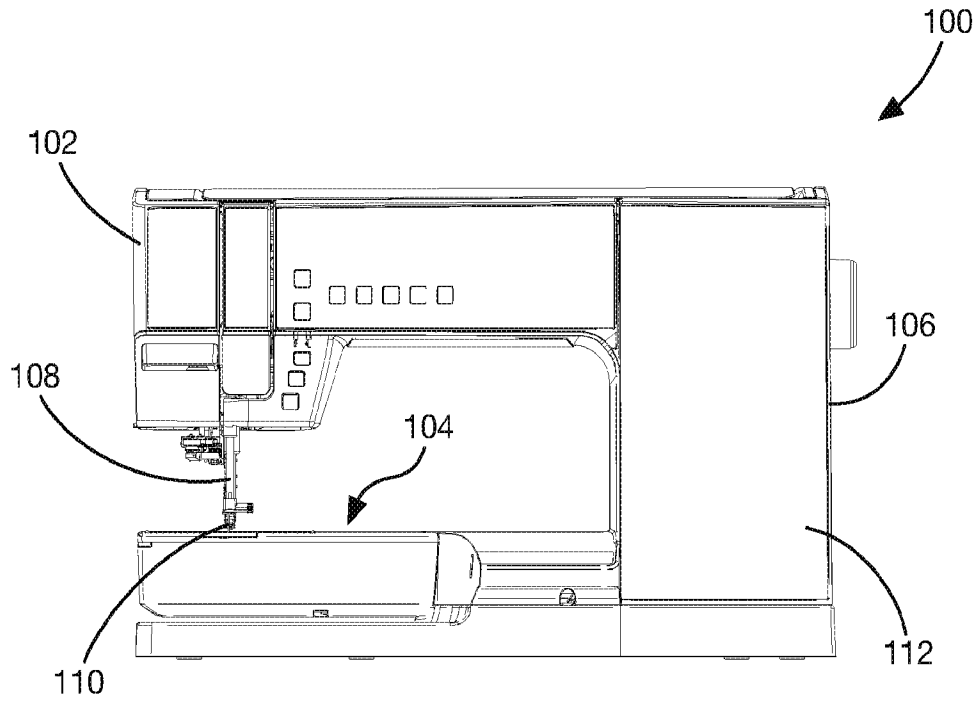


FIG. 91

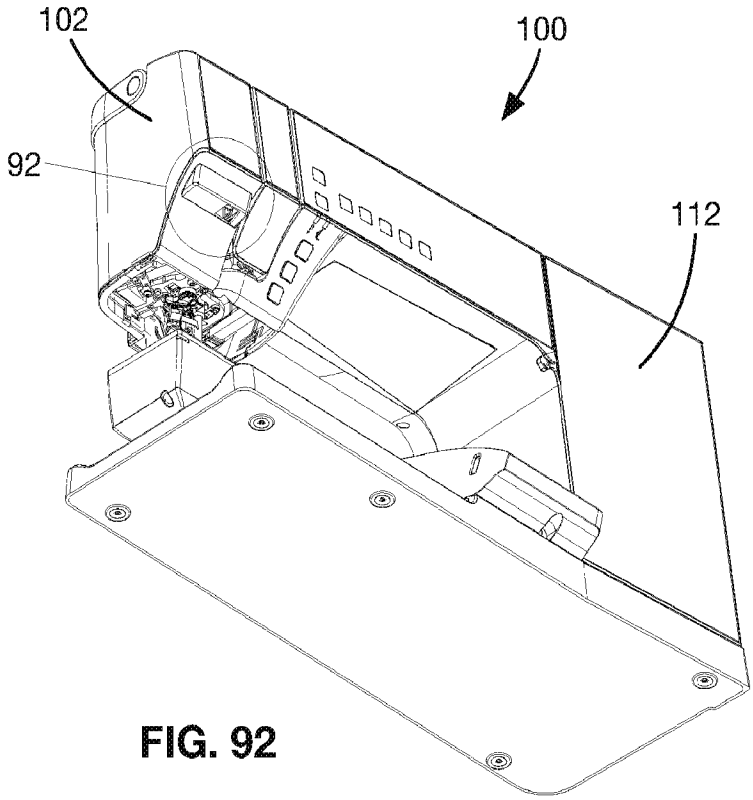


FIG. 92

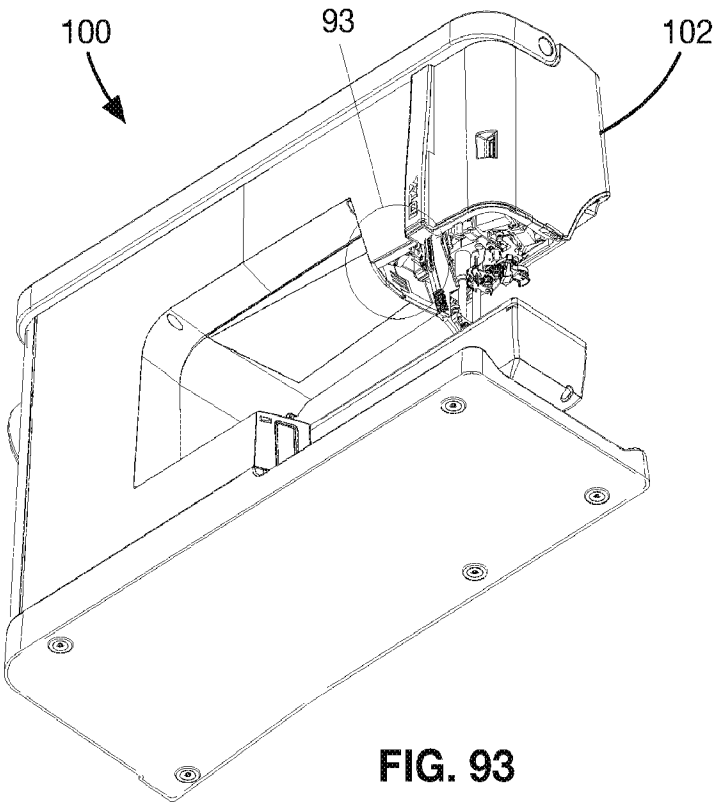


FIG. 93

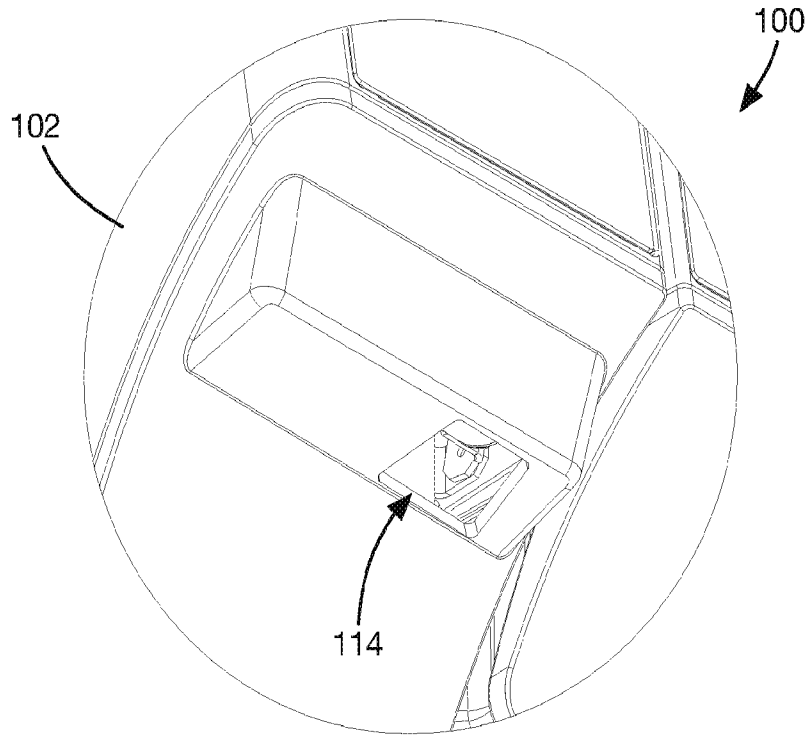


FIG. 94

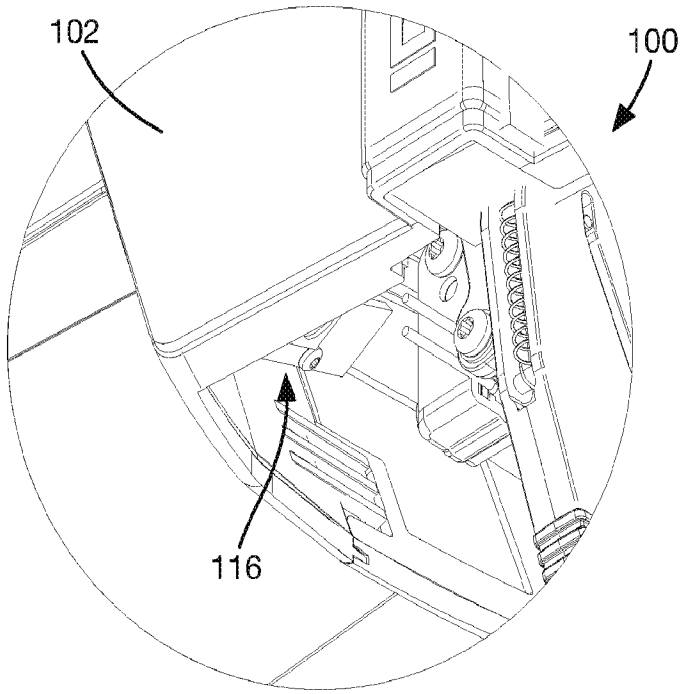


FIG. 95

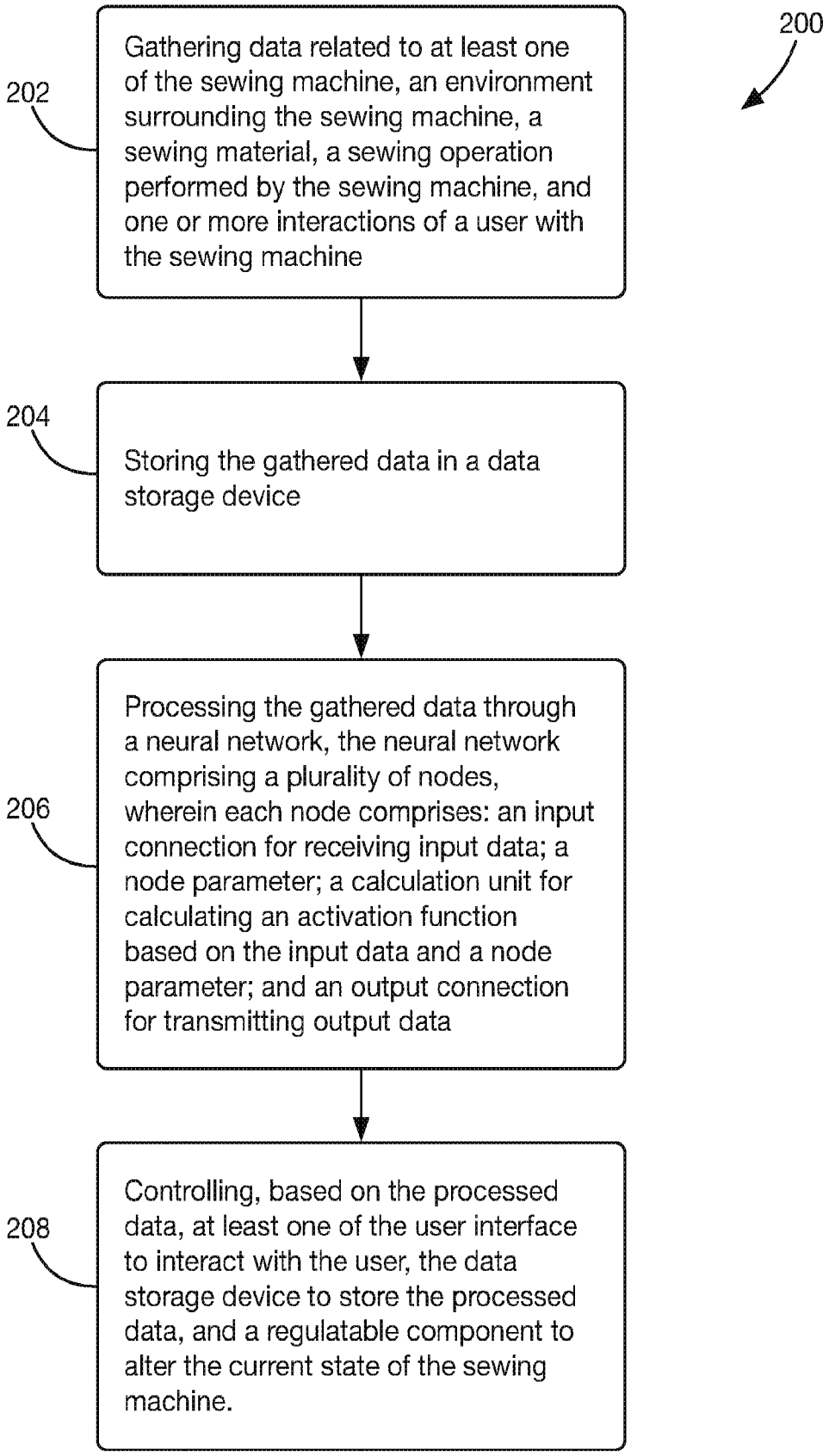

200
202
Gathering data related to at least one of the sewing machine, an environment surrounding the sewing machine, a sewing material, a sewing operation performed by the sewing machine, and one or more interactions of a user with the sewing machine
204
Storing the gathered data in a data storage device
206
Processing the gathered data through a neural network, the neural network comprising a plurality of nodes, wherein each node comprises: an input connection for receiving input data; a node parameter; a calculation unit for calculating an activation function based on the input data and a node parameter; and an output connection for transmitting output data
208
Controlling, based on the processed data, at least one of the user interface to interact with the user, the data storage device to store the processed data, and a regulatable component to alter the current state of the sewing machine.

FIG. 96

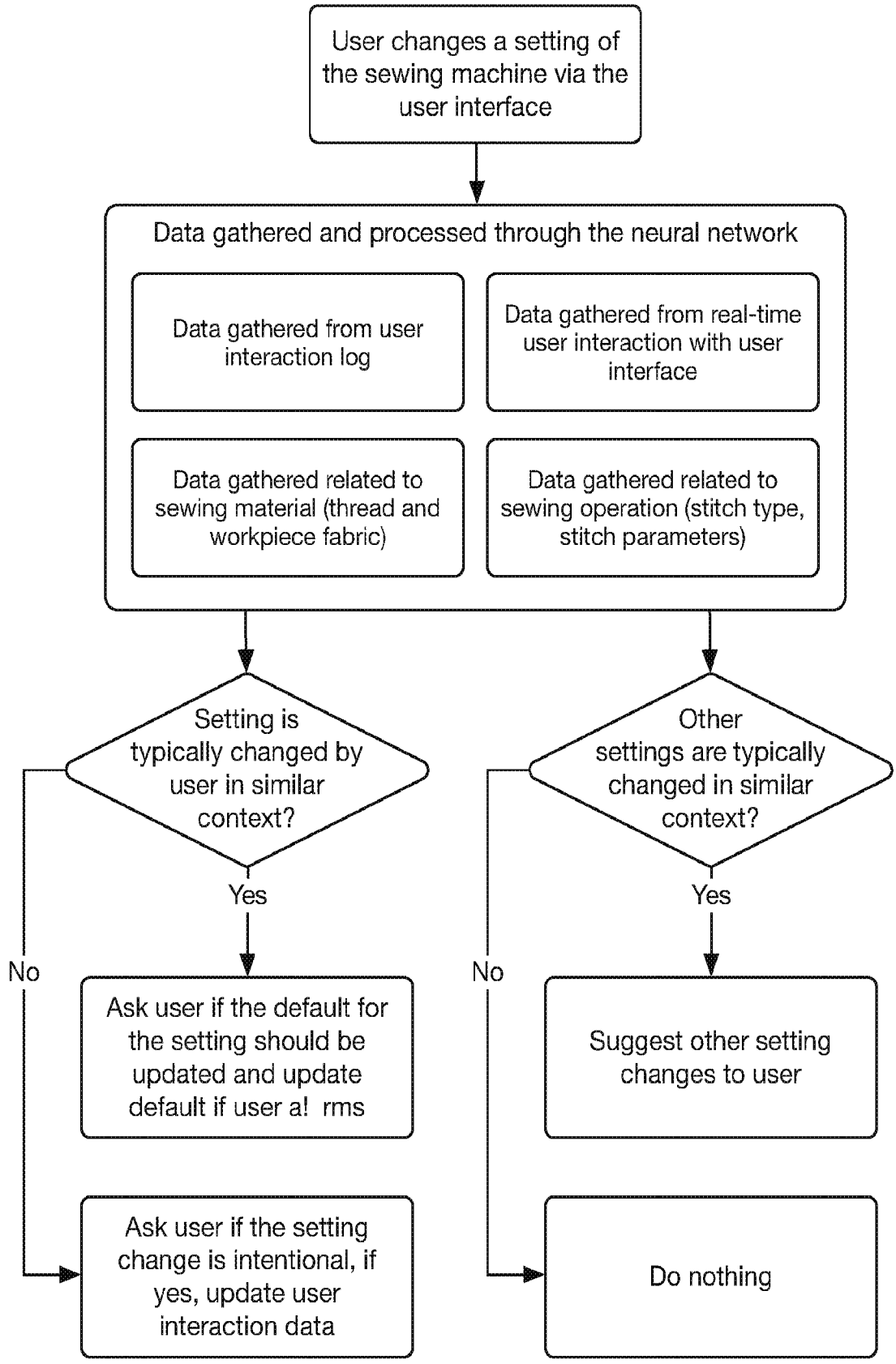

User changes a setting of the sewing machine via the user interface
Data gathered and processed through the neural network
Data gathered from user interaction log
Data gathered from real-time user interaction with user interface
Data gathered related to sewing material (thread and workpiece fabric)
Data gathered related to sewing operation (stitch type, stitch parameters)
Setting is typically changed by user in similar context?
Other settings are typically changed in similar context?
Yes
Yes
No
No
Ask user if the default for the setting should be updated and update default if user a! rms
Suggest other setting changes to user
Ask user if the setting change is intentional, if yes, update user interaction data
Do nothing

FIG. 97

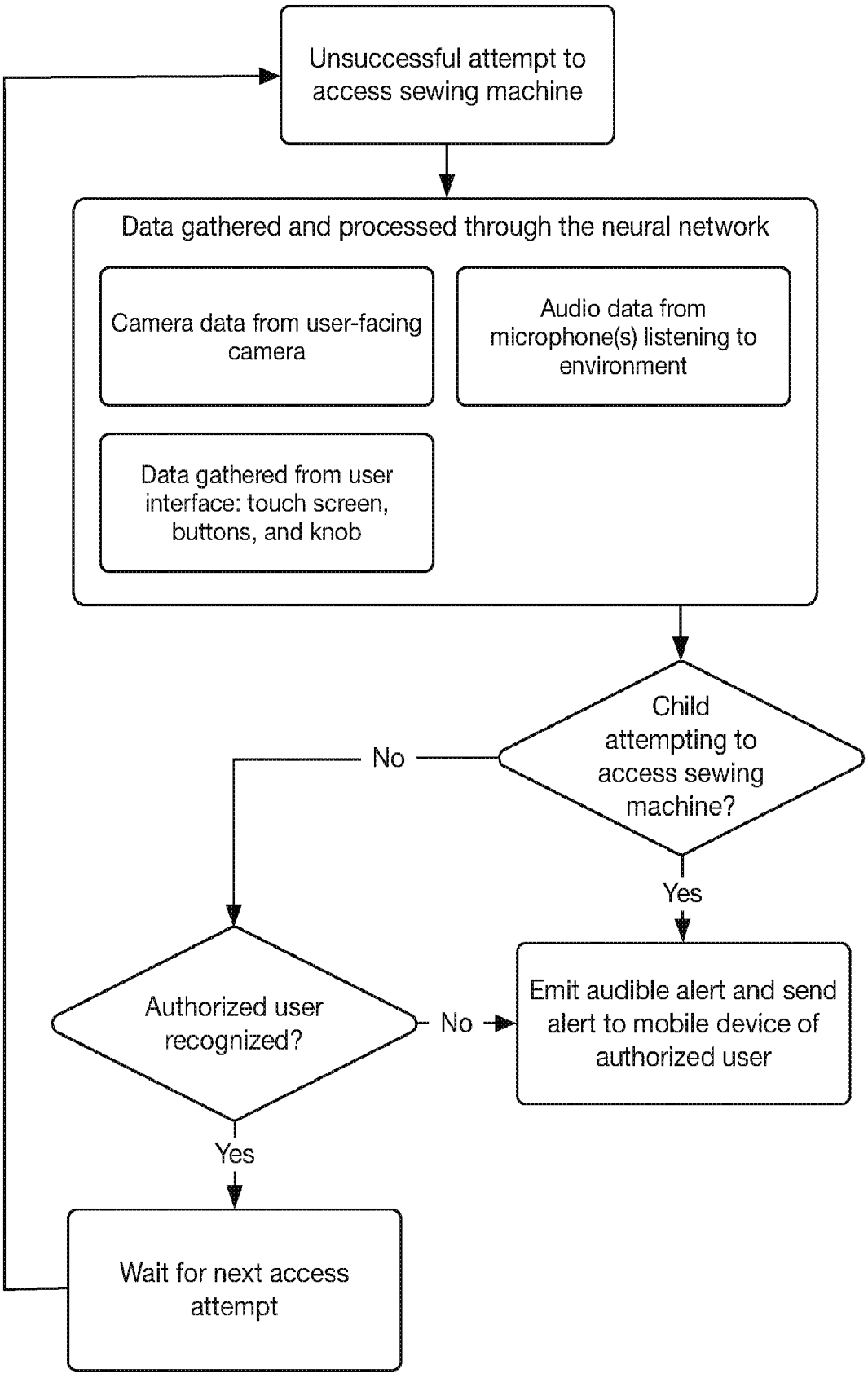

Unsuccessful attempt to access sewing machine
Data gathered and processed through the neural network
Camera data from user-facing camera
Audio data from microphone(s) listening to environment
Data gathered from user interface: touch screen, buttons, and knob
Child attempting to access sewing machine?
No
Yes
Authorized user recognized?
No
Emit audible alert and send alert to mobile device of authorized user
Yes
Wait for next access attempt

FIG. 98

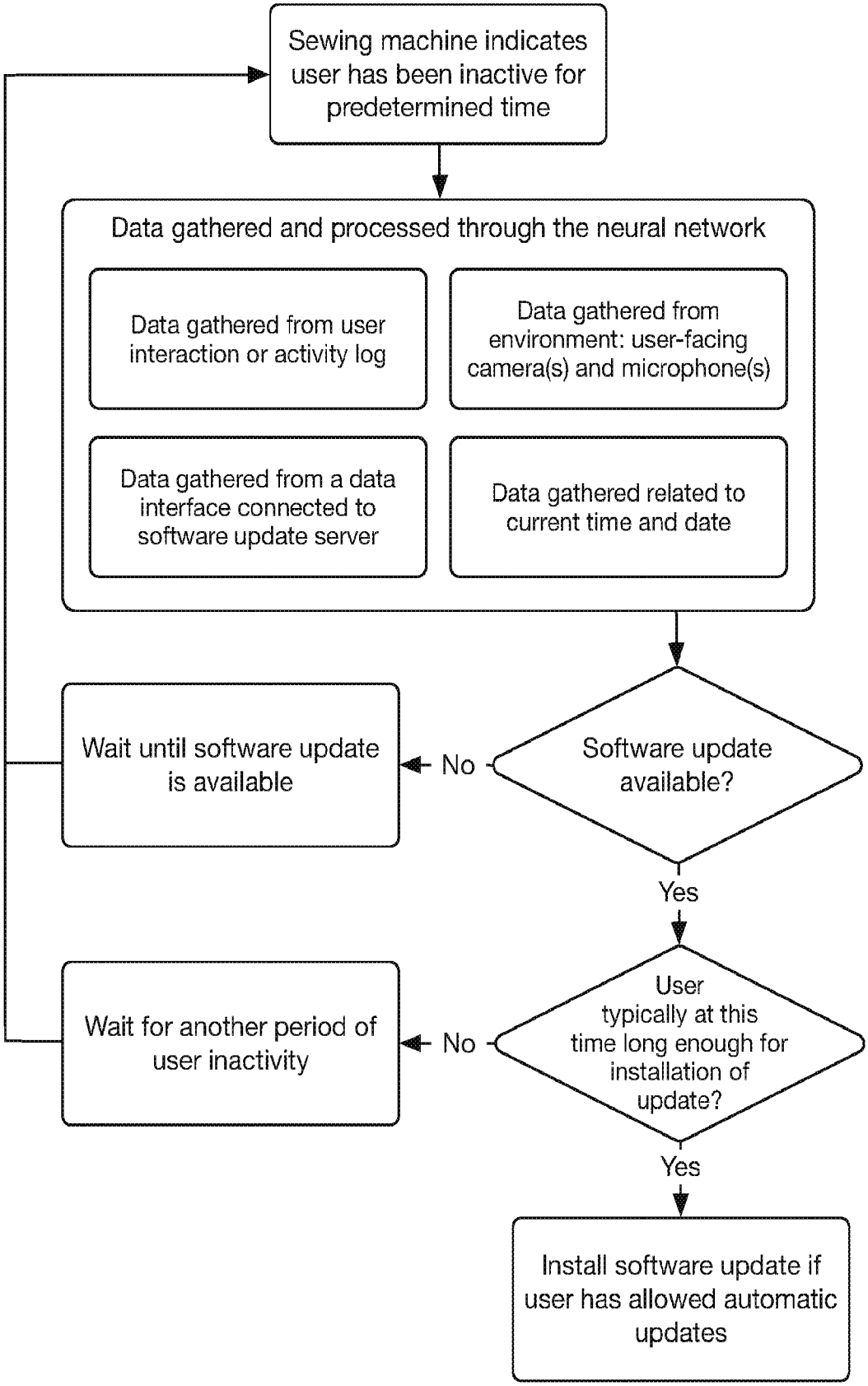

Sewing machine indicates user has been inactive for predetermined time
Data gathered and processed through the neural network
Data gathered from user interaction or activity log
Data gathered from environment: user-facing camera(s) and microphone(s)
Data gathered from a data interface connected to software update server
Data gathered related to current time and date
Software update available?
No
Wait until software update is available
Yes
User typically at this time long enough for installation of update?
No
Wait for another period of user inactivity
Yes
Install software update if user has allowed automatic updates

FIG. 99

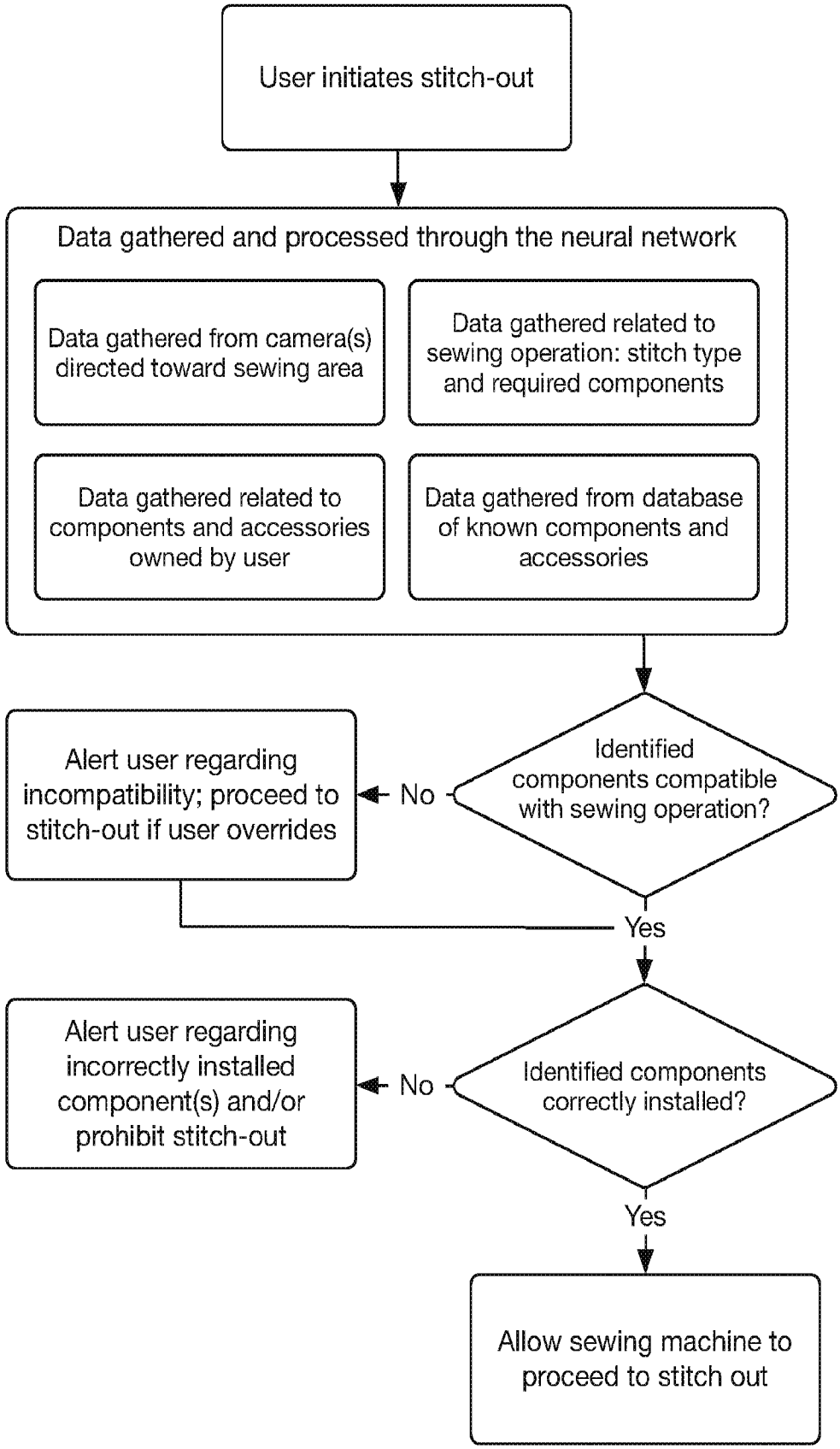

User initiates stitch-out
Data gathered and processed through the neural network
Data gathered from camera(s) directed toward sewing area
Data gathered related to sewing operation: stitch type and required components
Data gathered related to components and accessories owned by user
Data gathered from database of known components and accessories
Identified components compatible with sewing operation?
No
Alert user regarding incompatibility; proceed to stitch-out if user overrides
Yes
Identified components correctly installed?
No
Alert user regarding incorrectly installed component(s) and/or prohibit stitch-out
Yes
Allow sewing machine to proceed to stitch out

FIG. 100

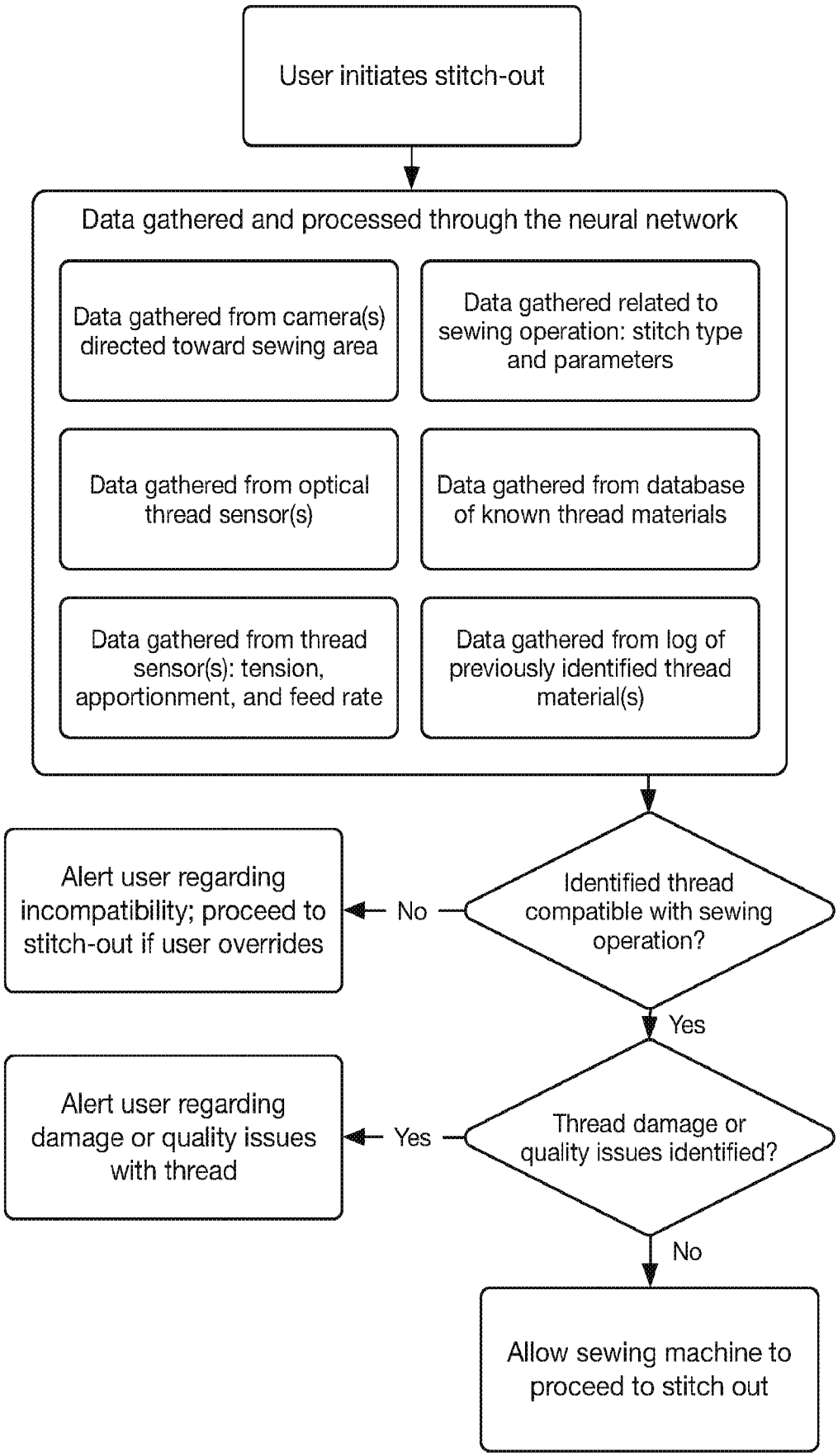

User initiates stitch-out
Data gathered and processed through the neural network
Data gathered from camera(s) directed toward sewing area
Data gathered related to sewing operation: stitch type and parameters
Data gathered from optical thread sensor(s)
Data gathered from database of known thread materials
Data gathered from thread sensor(s): tension, apportionment, and feed rate
Data gathered from log of previously identified thread material(s)
Identified thread compatible with sewing operation?
No
Alert user regarding incompatibility; proceed to stitch-out if user overrides
Yes
Thread damage or quality issues identified?
Yes
Alert user regarding damage or quality issues with thread
No
Allow sewing machine to proceed to stitch out

FIG. 101

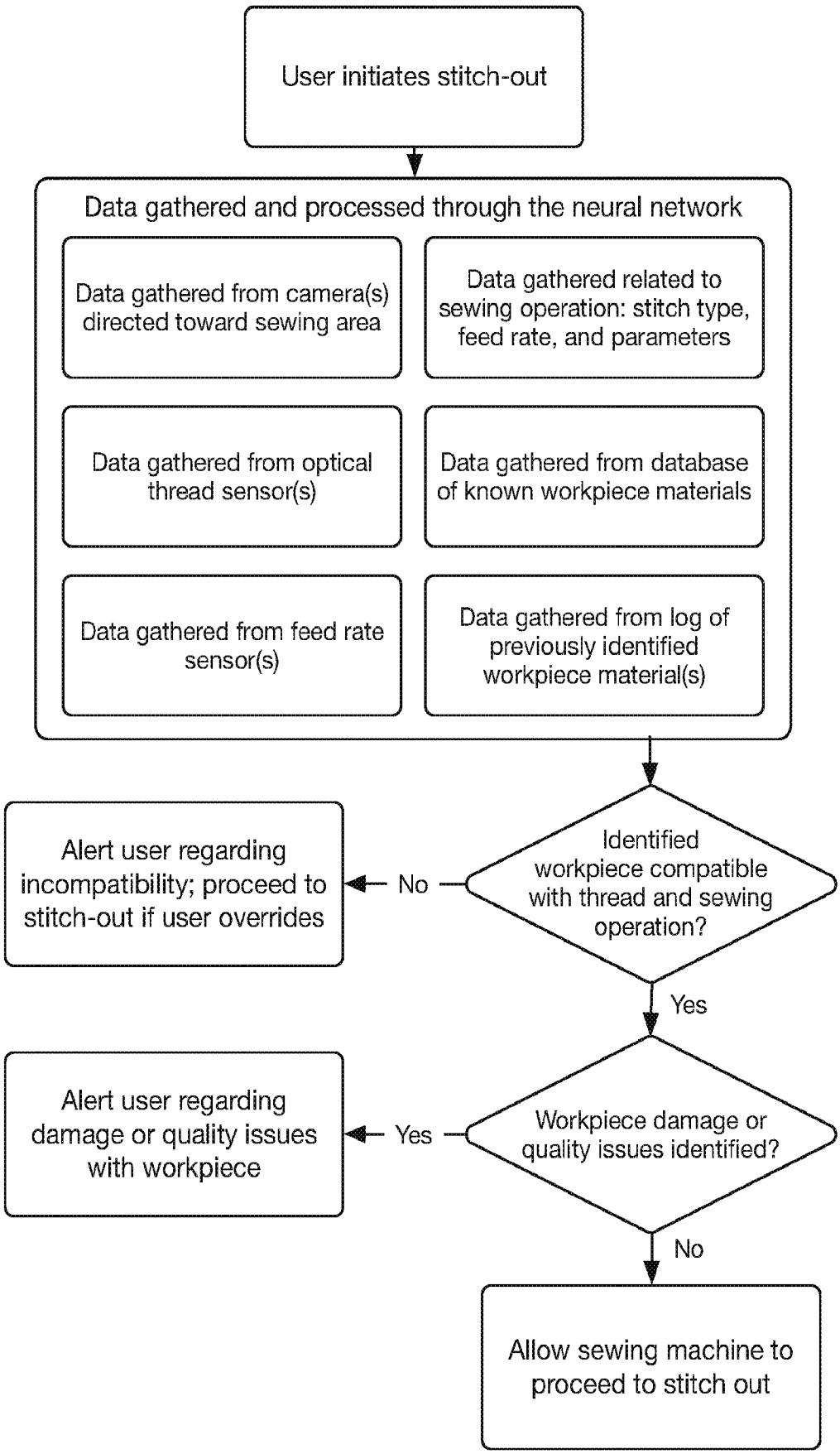

User initiates stitch-out
Data gathered and processed through the neural network
Data gathered from camera(s) directed toward sewing area
Data gathered related to sewing operation: stitch type, feed rate, and parameters
Data gathered from optical thread sensor(s)
Data gathered from database of known workpiece materials
Data gathered from feed rate sensor(s)
Data gathered from log of previously identified workpiece material(s)
Identified workpiece compatible with thread and sewing operation?
No
Alert user regarding incompatibility; proceed to stitch-out if user overrides
Yes
Workpiece damage or quality issues identified?
Yes
Alert user regarding damage or quality issues with workpiece
No
Allow sewing machine to proceed to stitch out

FIG. 102

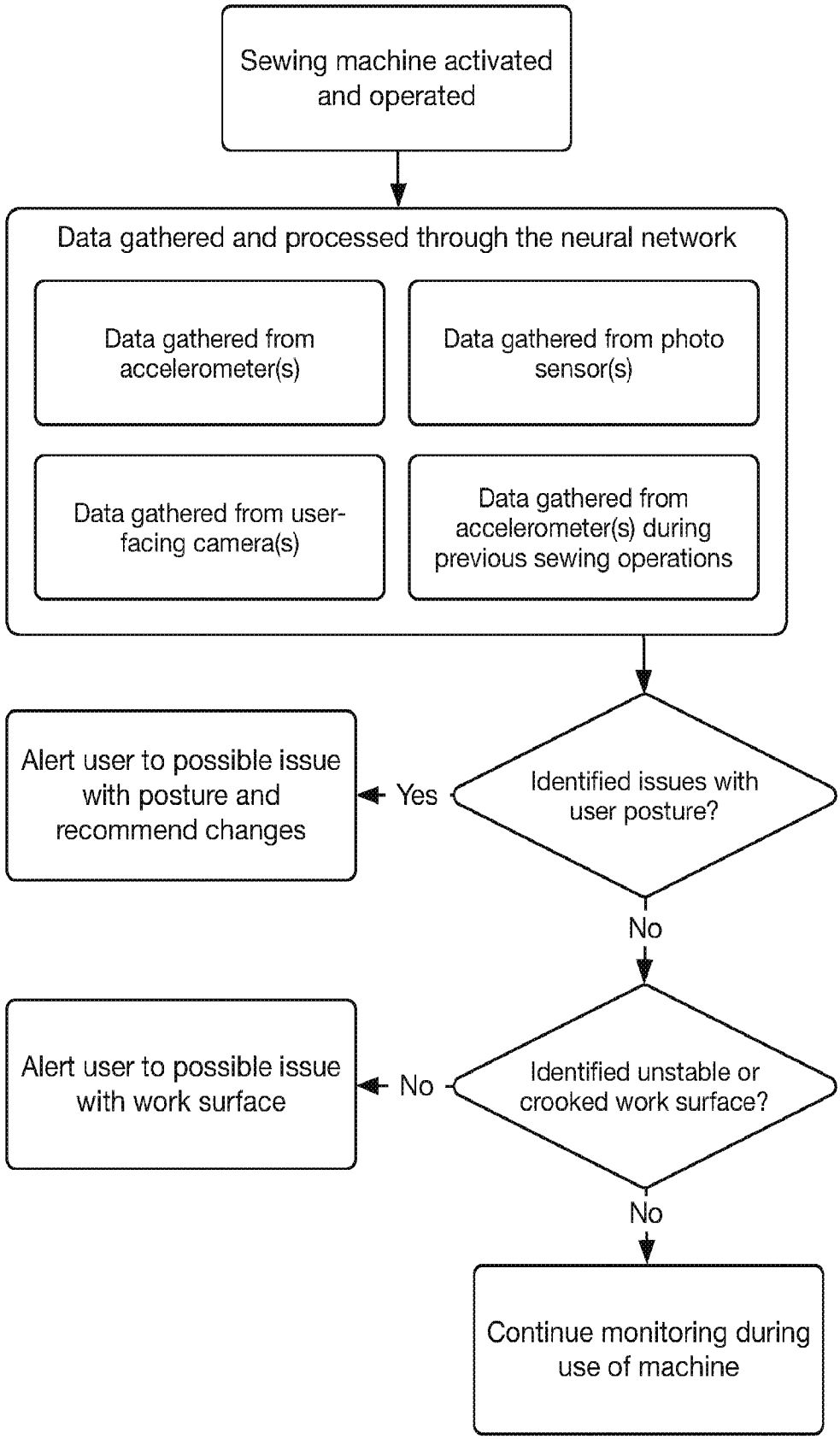

Sewing machine activated and operated
Data gathered and processed through the neural network
Data gathered from accelerometer(s)
Data gathered from photo sensor(s)
Data gathered from user-facing camera(s)
Data gathered from accelerometer(s) during previous sewing operations
Identified issues with user posture?
Yes
Alert user to possible issue with posture and recommend changes
No
Identified unstable or crooked work surface?
No
Alert user to possible issue with work surface
No
Continue monitoring during use of machine

FIG. 103

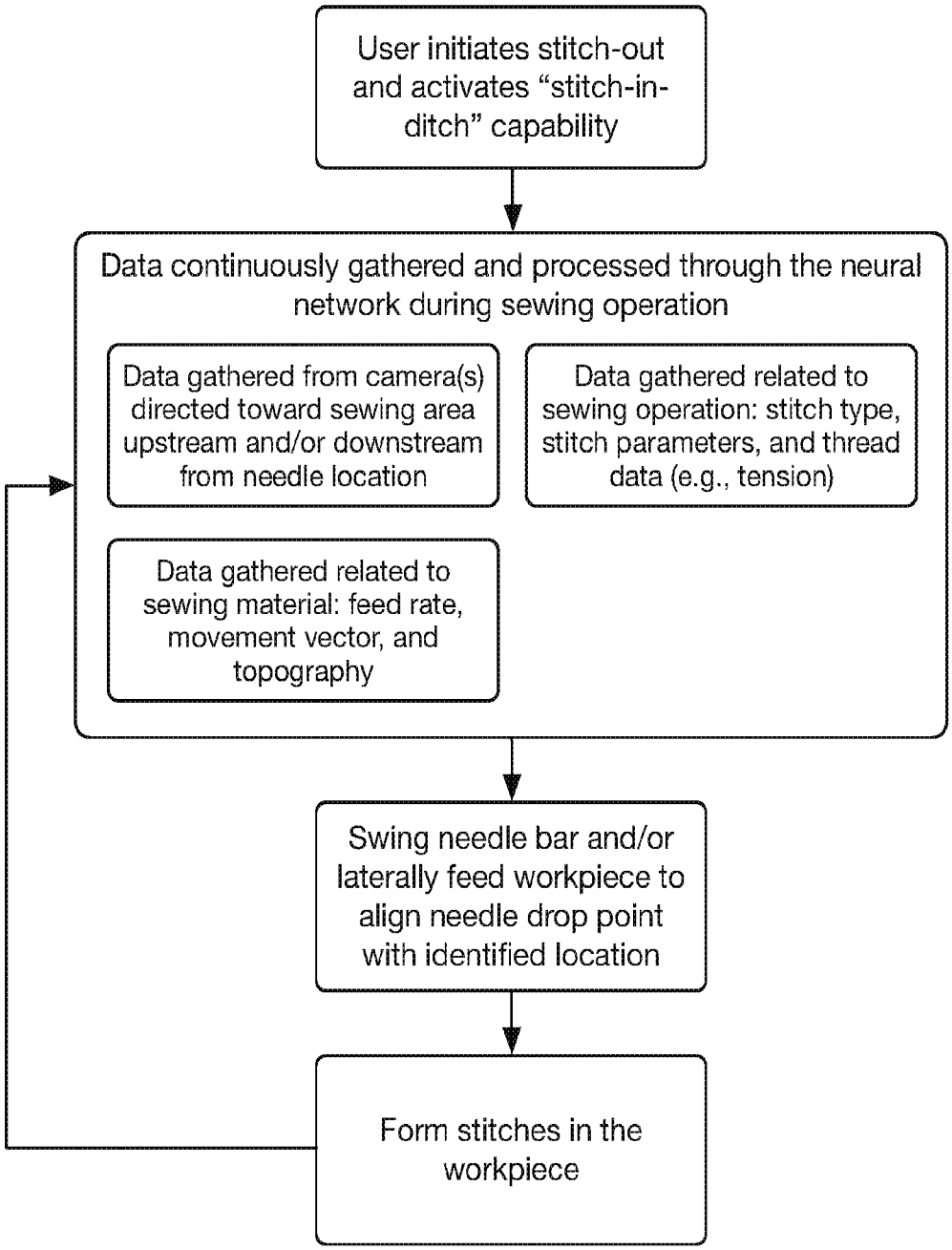

User initiates stitch-out and activates “stitch-in-ditch” capability
Data continuously gathered and processed through the neural network during sewing operation
Data gathered from camera(s) directed toward sewing area upstream and/or downstream from needle location
Data gathered related to sewing operation: stitch type, stitch parameters, and thread data (e.g., tension)
Data gathered related to sewing material: feed rate, movement vector, and topography
Swing needle bar and/or laterally feed workpiece to align needle drop point with identified location
Form stitches in the workpiece

FIG. 104

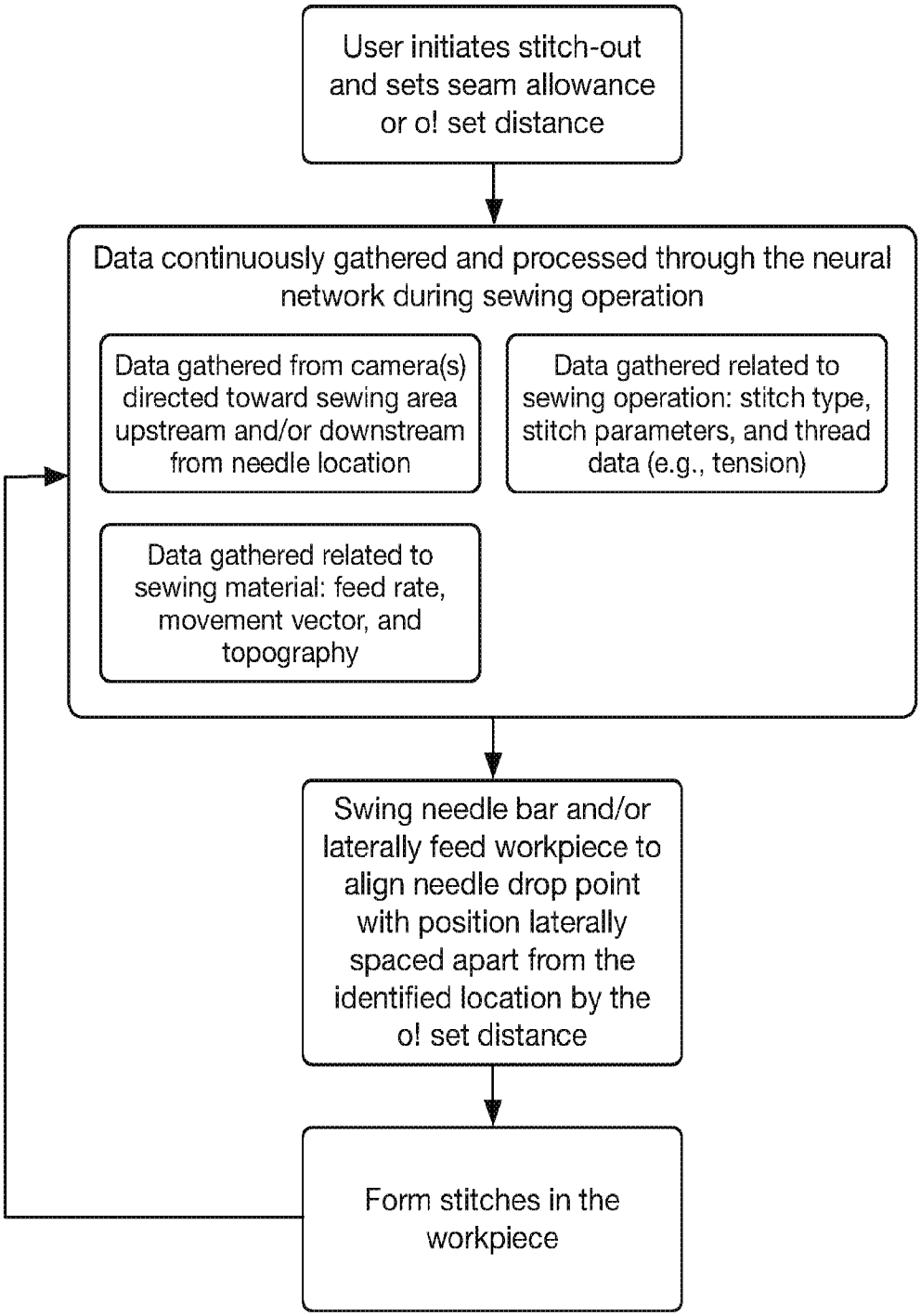

User initiates stitch-out and sets seam allowance or o! set distance
Data continuously gathered and processed through the neural network during sewing operation
Data gathered from camera(s) directed toward sewing area upstream and/or downstream from needle location
Data gathered related to sewing operation: stitch type, stitch parameters, and thread data (e.g., tension)
Data gathered related to sewing material: feed rate, movement vector, and topography
Swing needle bar and/or laterally feed workpiece to align needle drop point with position laterally spaced apart from the identified location by the o! set distance
Form stitches in the workpiece

FIG. 105

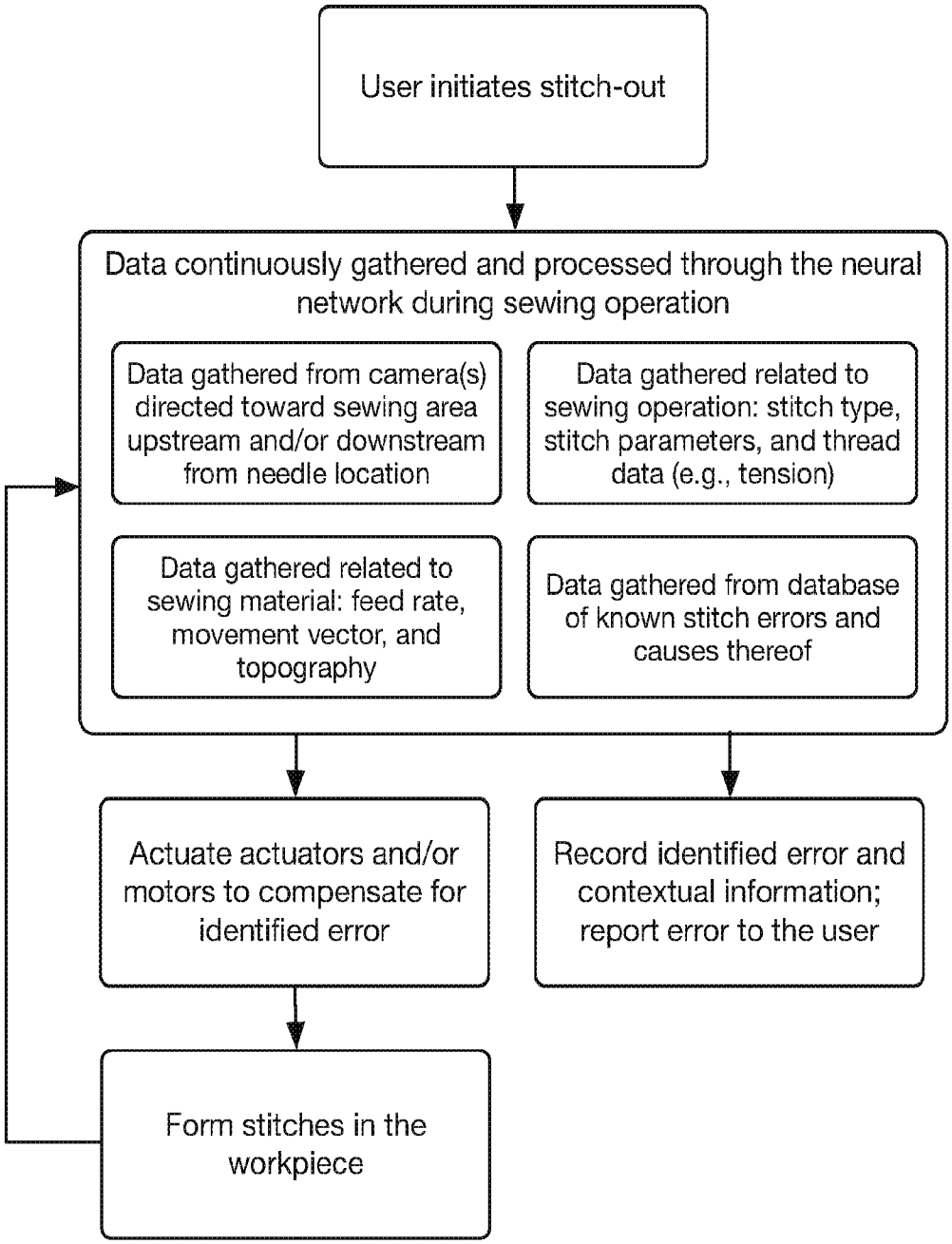

User initiates stitch-out
Data continuously gathered and processed through the neural network during sewing operation
Data gathered from camera(s) directed toward sewing area upstream and/or downstream from needle location
Data gathered related to sewing operation: stitch type, stitch parameters, and thread data (e.g., tension)
Data gathered related to sewing material: feed rate, movement vector, and topography
Data gathered from database of known stitch errors and causes thereof
Actuate actuators and/or motors to compensate for identified error
Record identified error and contextual information; report error to the user
Form stitches in the workpiece

FIG. 106

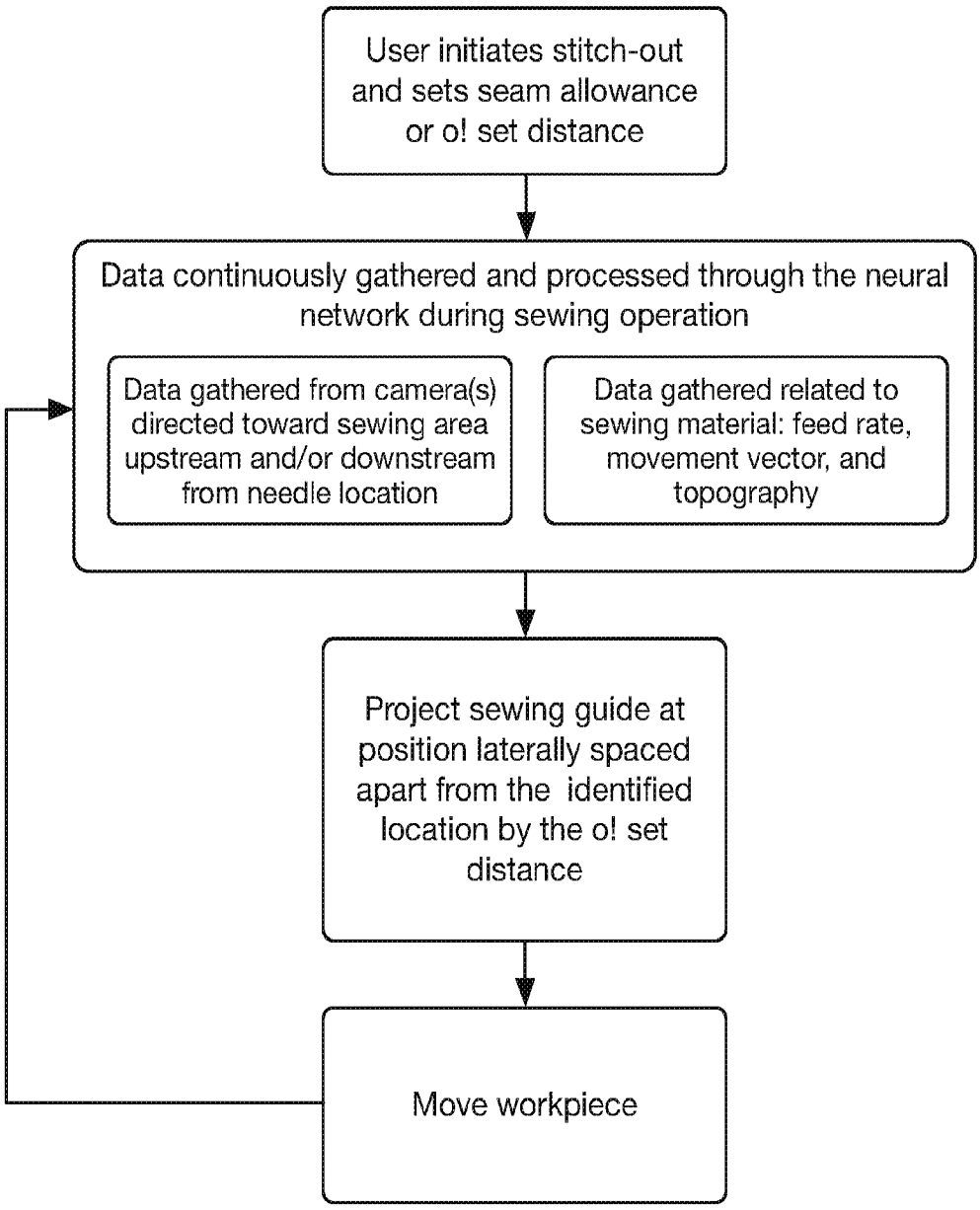

User initiates stitch-out and sets seam allowance or o! set distance
Data continuously gathered and processed through the neural network during sewing operation
Data gathered from camera(s) directed toward sewing area upstream and/or downstream from needle location
Data gathered related to sewing material: feed rate, movement vector, and topography
Project sewing guide at position laterally spaced apart from the identified location by the o! set distance
Move workpiece

FIG. 107

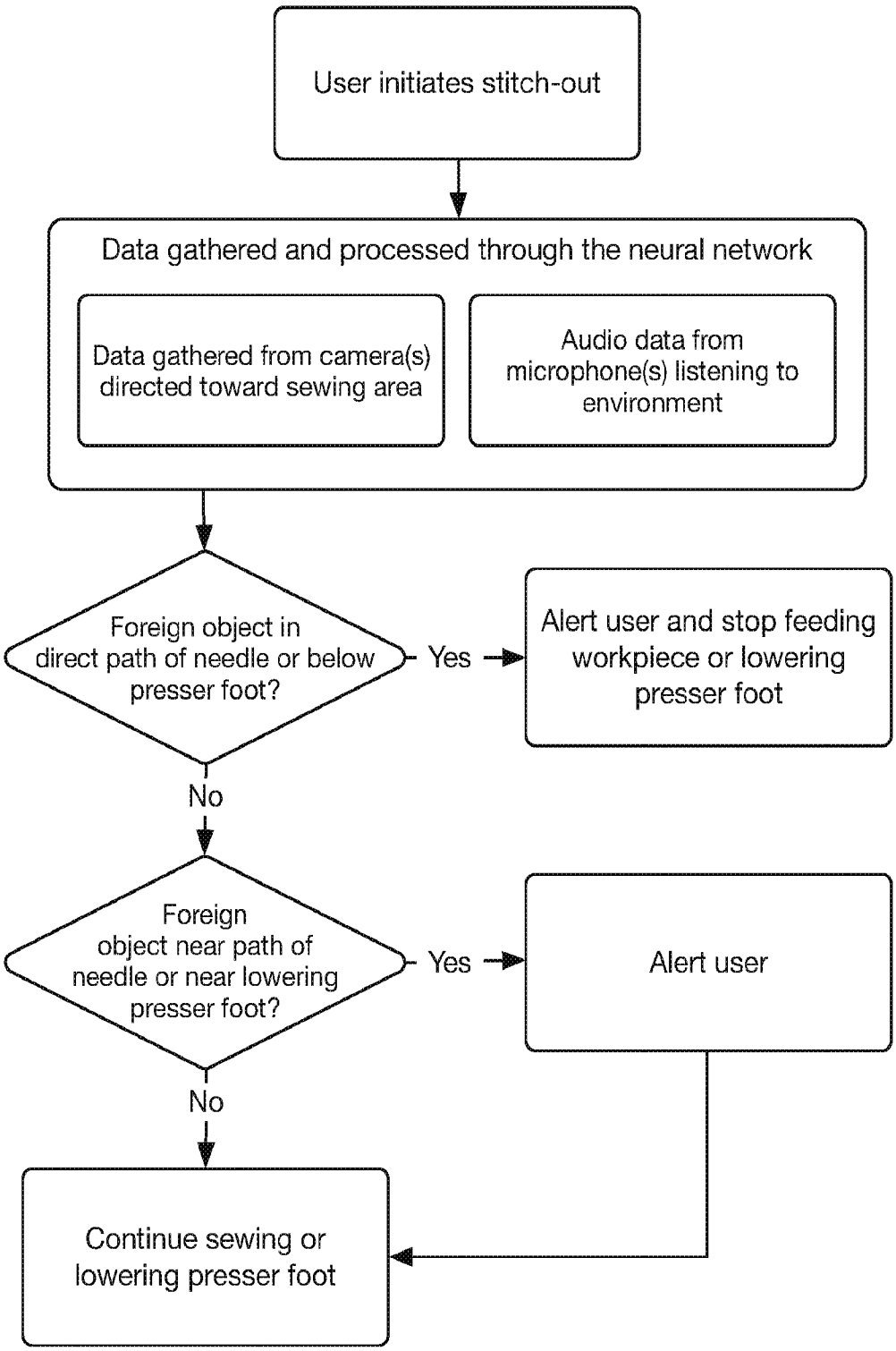

User initiates stitch-out
Data gathered and processed through the neural network
Data gathered from camera(s) directed toward sewing area
Audio data from microphone(s) listening to environment
Foreign object in direct path of needle or below presser foot?
Yes
Alert user and stop feeding workpiece or lowering presser foot
No
Foreign object near path of needle or near lowering presser foot?
Yes
Alert user
No
Continue sewing or lowering presser foot

FIG. 108

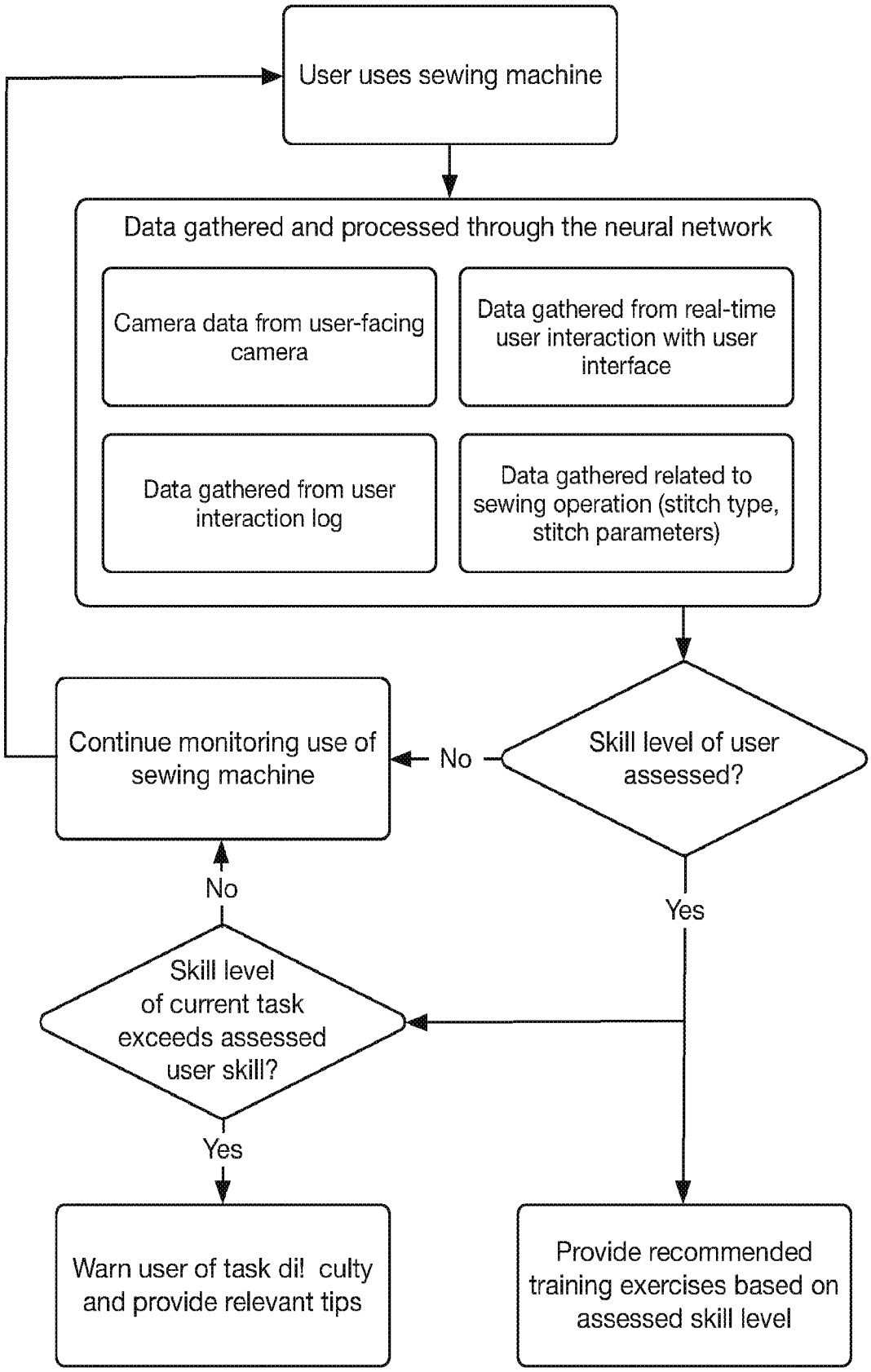

User uses sewing machine
Data gathered and processed through the neural network
Camera data from user-facing camera
Data gathered from real-time user interaction with user interface
Data gathered from user interaction log
Data gathered related to sewing operation (stitch type, stitch parameters)
Skill level of user assessed?
No
Continue monitoring use of sewing machine
Yes
No
Skill level of current task exceeds assessed user skill?
Yes
Warn user of task di! culty and provide relevant tips
Provide recommended training exercises based on assessed skill level

FIG. 109

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2021/038151

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06N3/04 G06N3/08 D05B19/12 D05B19/02
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)
G06N D05B D05C A61B H04B

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 20 2018 103728 U1 (VORWERK CO INTERHOLDING [DE]) 9 October 2019 (2019-10-09)	1-50, 66-87, 89-95
Y	abstract claims 1-15 figures 1-4 paragraph [0001] - paragraph [0007] paragraph [0010] - paragraph [0027] paragraph [0029] - paragraph [0033] paragraph [0035] - paragraph [0048] paragraph [0050] paragraph [0052] - paragraph [0062] paragraph [0064] paragraph [0066] - paragraph [0069] paragraph [0073] ----- -/--	88

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 September 2021	12/10/2021

Name and mailing address of the ISA/	Authorized officer
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X	CN 207 845 955 U (WU QINGLI) 11 September 2018 (2018-09-11) abstract claim 1 figures 1-6 paragraph [0006] paragraph [0009] paragraph [0016] paragraph [0018] - paragraph [0023] paragraph [0028] paragraph [0031] paragraph [0033] -----	51,61,62

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