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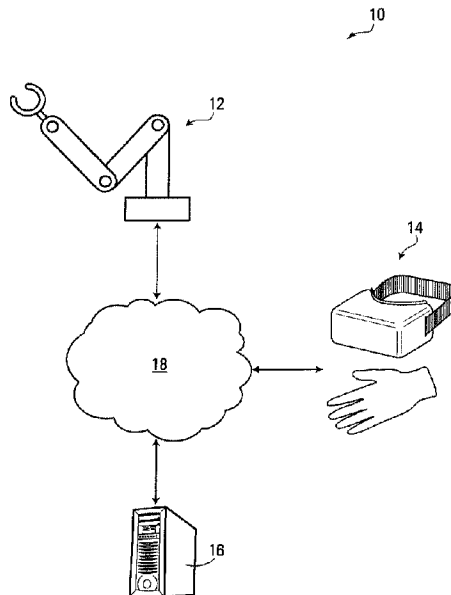
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(72) Inventeurs/Inventors:
GILDERT, SUZANNE, CA;
ROSE, GEORGE SAMUEL, CA;
TAYLOR, GRAHAM WILLIAM, CA;
BERGSTRA, JAMES, CA

(73) Propriétaire/Owner:
KINDRED SYSTEMS INC., CA

(74) Agent: SMART & BIGGAR LP

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(54) Title: FACILITATING GENERATION OF AUTONOMOUS CONTROL INFORMATION



(57) **Abrégé/Abstract:**

A method of deriving autonomous control information involves receiving one or more sets of associated environment sensor information and device control instructions. Each set of associated environment sensor information and device control instructions includes environment sensor information representing an environment associated with an operator controllable device and associated device control instructions configured to cause the operator controllable device to simulate at least one action taken by at least one operator experiencing a representation of the environment generated from the environment sensor information. The method also involves deriving autonomous control information from the one or more sets of associated environment sensor information and device control instructions, the autonomous control information configured to facilitate generating autonomous device control signals from autonomous environment sensor information representing an environment associated with an autonomous device, the autonomous device control signals configured to cause the autonomous device to take at least one autonomous action.

ABSTRACT

5 A method of deriving autonomous control information involves receiving one or
more sets of associated environment sensor information and device control
instructions. Each set of associated environment sensor information and device
control instructions includes environment sensor information representing an
environment associated with an operator controllable device and associated
device control instructions configured to cause the operator controllable device to
simulate at least one action taken by at least one operator experiencing a
10 representation of the environment generated from the environment sensor
information. The method also involves deriving autonomous control information
from the one or more sets of associated environment sensor information and
device control instructions, the autonomous control information configured to
facilitate generating autonomous device control signals from autonomous
15 environment sensor information representing an environment associated with an
autonomous device, the autonomous device control signals configured to cause
the autonomous device to take at least one autonomous action.

FACILITATING GENERATION OF AUTONOMOUS CONTROL INFORMATION

BACKGROUND OF THE INVENTION

1. Field of Invention

5 This invention relates to autonomous control of devices, and more particularly to facilitating generation of autonomous control information using analogous control of a device.

2. Description of Related Art

10 Robotic systems include devices that may be operated by an operator such as via remote control or that may operate autonomously without control of an operator. The devices may be specifically designed to carry out particular tasks that historically have been done by human beings. However, such devices usually do not execute tasks using the same actions and the same movements
15 as human beings. Accordingly, although a wealth of information included in human brains for performing various human executable tasks is available, devices used to execute these tasks historically do not utilize this information.

Autonomous devices may be programmed to execute certain tasks automatically.
20 However programming a device to react to the multitude of environments that it may experience can require immense time, effort and intelligence from the programmer. In some cases, it is impossible to adequately program a device to autonomously react to its environment.

25 There remains a need for improved systems for analogous control of devices and for facilitating generation of autonomous control information.

SUMMARY OF THE INVENTION

30 In accordance with one illustrative embodiment of the invention, there is provided a method of deriving autonomous control information. The method involves

receiving one or more sets of associated environment sensor information and device control instructions. Each set of associated environment sensor information and device control instructions includes environment sensor information representing an environment associated with an operator controllable device and associated device control instructions configured to cause the operator controllable device to simulate at least one action taken by at least one operator experiencing a representation of the environment generated from the environment sensor information. The method also involves deriving autonomous control information from the one or more sets of associated environment sensor information and device control instructions, the autonomous control information configured to facilitate generating autonomous device control signals from autonomous environment sensor information representing an environment associated with an autonomous device, the autonomous device control signals configured to cause the autonomous device to take at least one autonomous action, said autonomous control information comprising a representation of an artificial intelligence model derived from the one or more sets of associated environment sensor information and device control instructions.

In accordance with another illustrative embodiment of the invention, there is provided a computer-readable medium having stored thereon codes which, when executed by at least one processor, cause the at least one processor to perform the above method.

In accordance with another illustrative embodiment of the invention there is provided a system for deriving autonomous control information. The system includes means for receiving one or more sets of associated environment sensor information and device control instructions. Each set of associated environment sensor information and device control instructions includes environment sensor information representing an environment associated with an operator controllable device and associated device control instructions configured to cause the operator controllable device to simulate at least one action taken by at least one operator experiencing a representation of the environment generated from the environment sensor information. The system also includes means for deriving

autonomous control information from the one or more sets of associated environment sensor information and device control instructions, the autonomous control information configured to facilitate generating autonomous device control signals from autonomous environment sensor information representing an environment associated with an autonomous device, the autonomous device control signals configured to cause the autonomous device to take at least one autonomous action, said autonomous control information comprising a representation of an artificial intelligence model derived from the one or more sets of associated environment sensor information and device control instructions.

In accordance with another illustrative embodiment of the invention, there is provided a system for deriving autonomous control information. The system includes at least one processor configured to receive one or more sets of associated environment sensor information and device control instructions. Each set of associated environment sensor information and device control instructions includes environment sensor information representing an environment associated with an operator controllable device and associated device control instructions configured to cause the operator controllable device to simulate at least one action taken by at least one operator experiencing a representation of the environment generated from the environment sensor information. The at least one processor is also configured to derive autonomous control information from the one or more sets of associated environment sensor information and device control instructions, the autonomous control information configured to facilitate generating autonomous device control signals from autonomous environment sensor information representing an environment associated with an autonomous device, the autonomous device control signals configured to cause the autonomous device to take at least one autonomous action, said autonomous control information comprising a representation of an artificial intelligence model derived from the one or more sets of associated environment sensor information and device control instructions.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the invention,

- 5 **Figure 1** is a schematic view of a system for deriving autonomous control information in accordance with various embodiments of the invention;
- Figure 2** is a schematic view of a processor circuit for implementing an operator controllable device shown in **Figure 1**;
- 10 **Figure 3** is a schematic view of a processor circuit for implementing an operator interface shown in **Figure 1**;
- Figure 4** is a schematic view of a processor circuit for implementing an analyzer shown in **Figure 1**;
- 15 **Figure 5** is a flowchart depicting blocks of code for directing the operator controllable device shown in **Figure 2** to facilitate deriving of autonomous control information;
- 20 **Figure 6** is a representation of an exemplary device environment frame record used in the system shown in **Figure 1**;
- Figure 7** is a flowchart depicting blocks of code for directing the operator interface shown in **Figure 3** to facilitate deriving of autonomous control information;
- 25 **Figure 8** is a representation of an exemplary operator interface sensor frame record used in the system shown in **Figure 1**;
- 30 **Figure 9** is a representation of an exemplary device control instructions frame record used in the system shown in **Figure 1**;

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Figure 10 is a flowchart depicting blocks of code for directing the analyzer shown in Figure 4 to facilitate autonomous control information generation;
- Figure 11 is a flowchart depicting blocks of code for directing the operator controllable device shown in Figure 2 to facilitate autonomous control functions;
- 10
Figure 12 is a schematic view of a system for deriving autonomous control information in accordance with various embodiments of the invention;
- Figure 13 is a front elevation view depicting an operator controllable device in accordance with various embodiments of the invention;
- 15
Figure 14 is a side elevation view depicting the operator controllable device shown in Figure 13;
- Figure 15 is a front elevation view depicting an operator interface in accordance with various embodiments of the invention;
- 20
Figure 16 is a side elevation view depicting the operator interface shown in Figure 15;
- 25
Figure 17 is a front perspective view depicting the operator interface shown in Figure 15; and
- Figure 18 is a rear perspective view depicting the operator interface shown in Figure 15.
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DETAILED DESCRIPTION

5 In various embodiments, there are provided devices that include sensors and/or actuators or output systems that are directly analogous or analogous to the perception and/or actuation or output systems of an operator. In the case where an operator is human, for example, directly analogous devices may include grippers considered to be analogous to human hands, cameras in the visible spectrum considered to be analogous to human eyes, microphones considered to be analogous to human ears, touch sensors considered to be analogous to human touch, and/or speakers considered to be analogous to human vocal apparatus.

15 In various embodiments, data obtained from analogous control of a device by at least one operator can be used to train machine learning algorithms, with a purpose being to learn to imitate the actions of the operator. This data may comprise perception and actuation or output data. Generally an operator observes representations of the perception data – for example, video, audio or haptic feedback representing an environment of a robotic system – and then acts, conditioned by this perception data. These actions may cause actuation or output systems or devices to take action. In various embodiments, the data obtained from analogous control of a robotic system by an operator may be multimodal and time dependent.

25 Referring to Figure 1, according to one embodiment of the invention, there is provided a system 10 for deriving autonomous control information. In the embodiment shown, the system 10 includes an operator controllable device 12, an operator interface 14, and an analyzer 16. The operator controllable device 12, the operator interface 14, and the analyzer 16 may be in communication with one another. In various embodiments, the operator controllable device 12, the

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operator interface **14**, and the analyzer **16** may be in communication with one another through a network **18**.

5 In Figure **1**, the operator controllable device **12** and the operator interface **14** are shown as symbols having features which are shown for exemplary purposes only. In various embodiments, the operator controllable device **12** and the operator interface may include fewer, additional or alternative features compared to those shown in Figure **1**, for example, as described in further detail below.

10 Referring to Figure **1**, in various embodiments, an operator may use the operator interface **14** to facilitate direct analogous or analogous control of the operator controllable device **12** to cause the operator controllable device **12** to perform a task. In various embodiments, the task may be one that the operator is familiar with performing without use of the operator controllable device **12**. In various
15 embodiments where the operator is a human being, the task may be an activity commonly done by a human being, such as, by way of example only, the task of picking up a cup of coffee.

In various embodiments, the operator controllable device **12** may include
20 sensors, which are configured to sense an environment of the operator controllable device **12** and to produce environment sensor information representing the environment. The operator controllable device **12** may be directed to send the environment sensor information to the operator interface **14** and to the analyzer **16**, such as, for example, over the network **18**.

25 The operator interface **14** may be directed to receive the environment sensor information and to derive operator interface control signals from the first environment sensor information. The operator interface control signals may be configured to cause the operator interface **14** to simulate the environment of the
30 operator controllable device **12** for an operator interacting with the operator interface **14**.

The operator interacting with the operator interface **14** may take action in response to the interface simulating the environment, and the operator interface **14** may include sensors for detecting the action taken by the operator. The operator interface **14** may be directed to receive operator interface sensor information via the sensors of the operator interface **14** representing at least one action taken by the operator in response to the operator interface simulating the environment.

In various embodiments, the operator interface **14** may be directed to derive device control instructions from the operator interface sensor information. The operator interface **14** may be directed to send the device control instructions to the operator controllable device **12** to cause the operator controllable device to simulate the at least one action taken by the operator. The operator interface **14** may also be directed to send the device control instructions to the analyzer **16**.

Thus, in various embodiments, the system **10** is configured to facilitate the operator interface **14** simulating an environment of the operator controllable device **12** for an operator and the operator controllable device simulating actions taken by the operator in response to experiencing the simulated environment.

As discussed above, in various embodiments, environment sensor information representing an environment associated with the operator controllable device and associated device control instructions may be sent to the analyzer **16**. Where the environment sensor information and associated device control instructions are associated with performance of a task by the operator controllable device **12**, the environment sensor information and associated device control instructions may act as a set of associated environment sensor information and device control instructions. In various embodiments, the set of associated environment sensor information and device control instructions may

act as a representation of a task performed by the operator controllable device **12**.

5 In various embodiments, one or more operators may cause the operator controllable device **12** to perform a task a plurality of times and thus the analyzer **16** may be directed to receive a plurality of sets of associated environment sensor information and device control instructions. The analyzer **16** may be directed to derive autonomous control information from the sets of associated environment sensor information and device control instructions. In various
10 embodiments, the autonomous control information may include a representation of an artificial intelligence or learning model, such as, for example, a deep learning model, configured to generate or predict device control instructions given particular environment sensor information. The predicted device control instructions may be configured to cause an autonomous device to take at least
15 one autonomous action.

In various embodiments, the operator controllable device **12** may execute code to act as an autonomous device. The operator controllable device **12** acting as an autonomous device may be directed to receive environment sensor
20 information representing an environment of the autonomous device and to use the autonomous control information generated by the analyzer **16** to generate or predict device control instructions based on the received environment sensor information. The operator controllable device **12** acting as an autonomous device may then be directed to take action based on the generated device
25 control instructions.

In view of the foregoing, in various embodiments, the system **10** may facilitate the operator controllable device **12** acting autonomously and reacting based on an artificial intelligence model to its own environment wherein the actions of the
30 operator controllable device **12** are learned using analogous operator control of the operator controllable device **12**.

Processor Circuit – Operator Controllable Device

Referring to Figure 2, a schematic view of a processor circuit for implementing the operator controllable device 12 shown in Figure 1 according to one embodiment is shown. The operator controllable device 12 includes a device processor 40, a program memory 42, a variable memory 44, cameras 46, motors 48, microphones 50, a speaker 52 and an input/output (“I/O”) interface 58, all of which are in communication with the device processor 40. The I/O interface 58 may include a network interface having a network interface card with an input/output for connecting to the network 18, and through which communications may be conducted with devices connected to the network 18, such as the operator interface 14 and the analyzer 16 shown in Figure 1.

Referring to Figure 2, in various embodiments, program codes for directing the device processor 40 to carry out various functions are stored in the program memory 42, which may be implemented as a read only memory (ROM), random access memory (RAM), a hard disk drive (HDD), a network drive, flash memory, any other form of computer-readable memory or storage medium, and/or a combination thereof.

In various embodiments, the program memory 42 includes a block of codes 60 for directing the operator controllable device 12 to effect operator controlled functions and a block of codes 62 for directing the operator controllable device 12 to effect autonomous control functions.

In this specification, it may be stated that certain encoded entities such as applications perform certain functions. Whenever an application or encoded entity is described as taking an action, it will be understood that a processor (e.g. the device processor 40) is directed to take the action by code defining the application.

The variable memory **44** includes a plurality of storage locations including location **80** for storing environment sensor information and location **82** for storing device control instructions. In some embodiments, the variable memory includes location **84** for storing autonomous control information.

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In various embodiments, the variable memory **44** may be implemented as RAM, a hard drive, a network drive, flash memory, a memory stick or card, any other form of computer-readable storage medium or a combination thereof.

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In various embodiments, the operator controllable device **12** may be controllable by a human operator via the operator interface **14** shown in Figure 1. In such embodiments, the sensors and actuator and/or output devices of the operator controllable device **12** (i.e., the cameras **46**, motors **48**, microphones **50**, and speaker **52**) may be positioned and oriented to sense and react to an environment of the operator controllable device **12** in an analogous way to a human being.

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In various embodiments, the cameras **46** may act analogously to an operator's eyes and include first and second cameras spaced apart to provide binocular vision information. In various embodiments, the operator controllable device **12** may include a mechanical neck controllable by one or more of the motors **48** that may act analogously to an operator's neck. The motors **48** may include first and second servomotors which act as neck servomotors for controlling the mechanical neck, which is connected to the cameras **46** such that movement of the neck servomotors moves a target area or orientation of the cameras **46**.

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In various embodiments, the microphones **50** may act analogously to an operator's ears and may include two microphones positioned and oriented compared to the cameras **46**, generally analogously to how ears are positioned and oriented compared to eyes on a human being. The speaker **52** may act analogously to an operator's vocal apparatus (i.e., for providing speech communication capabilities) and may be positioned and oriented compared to the cameras **46** and the

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microphones **50** analogously to how a mouth is positioned and oriented compared to eyes and ears of a human being.

5 In various embodiments, the operator controllable device **12** may include a mechanical arm including a mechanical shoulder with two degrees of freedom and an elbow with one degree of freedom and a gripper or end effector. The mechanical shoulder, elbow, and gripper may be controllable by one or more of the motors **48** to cause the mechanical arm and gripper to act analogously to an operator's arm and hand. In various embodiments, the motors **48** may include third and fourth servomotors acting as shoulder servomotors for controlling a mechanical shoulder of the mechanical arm, a fifth servomotor acting as an elbow servomotor for controlling an elbow of the mechanical arm, and a sixth servomotor acting as a gripper servomotor for controlling a gripper attached to the end of the mechanical arm.

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Processor Circuit – Operator Interface

Referring to Figure **3**, a schematic view of a processor circuit for implementing the operator interface **14** shown in Figure **1** according to one embodiment is shown. The operator interface **14** includes an operator interface processor **100**, a program memory **102**, a variable memory **104**, displays **106**, potentiometers **108**, speakers **110**, a microphone **112**, an inertial measurement unit ("IMU") **114**, a haptic glove **116** and an input/output ("I/O") interface **120**, all of which are in communication with the operator interface processor **100**.

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In various embodiments, an operator interface generally similar to the operator interface **14** shown in Figure **3** may include additional or alternative motors, sensors, and/or output devices, such as, for example, as described in further detail with reference to Figures **15-18** below. In some embodiments, for example, the operator interface may include input mechanisms such as, a motion capture system, or a traditional computer interface input for a web version of the interface

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involving a keyboard, mouse, joystick, or gaming style inputs that may, in various embodiments, utilize existing game controllers.

5 In various embodiments, the program memory **102**, variable memory **104**, and I/O interface **120** may be implemented, for example, as described for the program memory **42**, variable memory **44**, and I/O interface **58** of the operator controllable device **12** shown in Figure 2.

10 In various embodiments, the program memory **102** includes a block of codes **140** for directing the operator interface **14** to effect device control functions.

15 The variable memory **104** includes a plurality of storage locations including location **160** for storing device environment sensor information, location **164** for storing operator interface sensor information, and location **166** for storing device control instructions.

20 In various embodiments, the operator interface **14** may be configured to be interacted with by a human operator. In such embodiments, the sensors and actuator and/or output devices of the operator interface **14** (i.e., the displays **106**, potentiometers **108**, microphone **112**, and speakers **110**) may be configured to be interacted with by a human operator such that the operator is able to experience and react to a representation or simulation of an environment sensed by the operator controllable device **12** shown in Figure 2.

25 In various embodiments, operator interface **14** may include a virtual reality headset, such as, for example an Oculus Rift™, configured to be worn by the operator. The virtual reality headset may include left and right displays, which may act as the displays **106**, for displaying left and right images to left and right eyes of an operator. The virtual reality headset may include the IMU **114**, which may be
30 configured to be mounted on the operator's head and sense position and orientation of the operator's head.

5 The operator interface **14** may include an operator wearable arm and shoulder mount to which the potentiometers **108** are connected. The potentiometers may include first and second potentiometers for measuring a shoulder position of the operator and a third potentiometer for measuring an elbow position of the operator.

10 The operator interface **14** may include headphones which may act as the speakers **110** and include left and right speakers. The microphone **112** may be mounted to the headphones and configured to sense speech from a vocal apparatus of the operator. The haptic glove **116** may be configured to sense movement and orientation of a hand of the operator.

Processor Circuit – Analyzer

15 Referring to Figure **4**, a schematic view of a processor circuit for implementing the analyzer **16** shown in Figure **1** according to one embodiment is shown. The analyzer **16** includes an analyzer processor **200**, a program memory **202**, a variable memory **204**, a display **206**, one or more input devices **208**, and an input/output (“I/O”) interface **210**, all of which are in communication with the analyzer processor **200**.

20 In various embodiments, the program memory **202**, variable memory **204**, and I/O interface **210** may be implemented, for example, as described for the program memory **42**, variable memory **44**, and I/O interface **58** of the operator controllable device **12** shown in Figure **2**. The one or more input devices **208** may include a pointing device such as a cursor or mouse and/or a text input device such as a keyboard.

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30 In various embodiments, the program memory **202** includes a block of codes **222** for directing the analyzer **16** to effect autonomous control information generation functions.

The variable memory **204** includes a plurality of storage locations including location **240** for storing environment sensor information, location **242** for storing device control instructions and locations **244**, **246**, and **248** for storing sets of associated environment sensor information and device control instructions. The variable memory **204** also includes location **260** for storing autonomous control information.

In various embodiments, any or all of the operator controllable device **12**, the operator interface **14**, and the analyzer **16** shown in Figure **1** may also or alternatively be implemented in whole, or in part, in the cloud, connected to the network **18** and/or as a GPU bank, for example.

Facilitating Generation of the Autonomous Control Information Using Analogous Control

As discussed above, in various embodiments, the operator controllable device **12** shown in Figure **1** may be controlled by an operator using the operator interface **14** to facilitate deriving of autonomous control information.

Referring to Figure **5**, a flowchart depicting blocks of code for directing the device processor **40** shown in Figure **2** to facilitate operator controlled functions, is shown generally at **300**. The flowchart **300** may be encoded in the block of codes **60** shown in Figure **2** for directing the device processor **40** to effect operator controlled functions.

Referring to Figure **5**, the flowchart **300** begins with block **302** which directs the device processor **40** shown in Figure **2** to receive environment sensor information representing an environment of the operator controllable device **12**. In various embodiments, block **302** may direct the device processor **40** to store a representation of the received environment sensor information in the location **80** of the variable memory **44** shown in Figure **2**.

In various embodiments, block **302** of Figure **5** may direct the device processor **40** of Figure **2** to store the representation of the environment sensor information as one or more device environment frame records, with each frame record associated with a time. In various embodiments, the frame records may be
5 sampled at a frame rate, which in some embodiments may be, for example, **30** frames per second such that the representation of the environment sensor information may include **30** frame records for every second.

Figure **6** depicts an exemplary device environment frame record **350** in
10 accordance with one embodiment. The device environment frame record **350** includes a left image field **352**, a right image field **354**, a left audio field **356**, a right audio field **358**, a first motor position field **360**, a second motor position field **362**, a third motor position field **364**, a fourth motor position field **366**, a fifth motor position field **368**, a sixth motor position field **370**, and a time field **372**.

15 In various embodiments, block **302** shown in Figure **5** may direct the device processor **40** to query the cameras **46** shown in Figure **2** and receive image information from the cameras **46**. As discussed above, the cameras **46** may include left and right cameras and thus the image information may include left
20 and right image information. In various embodiments, each of the left and the right image information may each include a representation of one or more **640x480** pixel RGB images. Block **302** may direct the device processor **40** to store the left and right image information in the left and right image fields **352** and **354** of the device environment frame record **350** shown in Figure **6**.

25 In various embodiments, the environment of the operator controllable device **12** may include an object, such as a coffee cup, and the left and right image fields **352** and **354** of the device environment frame record **350** may store image information representing two different views of the object.

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In various embodiments, block **302** shown in Figure **5** may direct the device processor **40** to query the microphones **50** shown in Figure **2** and receive audio information from the microphones **50**. As discussed above, the microphones **50** may include left and right microphones and thus the audio information may include left audio information and right audio information. In various embodiments, the audio information may be sampled at the frame rate of **30** frames per second, for example. The microphones **50** may capture audio signals at **22kHz** and so, in various embodiments, each of the left and right audio information may include approximately **733** subsamples. Block **302** may direct the device processor **40** to store representations of the left and right audio information in the left and right audio fields **356** and **358** of the device environment frame record **350** shown in Figure **6**.

In various embodiments, the environment of the operator controllable device **12** may include a sound wave communication, such as a person asking “How is the coffee?”, and the left and right audio fields **356** and **358** of the device environment frame record **350** may store audio information representing the sound wave communication sensed from the microphones **50**.

In various embodiments, block **302** shown in Figure **5** may direct the device processor **40** to query the motors **48** shown in Figure **2** and receive position information from the motors **48**. As discussed above, the motors **48** may include two neck servomotors, one gripper servomotor, one elbow servomotor, and two shoulder servomotors, and each of the servomotors may be configured to sense an absolute angle representing a position of the motor. In various embodiments, block **302** may direct the device processor **40** to receive a value for each of the servomotors included in the motors **48**, the value representing a position of the particular servomotor.

Block **302** may direct the device processor **40** to store the values representing the positions of the servomotors in the motor position fields **360**, **362**, **364**, **366**,

368, and **370** of the device environment frame record **350**. In various embodiments, the motor position fields **360**, **362**, **364**, **366**, **368**, and **370** may act as a position vector defining a position associated with the operator controllable device **12**.

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Block **302** shown in Figure **5** may also direct the device processor **40** shown in Figure **2** to store a representation of a time, at which the information stored in the fields **352-370** of the device environment frame record **350** was sampled, in the time field **372**. In the embodiment shown in Figure **6**, the format of the representation stored in the time field **372** represents a time and date where the time is accurate to a hundredth of a second.

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Referring to Figure **5**, block **304** then directs the device processor **40** to send the environment sensor information to the operator interface **14** and the analyzer **16**. In various embodiments, block **304** may direct the device processor **40** to retrieve the representation of the environment sensor information from the location **80** of the variable memory **44** and send the representation to the operator interface **14** and the analyzer **16** via the I/O interface **58** and the network **18**, for example.

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In some embodiments, block **304** may direct the device processor **40** to execute block **304** periodically to send representations of new environment sensor information at an environment refresh rate which may, in some embodiments differ from the frame rate. For example, in various embodiments, block **304** may direct the device processor **40** to send representations of new environment sensor information to the operator interface **14** and the analyzer **16** at **10** times per second and thus, where block **302** directs the device processor **40** to sample **30** device environment frame records per second, block **304** may direct the device processor **40** to send to the operator interface **14** and the analyzer **16**, three device environment frame records at a time, ten times per second.

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Referring now to Figure **7**, a flowchart **400** which may execute concurrently with the flowchart **300** is shown, depicting blocks of code for directing the operator

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interface **14** shown in Figure **3** to facilitate device control. The flowchart **400** may be encoded in the block of codes **140** shown in Figure **3** for directing the operator interface processor **40** to effect device control functions.

5 Referring to Figure **7**, the flowchart begins with block **402** which, in various embodiments may be executed after block **304** shown in Figure **5** has been executed. Block **402** directs the operator interface processor **100** shown in Figure **3** to receive environment sensor information. In various embodiments, block **402** may direct the operator interface processor **100** to receive representations of environment sensor information that were sent by the device processor **40** at block **304** shown in the flowchart **300**. Block **402** may direct the operator interface processor **100** to receive the representations of the environment sensor information via the network **18** and the I/O interface **120**, for example. In various embodiments, block **402** may direct the operator interface processor **100** to store the representations of the environment sensor information in the location **160** of the variable memory **104** shown in Figure **3**.

Block **404** then directs the operator interface processor **100** to produce operator interface control signals derived from the environment sensor information. In various embodiments, the operator interface control signals may be configured to cause the operator interface **14** to simulate the environment represented by the environment sensor information, for an operator interacting with the operator interface **14**.

25 In various embodiments, block **404** directs the operator interface processor **100** to retrieve the representations of the environment sensor information stored in the location **160** and to produce signals based on the representations.

30 As discussed above, left and right displays of a virtual reality headset, which may be worn by the operator, may act as the displays **106**. In various embodiments, for example, where a device environment frame record such as the device

environment frame record **350** shown in Figure **6** has been stored in the location **160** of the variable memory **104** shown in Figure **3**, block **404** may direct the operator interface processor **100** to produce signals for causing one or more images represented by the image information stored in the left image field **352** to be displayed by the left display of the virtual reality headset and block **404** may direct the operator interface processor **100** to produce signals for causing one or more images represented by the image information stored in the right image field **354** to be displayed by the right display of the virtual reality headset. Accordingly, in various embodiments, an operator wearing the virtual reality headset and interacting with the operator interface **14** may experience a binocular simulation of the visual environment of the operator controllable device **12**.

In various embodiments, block **404** may direct the operator interface processor **100** to cause various heads-up display items to be displayed to the operator to enhance the embodiment experience. For example, in various embodiments, if movements made by the operator are approaching an end of a range of allowed movements for the operator controllable device **12**, block **404** may direct the operator interface processor **100** to cause the operator's display to flash red

As discussed above, the operator interface **14** may include headphones which may include left and right speakers and act as the speakers **110**. In various embodiments, where a device environment frame record such as the device environment frame record **350** shown in Figure **6** has been received and stored in the location **160** of the variable memory **104** shown in Figure **3**, block **404** shown in Figure **7** may direct the operator interface processor **100** shown in Figure **3** to produce signals for causing audio represented by the audio information stored in the left audio field **356** to be output by the left speaker of the headphones and to produce signals for causing audio represented by the audio information stored in the right audio field **358** to be output by the right speaker of the headphones. Accordingly, in various embodiments, an operator wearing the

headphones and interacting with the operator interface **14** may experience an auditory representation or simulation of the auditory environment of the operator controllable device **12**.

5 In view of the foregoing, in various embodiments, an operator interacting with the operator interface **14** shown in Figure **3** may experience a representation or simulation of the environment of the operator controllable device **12** shown in Figure **2**. In some embodiments, the operator may wish to control the operator controllable device **12** to cause the operator controllable device to perform a task. To do so, the operator may take at least one action in response to experiencing the representation of the environment and block **406** may direct the operator interface processor **100** to receive operator interface sensor information representing the action taken.

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15 In various embodiments, block **406** may direct the operator interface processor **100** to receive the operator interface sensor information from sensors of the operator interface **14** and to store a representation of the operator interface sensor information in the location **164** of the variable memory **104**. In various embodiments, block **406** may direct the operator interface processor **100** to store the representation as one or more operator interface sensor frame records.

20
25 Figure **8** depicts an exemplary operator interface sensor frame record **450** in accordance with one embodiment. The operator interface sensor frame record **450** includes an operator audio field **452** for storing a representation of audio information received from the microphone **112** and an IMU x-axis field **462** and an IMU z-axis field **464** for storing angle values representing x-axis and z-axis orientations of the IMU **114**. The operator interface sensor frame record **450** also includes first, second, and third potentiometer fields **454**, **456**, and **458** for storing respective representations of position information received from the potentiometers **108** and a haptic glove condition field **466** for storing a representation of a condition of the haptic glove **116**. The operator interface

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sensor frame record also includes a time field **468** for storing a representation of a time when the information stored in the fields **452-466** was sampled.

5 In various embodiments, block **406** may direct the operator interface processor **100** to query the microphone **112** and receive audio information from the microphone **112**, which, In various embodiments the audio information may represent speech information received from an operator interacting with the operator interface **14**. Block **406** may then direct the operator interface processor **100** to store the audio information in the operator audio field **452** of the operator interface sensor frame record **450** shown in Figure **8**.
10

In various embodiments, block **406** shown in Figure **7** may direct the operator interface processor **100** to query the IMU **114** shown in Figure **3** and receive values representing an x-axis angle and a z-axis angle of an operator's head.
15 Block **406** may direct the operator interface processor **100** to store the values in the IMU x-axis and IMU z-axis fields **462** and **464** of the operator interface sensor frame record **450** shown in Figure **8**.

20 In various embodiments, the operator may begin moving their head using their neck to look more closely at the coffee cup displayed for them and so the operator may cause the values in the IMU x-axis and IMU z-axis fields **462** and **464** of the operator interface sensor frame record **450** to represent a new head position.

25 In various embodiments, block **406** shown in Figure **7** may direct the operator interface processor **100** to query the first and second potentiometers of the potentiometers **108** shown in Figure **3** to determine an orientation of a shoulder of the operator and to query the third potentiometer to determine an orientation of an elbow of the operator. Block **406** may direct the operator interface processor
30 **100** to receive from the first, second, and third potentiometers values representing angles of the potentiometers. Block **406** may direct the operator

interface processor **100** to store the values representing angles of the first, second, and third potentiometers in the first, second, and third potentiometer fields **454**, **456**, and **458** respectively of the operator interface sensor frame record **450** shown in Figure **8**.

5

In various embodiments, the operator may have begun moving their arm to cause the operator controllable device **12** to reach out to a coffee cup displayed and so the operator may cause the values in the first, second, and third potentiometer fields **454**, **456**, and **458** of the operator interface sensor frame record **450** to reflect a new arm and shoulder position.

10

In various embodiments, block **406** shown in Figure **7** may direct the operator interface processor **100** to query the haptic glove **116** shown in Figure **3** and receive a value from the haptic glove **116** representing a condition sensed by the glove. For example, in various embodiments, the haptic glove may provide a value between **0** and **100** wherein **0** corresponds to a closed condition and **100** corresponds to a fully open condition of an operator's hand within the haptic glove **116**. Block **406** may direct the operator interface processor **100** to store the value received from the haptic glove **116** in the haptic glove condition field **466**.

15

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In various embodiments, the operator may begin opening their hand to cause the gripper of the operator controllable device **12** to open and so the operator may cause the values in the haptic glove condition field **466** of the operator interface sensor frame record **450** to reflect an opening hand.

25

Block **406** shown in Figure **7** may direct the operator interface processor **100** shown in Figure **3** to store a time associated with the operator interface sensor information represented by the information stored in the fields **452-466** in the time field **468**. In the embodiment shown in Figure **8**, the operator interface sensor frame record **450** represents operator interface sensor information that

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was sensed a hundredth of a second after the environment sensor information represented by the device environment frame record **350** shown in Figure **6** was sensed.

5 Block **408** shown in Figure **7** then directs the operator interface processor **100** to derive device control instructions from the operator interface sensor information, the device control instructions being configured to cause the operator controllable device **12** to simulate the at least one action taken by the operator. In various
10 embodiments, block **408** may direct the operator interface processor **100** to store a representation of the device control instructions in the location **166** of the variable memory **104**. The representation of the device control instructions may include one or more device control instructions frame records, each representing device control instructions associated with a time.

15 An exemplary device control instructions frame record **500** according to one embodiment is shown in Figure **9**. The device control instructions frame record **500** includes a speaker control field **502** for storing audio information to be output by a speaker such as the speaker **52** of the operator controllable device **12** shown in Figure **2**. The device control instructions frame record **500** also
20 includes first, second, third, fourth, fifth and sixth motor control fields **504**, **506**, **508**, **510**, **512**, and **514** for storing motor control instructions for controlling motors such as the first, second, third, fourth, fifth, and sixth servomotors of the motors **48** of the operator controllable device **12** shown in Figure **2**. In the embodiment shown, the motor control instructions represent a desired position of a motor. The device control instructions frame record also includes a time field
25 **516** for storing a time associated with the instructions represented by the fields **502-514**.

30 In various embodiments, block **408** of Figure **7** may direct the operator interface processor **100** shown in Figure **3** to derive information for the fields **502-514** of the device control instructions frame record **500** shown in Figure **9** from fields of

an operator interface frame record, such as the fields **452-468** of the operator interface sensor frame record **450** shown in Figure 8.

5 For example, in various embodiments, block **408** of Figure 7 may direct the operator interface processor **100** shown in Figure 3 to copy audio information stored in the operator audio field **452** of the operator interface sensor frame record **450** shown in Figure 8 into the speaker control field **502** of the device control instructions frame record **500** shown in Figure 9. Block **408** may direct the operator interface processor **100** to copy the values representing angles from
10 the potentiometer fields **454**, **456**, and **458** of the operator interface sensor frame record **450** into the first, second, and third motor control fields **504**, **506**, and **508** of the device control instructions frame record **500**.

15 In various embodiments, block **408** may direct the operator interface processor **100** to copy the angle values from the IMU x-axis and the IMU z-axis fields **462** and **464** of the operator interface sensor frame record **450** into the fourth and fifth motor control fields **510** and **512** of the device control instructions frame record **500**.

20 In various embodiments, block **408** may direct the operator interface processor **100** to scale the value stored in the glove condition field **466** by a scaling factor to produce a desired position value that may act as motor control instructions and to store the desired position value in the sixth motor control field **514**.

25 In various embodiments, other functions besides copying and scaling may be used to derive the device control instructions. In various embodiments, block **408** may direct the operator interface processor **100** audio encoding, vocoders, text-to-speech and/or speech-to-text functions to the operator interface sensor information on the fly. In various embodiments, a voice of an operator may be
30 modulated, for example by sending it through a vocoder, to produce a variety of voices.

5 In various embodiments, this may provide a range of personalities that can be embodied by the operator controllable device **12**, which may facilitate tailoring the operator controllable device **12** to a specific environment or user interacting with the device. In various embodiments, such tailoring may facilitate use of the operator controllable device **12** as a companion.

10 In some embodiments, block **408** may direct the operator interface processor **100** to apply non-linear response functions to the operator interface sensor information, such as, for example, by scaling down the operator interface sensor information when deriving the device control instruction records if the operator is approaching a limit of the environment and/or the operator controllable device. This may facilitate slowing of movements of the operator controllable device **12** towards a limit, when the operator controllable device nears the limit.

15 In various embodiments, block **408** may direct the operator interface processor **100** to recognize a gesture made by an operator using functional mappings. Block **408** may direct the operator interface processor **100** to include in a set of device control instruction records, a set of pre-saved device control instructions for a particular pre-recorded set of actuations. For example, in various
20 embodiments, the pre-recorded set of actuations may include facial expressions and/or common gestures.

25 Block **410** of the flowchart **400** shown in Figure **7** then directs the operator interface processor **100** shown in Figure **3** to send the device control instructions to the operator controllable device **12** and the analyzer **16** shown in Figure **1**. In various embodiments, block **410** may direct the operator interface processor **100** to retrieve a representation of the device control instructions from the location **166** of the variable memory **104** and to send the representation to the operator controllable
30 device **12** and the analyzer **16** via the I/O interface **120** and the network **18**.

Referring again to Figure 5, block 306 directs the device processor 40 shown in Figure 2 to receive device control instructions. In various embodiments, block 306 may direct the device processor 40 to receive a representation of device control instructions via the I/O interface 58 and the network 18. The representation of the device control instructions may have been sent by the operator interface 14 at block 410 of the flowchart 400 shown in Figure 7, for example. In various embodiments, block 306 directs the device processor 40 to store the representation of the device control instructions in the location 82 of the variable memory 44.

Block 308 shown in Figure 5 then directs the device processor 40 to produce signals for causing the operator controllable device 12 shown in Figure 2 to take action based on the device control instructions. In various embodiments, block 308 may direct the device processor 40 to produce signals for causing the operator controllable device 12 to simulate at least one action taken by an operator experiencing a representation or simulation of the environment of the operator controllable device 12.

In various embodiments, block 308 of Figure 5 may direct the device processor 40 to read the representation of the device control instructions from the location 82 of the variable memory 44 shown in Figure 2 and to produce signals based on the device control instructions for causing at least one actuator or output device of the operator controllable device 12 to take action.

For example, in various embodiments a device control instructions frame record such as the device control instructions frame record 500 shown in Figure 9 may be included in the representation of the device control instructions stored in the location 82 of the variable memory 44 shown in Figure 2. Block 308 of Figure 5 may direct the device processor 40 to read audio information from the speaker control field 502 and to produce signals for causing the speaker 52 of the operator controllable device 12 to output audio represented by the audio information. In various embodiments, by outputting the audio represented by the audio information,

the speaker **52** may be simulating audio sensed by the microphone **112** of the operator interface **14** and causing the speaker **52** to act analogously to a vocal apparatus of an operator interacting with the operator interface **14**.

5 In various embodiments, block **308** of Figure **5** may direct the device processor **40** to produce signals for causing the first, second, third, fourth, fifth, and sixth servomotors of the motors **48** to take action based on the values stored in the motor control fields **504-514**. In various embodiments, by moving according to the motor control fields **504-514**, the first, second, third, fourth, fifth, and sixth
10 servomotors of the motors **48** may cause the operator controllable device **12** to act analogously to an operator interacting with the operator interface.

In various embodiments, the first and second servomotors may cause the mechanical neck of the operator controllable device **12** to move analogously to the
15 neck of the operator interacting with the operator interface **14**, the third and fourth servomotors may cause the mechanical shoulder of the operator controllable device **12** to move analogously to the shoulder of the operator, the fifth servomotor may cause the mechanical elbow of the operator controllable device **12** to move analogously to the elbow of the operator, and the sixth servomotor may cause the
20 gripper of the operator controllable device **12** to move analogously to a hand of the operator.

In various embodiments, flowcharts **300** and **400** shown in Figures **5** and **7** may be executed a plurality of times to facilitate an operator causing the operator
25 controllable device **12** to complete a task. For example, in various embodiments, the operator may cause the operator controllable device **12** to pick up a coffee cup and/or to set the coffee cup down.

In various embodiments, the operator may cause the operator controllable device
30 **12** to interact with features of its environment. For example, in various

embodiments, a feature may be considered to be any aspect of the environment that is not included in the operator controllable device **12**.

Generating the Autonomous Control Information

5 Referring to Figure **10**, a flowchart depicting blocks of code for directing the analyzer processor **200** shown in Figure **4** to facilitate autonomous control information generation, is shown generally at **550**. The flowchart **550** may be encoded in the block of codes **222** shown in Figure **4** for directing the analyzer processor **200** to effect autonomous information generation functions.

10

Referring to Figure **10**, the flowchart **550** begins with block **552** which directs the analyzer processor **200** shown in Figure **4** to receive sets of associated environment sensor information and device control instructions. In various embodiments, each of the sets may include environment sensor information and device control instructions that were used to cause the operator controllable device **12** to complete a task. In various embodiments, block **552** may direct the analyzer processor **200** to receive one or more device environment frame records and one or more device control instructions frame records.

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20 In some embodiments, block **552** of Figure **10** may direct the analyzer processor **200** shown in Figure **4** to store received environment sensor information in the location **240** of the variable memory **204** and to store received device control instructions in the location **242** of the variable memory **204**. In various embodiments, the received environment sensor information and device control instructions may have been sent by the device processor **40** and the operator interface processor **100** at blocks **304** and **410** of flowcharts **300** and **400** shown in Figures **5** and **7** respectively.

25

30 When a task has been completed, block **552** of Figure **10** may direct the analyzer processor **200** shown in Figure **4** to retrieve or receive from the locations **240** and **242** of the variable memory **44** a set of associated environment sensor information

and device control instructions that were included in the received environment sensor information and device control instructions and which are associated with completion of a task. For example, a user may use the display **206** and the one or more input devices **208** to identify a set of associated environment sensor information and device control instructions that were associated with completion of a task, and the user may cause block **552** to retrieve or receive from the locations **240** and **242** the set of associated environment sensor information and device control instructions that were associated with completion of the task.

10 In various embodiments, a task may have been started and completed within a particular time period and so a user may cause block **552** of Figure **10** to direct the analyzer processor **200** shown in Figure **4** to retrieve from the variable memory **204** a set of associated environment sensor information and device control instructions that include device environment frame records and device control instructions
15 frame records that include time fields storing times that fall within the particular time period. Block **552** may then direct the analyzer processor to store the set as a first set of associated environment sensor information and device control instructions in the location **244** of the variable memory **204**. In some embodiments, the user may cause only sets of information associated with a successful completion of the task
20 to be received at block **552**.

In various embodiments, the sets stored in the variable memory **204** may be identified as such using semantic labels. For example, where the first set of associated sensor information and device control instructions stored in the location
25 **244** shown in Figure **4** includes frame records, each frame record may include at least one label field for storing a semantic label for indicating that the frame record belongs to a set, such as, for example, the first set. In various embodiments subsets may be identified similarly with additional or alternative label fields.

30 In various embodiments, some sets of associated environment sensor information and device control instructions may represent a failed attempt at a task. A user

may wish to exclude such sets from those considered when generating the autonomous control information. Accordingly, a user may cause frame records belonging to such sets to include a label field value that indicates that the frame record represents a failed task and should be ignored when generating the autonomous control information.

In various embodiments, the operator controllable device **12** shown in Figure **2** may be directed to complete the same task a plurality of times and thus block **552** of the flowchart **550** shown in Figure **10** may direct the analyzer processor **200** shown in Figure **4** to receive a plurality of sets of associated environment sensor information and device control instructions, each associated with an instance of completion of the task. In various embodiments, block **552** may direct the analyzer processor **200** to store each set in the variable memory **204** shown in Figure **4**, such as in the locations **244**, **246**, and **248**.

In various embodiments, for example, block **552** may direct the analyzer processor **200** to receive about **10,000** sets and to store the sets in the variable memory **204**.

Block **556** then directs the analyzer processor **200** to derive autonomous control information from the sets of associated environment sensor information and device control instructions. The autonomous control information may be configured to facilitate generating autonomous device control signals from autonomous environment sensor information representing an environment associated with an autonomous device, wherein the autonomous device control signals are configured to cause the autonomous device to take at least one autonomous action.

In various embodiments, the autonomous control information may be configured to produce behaviour in the autonomous device that mimics types of behaviour learned from the actions of operators given similar environment sensor information representing similar situations.

In various embodiments, block **556** of Figure **10** may direct the analyzer processor **200** shown in Figure **4** to retrieve from the variable memory **204** the sets of associated environment sensor information and device control instructions including the sets stored in the locations **244**, **246**, and **248** and to
5 derive a model, such as, for example, a deep hierarchical model, from the sets. In various embodiments, block **556** may direct the analyzer processor **200** to store a representation of the model as autonomous control information in the location **260** of the variable memory **204**.

10 In some embodiments, block **556** may be executed concurrently with an operator using the operator interface **14** to control the operator controllable device **16** (online training). In various embodiments, block **556** may be executed on stored sets of associated environment sensor information and device control instructions that were created in the past (offline training).

15 In various embodiments block **556** of Figure **10** may direct the analyzer processor **200** shown in Figure **4** to use the sets of associated environment sensor information and device control instructions to train machine learning models or algorithms, such as, for example, generative deep hierarchical learning algorithms
20 which treat time explicitly. Examples of such models or algorithms include Deep Boltzmann Machines (DBMs), including Locally Connected Deep Boltzmann Machines (LCDBMs). An exemplary description of an LCDBM with a concrete implementation is provided at
<http://dwave.wordpress.com/2014/01/07/separating-sensor-modalities-using-an-lc-dbm/>.
25

Other algorithms which may also or alternatively be used to derive autonomous control information from the sets of associated environment sensor information include Conditional Restricted Boltzmann Machines (CRBMs); memory-
30 prediction algorithms, such as, for example, those described by Jeff Hawkins / Numenta / Grok..

5 Block **558** of Figure **10** then directs the analyzer processor **200** shown in Figure **4** to send the autonomous control information to an autonomous device. In various embodiments, the operator controllable device **12** shown in Figure **2** may be capable of acting as an autonomous device, such as when the operator controllable device **12** executes the block of code **62** shown in Figure **2**, and thus block **558** may direct the analyzer processor **200** to send the autonomous control information to the operator controllable device **12**.

10 In various embodiments, block **558** of Figure **10** may direct the analyzer processor **200** shown in Figure **4** to retrieve the autonomous control information from the location **260** of the variable memory **204** and send the autonomous control information to the operator controllable device **12** shown in Figure **2** via the I/O interface **210** and the network **18**.

15

Autonomous Control

After the autonomous control information has been generated, this information may be used to facilitate autonomous control of an autonomous device. As discussed above, in various embodiments, the operator controllable device **12** may act as an autonomous device.

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Referring to Figure **11**, a flowchart depicting blocks of code for directing the device processor **40** shown in Figure **2** to facilitate autonomous control functions, is shown generally at **600**. The flowchart **600** may be encoded in the block of codes **62** for directing the device processor **40** shown in Figure **2** to effect autonomous control functions.

25

The flowchart **600** of Figure **11** begins with block **602** which directs the device processor **40** shown in Figure **2** to receive autonomous control information. In various embodiments, block **602** may direct the device processor **40** to store the autonomous control information in the location **84** of the variable memory **44**.

30

In various embodiments, block **602** of Figure **11** may direct the device processor **40** shown in Figure **2** to receive autonomous control information that was sent by the analyzer processor **200** at block **558** of the flowchart **550** shown in Figure **10**.

5

Block **604** of Figure **11** then directs the device processor **40** shown in Figure **2** to receive environment sensor information. Block **604** may be generally similar to block **302** of the flowchart **300** shown in Figure **5**. Accordingly, block **604** may direct the device processor **40** to store the environment sensor information in the location **80** of the variable memory **44** shown in Figure **2**.

10

Block **606** of Figure **11** then directs the device processor **40** shown in Figure **2** to derive device control instructions from the environment sensor information using the autonomous control information. The derived device control instructions may act as autonomous device control instructions.

15

In various embodiments, block **606** of Figure **11** may direct the device processor **40** shown in Figure **2** to retrieve the autonomous control information from the location **84** of the variable memory **44** and to use the autonomous control information to generate a model which is configured to take, as inputs, the environment sensor information and to produce, as outputs, device control instructions. Block **606** may direct the device processor **40** to input the environment sensor information into the model to generate or derive device control instructions. In various embodiments, block **606** may direct the device processor **40** to store the generated or derived device control instructions in the location **82** of the variable memory **44** as autonomous device control instructions.

20

25

Block **608** of Figure **11** then directs the device processor **40** shown in Figure **2** to produce signals for causing the device to take action based on the device control instructions. In various embodiments, block **608** may direct the device processor **40** to produce device control signals representing the autonomous device control

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instructions for causing the operator controllable device **12** to take at least one autonomous action. For example, block **608** may direct the device processor **40** to produce signals for causing the speaker **52** and/or one or more of the motors **48** to take action. In various embodiments, block **608** may be generally similar to the block **308** of the flowchart **300** shown in Figure 5.

Accordingly, in various embodiments, the operator controllable device **12** shown in Figure 2 may react to environment sensor information and take action and the manner in which the device reacts and takes action may be learned from previously received environment sensor information and device control instructions generated during analogous control of the device.

Multiple Devices and Interfaces

Referring to Figure 12, according to an embodiment of the invention, there is provided a system **700** for deriving autonomous control information. In the embodiment shown, the system **700** includes a plurality of operator controllable devices including operator controllable devices **702**, **704**, and **706**. The system **700** also includes a plurality of operator interfaces including operator interfaces **710**, **712**, and **714**. The system also includes an analyzer **718** and an autonomous device **720**. The operator controllable devices **702**, **704**, and **706** may be in communication with the analyzer **718** and the operator interfaces **710**, **712**, and **714** through a network **730**. The operator interfaces **710**, **712**, and **714** and the autonomous device **720** may also be in communication with the analyzer **718** through the network **730**.

In various embodiments, each of the operator controllable devices **702**, **704**, and **706** may be generally similar to the operator controllable device **12** shown in Figure 2, although in some embodiments, the operator controllable devices **702**, **704** and **706** may not include the block of codes **62** shown in Figure 2 for directing the operator controllable device **12** to effect autonomous control functions. The autonomous device **720** may be generally similar to the operator controllable device

12 although in some embodiments the autonomous device **720** may not include the block of codes **60** shown in Figure **2** for directing the operator controllable device **12** to effect operator controlled functions. Each of the operator interfaces **710**, **712**, and **714** may be generally similar to the operator interface **14** shown in Figure **3** and the analyzer **718** may be generally similar to the analyzer **16** shown in Figure **4**.

In various embodiments, the operator controllable devices **702**, **704**, **706** may be controlled by operators interacting with the operator interfaces **710**, **712**, and **714**, generally as described above having regard to the operator controllable device **12** and the operator interface **14**. In some embodiments, the operator interfaces **710**, **712**, and **714** may be configured to control any of the operator controllable devices **702**, **704**, **706**. In some embodiments, the operator interfaces **710**, **712**, and **714** may be configured to control only one, or a subset of the operator controllable devices **702**, **704**, **706**.

In the embodiment shown in Figure **12**, operators interacting with the operator interfaces **710**, **712**, and **714** may cause the operator controllable devices **702**, **704**, **706** to perform tasks. The analyzer **718** may derive autonomous control information from sets of associated environment sensor information and device control instructions used by the operator interfaces **710**, **712**, and **714** and the operator controllable devices **702**, **704**, **706** to perform the tasks.

In some embodiments the analyzer **718** may send the autonomous control information to the operator controllable devices **702**, **704**, and **706** such that these devices can act as autonomous devices. In some embodiments, the analyzer **718** may send the autonomous control information to the autonomous device **720** to cause the autonomous device **720** to act autonomously.

In various embodiments, the system **700** shown in Figure **12** may include a plurality of autonomous devices generally similar to the autonomous device **20** shown in

Figure **12** and each of the plurality of autonomous devices may be in communication with the analyzer **718** through the network **730**.

5 In various embodiments, more than one operator interface may alternatingly control a single operator controlled device over time. For example, in various
embodiments, operators interacting with the operator interfaces **710**, **712**, and **714**
may alternatingly cause the operator controllable device **702** to perform a task or
tasks. In various embodiments, generally at least one operator and/or at least
10 one autonomous controller (machine) may control one or more operator
controllable device.

Combined Devices

In various embodiments, any or all of the operator controllable device **12**, the
operator interface **14**, and the analyzer **16** shown in Figure **1**, or aspects thereof,
15 may be implemented within a single processor circuit having at least one
processor. In such embodiments, some information and/or instructions described
above may not need to be sent between processors. Accordingly, flowcharts
similar to the flowcharts **300**, **400** and **550** shown in Figures **5**, **7**, **10**, and **11** may
be executed wherein the flowcharts include blocks that differ from blocks **304**,
20 **410** and/or **558** and/or do not include blocks similar to blocks **304**, **410** and/or
558.

Sensors, Actuators and/or Output Devices

In various embodiments an operator controllable device generally similar to the
25 operator controllable device **12** shown in Figure **2** may include fewer, additional,
or alternative sensors, actuators and/or output devices to those of the operator
controllable device **12**. In some embodiments, an operator controllable device
generally similar to the operator controllable device **12** may appear humanoid
and may include a mechanical torso, mechanical appendages and a mechanical
30 head that act analogously to a human operator's arms, legs, and head.

5 Some examples of sensors that may be included in an operator controllable device generally similar to the operator controllable device **12** shown in Figure **2** include a touch or force feedback sensor, a location sensor, such as a global positioning system (“GPS”), a range finder, a proximity sensor for detecting feature proximity, a chemical sensor, a temperature sensor, and/or an orientation sensor such as a gyroscope.

10 Some examples of actuators and/or output devices or systems that may be included in an operator controllable device generally similar to the operator controllable device **12** shown in Figure **2** include motor systems providing functionality including gripping, pushing, pulling, propulsion, and/or moving the operator controllable device and/or objects in proximity to the operator controllable device, and communication systems for producing carriers and signals including sound including human speech, RF, Wi-Fi™, Bluetooth™, Ethernet, and/or light sources including screens, LEDs and lasers, for example.

15 In various embodiments an operator interface generally similar to the operator interface **14** shown in Figure **3** may include fewer, additional, or alternative sensors, actuators and/or output devices to those of the operator interface **14** shown in Figure **3**.

20 For example, in some embodiments, the operator interface may include at least one camera for tracking movement of an operator. In some embodiments, the operator interface may include haptic or force sensing and/or feedback systems.

25 For example, in various embodiments, the operator interface may include actuators for simulating touch or forces felt by sensors of the operator controllable device. In some embodiments, the operator interface may include sensors for sensing touch or forces applied by the operator to the sensors. In various embodiments, the operator interface may include sensors and/or devices

30 for facilitating electroencephalography (EEG), functional magnetic resonance imaging (fMRI), transcranial magnetic stimulation, electromyography (EMG),

and/or electrocardiography (ECG). In various embodiments, the operator interface may include temperature sensors, which may, in various embodiments be configured to measure skin temperature of an operator, chemical sensors and biometrics sensors. In some embodiments the operator interface may include multi-spectral or hyper-spectral imaging sensors. In various embodiments, generally, any sensor allowing capture of signals produced by an operator (human or otherwise) may be included in the operator interface.

Predetermined environment

In various embodiments, an operator controllable device may be placed in a training environment where the environment and changes to the environment are predetermined. In such embodiments, the operator interface may be able to simulate the predetermined environment without receiving signals from the operator controllable device representing the environment, since the environment, being predetermined is already known.

For example, in one embodiment, there may be provided an operator controllable device that includes a locomotion system configured to simulate movement of a cockroach, which may act as an operator. The operator controllable device may be placed into a training environment, which may for example be a 2 foot by 2 foot encasement with a first programmable lighting system that is configured to provide a predetermined lighting environment. An operator interface may be provided that includes a similar 2 foot by 2 foot encasement with a second programmable lighting system. The second programmable lighting system may be configured to provide a lighting environment that is equivalent to the predetermined lighting environment provided by the first programmable lighting system. Accordingly, the operator interface may be configured to simulate the environment of the operator controllable device. The operator interface may include a sensor for tracking movement and/or position of a cockroach within the encasement of the operator interface.

A cockroach may be placed in the encasement of the operator interface and the first and second programmable lighting systems may be directed to provide the predetermined lighting environment. The cockroach may act, conditioned on the time-varying changing of its lighting environment. The cockroach's actions, and specifically its movement, may be sensed by the operator interface and analogous control of the operator controllable device may be provided, generally as described in various embodiments above, by controlling actuation of the operator controllable device's locomotion system.

One or more sets of associated environment sensor information and device control instructions may be generated from environment sensor information produced by the light sensors of the operator controllable device and device control instructions produced by the operator interface over a fixed period of time. In various embodiments, semantic labels may be applied to frame records to identify sets of associated environment sensor information and device control instructions.

Machine learning algorithms can then be applied to the one or more sets of associated environment sensor information and device control instructions, in order to produce autonomous control information. The autonomous control information may then be used to facilitate autonomous behavior in the cockroach operator controllable device absent the cockroach operator. In various embodiments, the operator controllable device may then be configured to act autonomously and be released into as yet unseen environments to act like a cockroach.

Operators

As described above, in various embodiments, an operator may include a human and in various embodiments an operator may include a cockroach. More generally, in various embodiments an operator may include an entity that is capable of reacting to its environment. For example, an operator may include a

biological entity or group of biological entities or a machine, such as a robotic system (either autonomous or operator controllable) or group of machines, or any combination thereof.

5 For example, in various embodiments, an operator may include an industrial
manufacturing robot, and the operator controllable device may include analogous
but not necessarily identical sensor and actuation and/or output systems to that
of the manufacturing robot. As described above, environment sensor information
10 and device control instructions may be generated based on environment sensor
information over multiple runs. Sets of associated environment sensor
information and device control instructions may be received and in some
embodiments semantic labels may be applied to frame records to identify sets of
associated environment sensor information and device control instructions.
15 Autonomous control information may then be derived from the sets of associated
environment sensor information and device control instructions and the
autonomous control information may be used to facilitate autonomous behaviour
in an autonomous device that may mimic the actions of the industrial
manufacturing robot.

20 Operator controllable device

As discussed above, in various embodiments an operator controllable device
generally similar to the operator controllable device **12** shown in Figure **2** may
include fewer, additional, or alternative sensors, actuators and/or output devices
to those of the operator controllable device **12**. For example, referring to Figure
25 **13**, an operator controllable device in accordance with various embodiments of the
invention is shown generally at **800**.

The operator controllable device **800** includes a first arm **801** and a second arm
803. The first arm **801** includes two shoulder servos **802**, an upper arm servo **804**,
30 an elbow servo **806**, a wrist servo **808**, and a haptic feedback hand **810**.

Accordingly, in various embodiments, the first arm **801** may have **5** degrees of freedom and thus may facilitate all motions a human arm is able to perform.

5 The second arm **803** is generally similar to the first arm **801** but mirrored. Referring to Figure **14**, the second arm **803** includes two shoulder servos, one of which is shown in Figure **14** at **815**, an upper arm servo **805**, an elbow servo **807**, a wrist servo **809**, and a haptic feedback hand **811**.

10 Referring back to Figure **13**, in various embodiments, the operator controllable device **800** also includes motility treads **812**, strut supports **814**, an electronics compartment **816**, two DC motors **818**, one speaker **820**, a waist servo **822**, an interlock mechanism **826**, a single board computer (SBC) **828**, two neck servos **830**, a carrying handle and chassis **832**, two ears and ear servos **834**, two cameras **836**, two microphones **838**, and two cable bundles **840**. Referring to Figure **14**, the operator controllable device **800** also includes a backstop mechanism **824**

20 Referring to Figures **13** and **14**, in various embodiments, the shoulder servos **802** and **815** may each control pitch and roll of a shoulder of the operator controllable device **800**. In various embodiments, the shoulder servos **802** and **815** may, for example be MX-28 or Dynamixel AX-12 servo motors.

25 Referring to Figures **13** and **14**, in various embodiments, the upper arm rotation servos **804** and **805** may each control the yaw of an arm of the operator controllable device. In various embodiments, the upper arm rotation servos **804** and **805** may, for example, be Dynamixel AX-12 servo motors.

30 In various embodiments, the elbow servos **806** and **807** may each control an elbow of the operator controllable device **800**. In various embodiments, the elbow servos **806** and **807** may, for example be Dynamixel AX-12 servo motors.

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In various embodiments, the wrist servos **808** and **809** may each control a forearm rotation of the operator controllable device **800**. In various embodiments, the wrist servos **808** and **809** may, for example be Dynamixel AX-12 servo motors.

5 In various embodiments, the haptic hands **810** and **811** may each include two fingers and a thumb with embedded force sensitive resistors. Respective servos, which may, for example be Dynamixel XL-320 servo motors, may operate each finger independently. Thus, in various embodiments, the haptic hands **810** and **811** may have **3** degrees of freedom (servos for two fingers and an opposing thumb)
10 which may, in some embodiments, facilitate dextrous manipulation.

In various embodiments, the fingers of the haptic hands **810** and **811** may have polymer filled fingers and rubber finger pads, which may, in various embodiments enhance gripping and simulate the resistance of a human finger. In some
15 embodiments, the fingers may each have pressure sensors which may produce signals proportional to a pressure applied to the sensors.

Referring to Figure **13**, in various embodiments, the motility treads **812** may provide the capacity for locomotion to the operator controllable device **800**. In one
20 embodiment, the treads **812** may include **28** link **2**" treads with **6**" sprockets. In various embodiments, the motility treads **812** may provide a broad base which may, in some embodiments, increase stability of the operator controllable device **800**.

25 Referring to Figure **13**, in various embodiments, the strut supports **814** may be made of a light weight and strong material, such as, for example, aluminium. In various embodiments, the strut supports **814** may include an open beam support structure.

30 In various embodiments, the electronics compartment **816** may include a shelf-like cabinet that may, in various embodiments, provide access to various wiring and

5 electronic components. In various embodiments for example, three batteries may be found in the compartment **816**. The batteries may include a first battery for providing power to the motor bus (the DC motors **818**) and all the servos except the servos for controlling the fingers of the haptic hand **810** and the ear servos **834**, a second battery for powering the SBC **828** and the speaker **820**, and a third battery which may be used to power a motor control board (such as, for example an OpenCM motor control board) which may drive the ear servos **834** and the servos for controlling the fingers of the haptic hand **810**.

10 In various embodiments, the first battery may, for example, be a lithium polymer **4000mAh 3 cell 12 V** battery, the second battery may be a **5V 9600mAh**, USB mobile charging power pack, and the third battery may include two combined **3.7V** lithium ion batteries.

15 Referring still to Figure **13**, the electronics compartment **816** may contain, in certain embodiments, an Arduino Leonardo with a motor shield on top which may control the DC motors, device chest LEDs and may receive signals from the force sensors in the haptic hands **810**.

20 In some embodiments the electronics compartment **816** may also contain a power breakout board which may act as a patch panel including patching of the hand sensor signal and some ground pins. In some embodiments, the electronics compartment **816** may contain a motor control board, for example an OpenCM board made by Robotis. In some embodiments, the electronics compartment **816**
25 may also contain switches, which may facilitate independent powering of **12V** and **5V** trains.

In various embodiments, the two DC motors **818** may be configured to turn one of the sprockets that then rotates the entire tread assembly. In various embodiments,
30 the DC motors **818** may act as drive motors. In certain embodiments, the DC motors **818** may be generic **12V** DC motors.

In various embodiments, the speaker **820**, may allow projection of audio signals into an environment of the operator controllable device **800**. For example, the audio signals may represent speech. In one embodiment, the speaker **820** may be a Blue
5 Piston Bluetooth wireless speaker. As discussed above, having regard to the operator controllable device **12**, in various embodiments, a voice of an operator may be modulated before it is communicated by the speakers **820**, for example by sending it through a vocoder, to produce a variety of voices. In various
10 embodiments, this may facilitate use of the operator controllable device **800** as a companion.

In some embodiments, the operator's voice may be translated to text automatically, and the text may be read by automatic text to speech programs.

15 Referring still to Figure **13**, in various embodiments, the waist servo **822** may control forward pitch of the operator controllable device. In various embodiments, the waist servo **822** may enable the device to reach the floor using the hands **810** and **811**. The waist servo **822** servo may, for example be a Dynamixel MX-64.

20 Referring to Figure **14**, in various embodiments, the backstop mechanism **824** may simulate the human spine so the operator controllable device **800** cannot bend backwards.

25 Referring back to Figure **13**, in various embodiments, the interlock device **826** may provide structural stability to a torso of the operator controllable device **800** when the power is off.

30 The SBC **828**, in one embodiment may for example be an Odroid-XU3 board. In some embodiments, the SBC **828** may include periphery devices such as a USB hub (extender for USB ports), a Wifi adapter, and/or a Pure Audio or generic sound

card which may, in some embodiments, be used for both incoming and outgoing audio signal processing.

5 In various embodiments, the neck servos **830** may provide pitch and yaw to a head of the operator controllable device **800**. In various embodiments, the neck servos **830** may allow the operator controllable device **800** to look around in its environment. In various embodiments, the neck servos **830** may, for example be Dynamixel **AX-12** servo motors.

10 Referring still to Figure **13**, in various embodiments, the carrying handle **832** may facilitate easy transportation. In various embodiments, the chassis of the operator controllable device **800** may have plates installed primarily on the arms and chest. In various embodiments, the plates may provide decoration. The plates may be different colors, materials and/or finishes to cater to a client or to a personality of a
15 particular operator controllable device.

In various embodiments, the ears and ear servos **834** may provide expressive feedback from the operator controllable device **800**. Thus, in various embodiments, the ears and ear servos **834** may increase an expressiveness of a face of the
20 operator controllable device **800** and thus allow the appearance of emotional states to be displayed. In various embodiments, for example, the ear servos **834** may be Dynamixel **XL-320** servo motors.

In various embodiments, the cameras **836** may be spaced to simulate the distance
25 of the human eyes for optimized stereo vision. The cameras **836** may provide the ability to capture visual signals from the environment. For example, the cameras **836** may in one embodiment be Logitech **C920** HD wide angle lens cameras.

In various embodiments, the microphones **838** may facilitate the capture of audio
30 information in a stereo manner from the environment of the operator controllable

device **800**. In one embodiment, the microphones **838** may, for example, be MM-BSM-5 "Micro" Binaural Stereo Microphones.

5 In various embodiments, the cable bundling **840** may provide an aesthetic function and appeal. In some embodiments, the cable bundling **840** may also prevent cable tangling and optimize organization. In various embodiments, the two separate cable bundles may extend from the back plate down to the electronics compartment **816**.

Operator interface

10 As discussed above, in various embodiments an operator interface generally similar to the operator interface **14** shown in Figure **3** may include fewer, additional, or alternative sensors, actuators and/or output devices to those of the operator interface **14** shown in Figure **3**. For example, referring to Figure **15**, there is shown an operator interface **900** in accordance with various
15 embodiments of the invention.

In various embodiments, the operator interface **900** may include left/right audio input **902**, left/right visual display **904**, a head/neck motion sensor **906**, and first and second arm sensor assemblies **907** and **909**.

20

In various embodiments, the first arm sensor assembly **907** may include two shoulder servos **908**, an upper-arm rotator cuff and securing band **910**, an elbow servo **912**, a lower-arm rotator cuff and securing band **914**, a forearm cuff **916**, and a haptic glove **918**. The second arm sensor assembly **909** may be generally
25 similar to the first arm sensor assembly **907** but mirrored.

25

Referring still to Figure **15**, the operator interface **900** may include three locomotion pedals **920**, an extension arm and waist servo **922**, a suit vest **924**, an electronic back-box **926** (shown in Figure **16**) and a chest/shoulder suit support structure **928**.

30

Referring to Figure 15, in various embodiments, the left/right audio input 902 may provide an interface for transferring audio information from an operator controllable device, such as the operator controllable device 800 shown in Figure 13, to an operator using the operator interface 900 shown in Figure 15.

5

In various embodiments, generated audio input from an analyzer or based on other input information may also or alternatively be played through the left/right audio input 902. An example of generated audio that may be played to the operator, in one embodiment, may be an audible communication of relative proximity of the operator controllable device 800 shown in Figure 13 to nearby objects using beeping of various frequencies.

10

In various embodiments, the left/right audio input 902 may include a set of headphones which may be designed for gaming and therefore comfortable to wear for extended periods. In various embodiments, the left/right audio input 902 may include, for example, Sand Blaster Tactic headphones.

15

In various embodiments, the left and right visual display 904 may provide an interface for displaying visual information captured by the cameras 836 of the operator controllable device 800 shown in Figure 13. In some embodiments, visual information may be generated for display on the left and right displays 904. An example of generated information which may be displayed on the left and right displays 904, in one embodiment, may be battery charge levels of the operator controllable device 800 shown in Figure 13 or proximity estimation of objects in a field of view of the operator controllable device. In one embodiment, the left and right visual display 904 may be implemented using a virtual reality headset, such as, for example an Oculus Rift™.

20

25

Referring to Figure 15, in various embodiments, the head/neck motion sensor 906 may sense or capture movement of an operator's head, specifically pitch and yaw. In one embodiment, the head/neck motion sensor 906 may include a

30

gyroscope, an accelerometer, a magnetometer, and/or another inertial measurement unit (IMU). In various embodiments, the head/neck motion sensor **906** may be built into a virtual reality headset such as, for example, the Oculus Rift™.

5

In various embodiments, the shoulder servos **908** may sense or capture pitch and roll of an operator's shoulder. In some embodiments, the servos may contain feedback resistors that provide absolute position measurements. In one embodiment, for example, these servos may be Dynamixel AX-12 servos.

10

Referring still to Figure **15**, in various embodiments, the upper arm rotator cuff and securing band **910** may sense or capture rotation of an upper arm of an operator. In various embodiments, the upper arm rotator cuff and securing band **910** may include a semi-circular gear mechanism that wraps around the upper arm and couples with a second semi-circular gear mechanism at **90** degrees to the first. In various embodiments, this gear arrangement may transfer the rotation of the upper arm to the rotation of a potentiometer centered around and connected to the second gear mechanism.

15

In various embodiments, a non-moving part of the potentiometer may be fixed to the operator's shoulder. In one embodiment, the potentiometer may have a wider than normal central shaft with a hole in the center which may facilitate firm fixation of the potentiometer to the shoulder. In one embodiment, the potentiometer may be, for example, a **39/20** mm Center Space Rotary Potentiometer.

20

25

In various embodiments, the elbow servo **912** may capture or sense an angle of an operator's elbow. For example, in one embodiment, the elbow servo **912** may be a Dynamixel AX-12.

30

Referring to Figure **15**, in various embodiments, the lower arm rotator cuff and securing band **914** may capture or sense the rotation of the lower arm of the operator. In various embodiments, the lower arm rotator cuff and securing band **914** may include a semi-circular gear mechanism that wraps around the lower arm and couples with a second semi-circular gear mechanism at **90** degrees to the first. This gear arrangement may transfer the rotation of the lower arm to the rotation of a potentiometer centered around and connected to the second gear mechanism. In various embodiments, a non-moving part of the potentiometer may be fixed to the operator's arm. In one embodiment, the potentiometer may have a wider than normal central shaft with a hole in the center which may facilitate firm fixation of the potentiometer to the arm. In one embodiment, the potentiometer may, for example, be a **39/20** mm Center Space Rotary Potentiometer.

In various embodiments, the forearm cuff **916** may secure the first arm sensor assembly **907** of the operator interface **900** to the operator.

Referring to Figure **15**, in various embodiments, the haptic glove **918** may capture or sense a position of the operator's pointer finger and thumb relative to one another. A servo may be affixed to the haptic glove **918** at the center point of rotation of the thumb and pointer finger of the operator. The angle of the servo may be controlled by two armatures with rings allowing coupling of the operator fingers to the armatures. In various embodiments, the servo may be configured to provide feedback information garnered from the haptic hand **810** of the operator controllable device **800** shown in Figure **13** to the fingers of the operator using the operator interface **900** shown in Figure **15** in the form of resistance as the operator guides the operator controllable device **800** to pick up an object.

Referring still to Figure **15**, in various embodiments, the haptic glove **908** may have a buzzer, which may be configured to buzz with an amplitude that is a function of the signals coming from the finger pressure sensors of the haptic

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hand **810** of the operator controlled device **800** shown in Figure **13**. In one embodiment, for example, the haptic glove **918** may use a Dynamixel AX-12 servo.

5 As discussed above, the second arm sensor assembly **909** may be generally similar to the first arm assembly **907**, except that it is mirrored.

Referring to Figure **15**, in various embodiments, the locomotion pedals **920** may be controlled by the operator's feet. The locomotion pedals **920** may be
10 configured such that the angle captured by the pedals drives the locomotion of the operator controllable device **800** shown in Figure **13**. Referring to Figure **15**, in various embodiments, left and right forward motion pedals may operate independently triggering left and right treads respectively of the motility treads **812** of the operator controllable device **800** shown in Figure **13** and may facilitate
15 turning of the operator controllable device **800**.

In various embodiments, the locomotion pedals **920** may include a reverse motion pedal configured to operate on both left and right treads of the motility treads **812** shown in Figure **13**. All three pedals may be fixed to a single rubber
20 mat to prevent movement or sliding during use. In one embodiment, the locomotion pedals **920** may include a rotating foot platform, a potentiometer to capture the angle of the foot platform and a spring to return the pedal to a neutral position when the operator's foot is removed.

Referring to Figure **15**, in various embodiments, the waist servo **922** may capture or sense the angle of the operator's torso relative to their legs. The extension arm on which the servo is mounted may connect to the operator interface **900** by a hinge. In various embodiments, the extension arm may firmly connect to the operator's upper thigh. In one embodiment, the waist servo **922** may, for
25
30 example, be a Dynamixel AX-12 servo.

Referring still to Figure 15, in various embodiments, the operator vest 924 may provide a mounting structure for components of the operator interface 900. The operator vest 924 may attach and anchor the operator interface 900 firmly to the operator's body. In some embodiments the operator vest 924 may have decorative LEDs on the front and/or the back. In one embodiment, the operator vest 924 may, for example, be a Fox Racing Airframe Roost Deflector.

Referring to Figure 15, in various embodiments, the electronic back-box 926 may be attached to the vest 924 and may contain electronic components associated with the operator interface 900. In one embodiment the electronic back-box 926 may contain an Arduino Pro Mini which captures the sensor signals from the potentiometers and controls the LEDs mounted on the vest 924, power boards for the Dynamixel bus, a power-breakout board which also may also act as a patch panel including patching of the hand sensor signals and some ground pins, an Odroid which handles the wireless adapter for Wifi communication as well as a USB2AX connector which allows the Odroid to send signals to the Dynamixels. The Odroid may also send signals to the Android Pro mini.

The chest/shoulder suit support structure 928 allows for suspension of operator interface suit items from the frame rather than from the operator's limbs. In various embodiments, the chest/shoulder suit support structure 928 may facilitate removal of the suit weight off of the operator's arms onto the operators shoulder and back.

Figure 16 shows a side elevation view of the operator interface 900 shown in Figure 15. Figure 17 shows a front perspective view of the operator interface 900 shown in Figure 15. Figure 18 shows a rear perspective view of the operator interface 900 shown in Figure 15.

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While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

- 5 1. A method of deriving autonomous control information, the method comprising:

 receiving one or more sets of associated environment sensor information and device control instructions, wherein each set of associated environment sensor information and device control instructions comprises:

 environment sensor information representing an environment associated with an operator controllable device; and

 associated device control instructions configured to cause the operator controllable device to simulate at least one action taken by at least one operator experiencing a representation of the environment generated from the environment sensor information;

 deriving autonomous control information from the one or more sets of associated environment sensor information and device control instructions, said autonomous control information configured to facilitate generating autonomous device control signals from autonomous environment sensor information representing an environment associated with an autonomous device, said autonomous device control signals configured to cause the autonomous device to take at least one autonomous action, said autonomous control information comprising a representation of an artificial intelligence model derived from the one or more sets of

associated environment sensor information and device control instructions.

2. The method of claim 1 further comprising:

5

receiving first autonomous environment sensor information representing an environment associated with a first autonomous device;

10

deriving first autonomous device control instructions from the first autonomous environment sensor information using the autonomous control information;

15

producing first autonomous device control signals representing the first autonomous device control instructions for causing the first autonomous device to take at least one autonomous action.

3. The method of claim 1 wherein receiving the one or more sets of associated environment sensor information and device control instructions comprises:

20

receiving first environment sensor information representing a first environment of a first operator controllable device;

25

producing first operator interface control signals derived from the first environment sensor information for causing a first operator interface to simulate the first environment for a first operator interacting with the first operator interface;

30

receiving first operator interface sensor information representing at least one action taken by the first operator in response to the first operator interface simulating the first environment;

5 deriving first device control instructions from the first operator interface sensor information, said first device control instructions configured to cause the first operator controllable device to simulate the at least one action taken by the first operator;

10 wherein one of the one or more sets of associated environment sensor information and device control instructions comprises the first environment information and the first device control instructions.

- 15 4. The method of claim 1 wherein the environment sensor information for each of the one or more sets of associated environment sensor information and device control instructions comprises at least one of the following:

visual information;

20 audio information;

location information;

feature proximity information;

25 force feedback information;

chemical information;

30 temperature information; and

orientation information.

5. The method of claim 1 wherein the device control instructions for each of the one or more sets of associated environment sensor information and device control instructions represents signals for causing the device to take at least one of the following actions:

5

gripping a feature;

pushing a feature;

10

pulling a feature;

propelling the device;

moving the device;

15

moving a feature; and

emitting communication signals.

20

6. A computer-readable medium having stored thereon codes which, when executed by at least one processor, cause the at least one processor to perform the method of any one of claims 1 to 5.

25

7. A system for deriving autonomous control information, the system comprising:

means for receiving one or more sets of associated environment sensor information and device control instructions, wherein each set of associated environment sensor information and device control instructions comprises:

30

environment sensor information representing an environment associated with an operator controllable device; and

5 associated device control instructions configured to cause the operator controllable device to simulate at least one action taken by at least one operator experiencing a representation of the environment generated from the environment sensor information;

10 means for deriving autonomous control information from the one or more sets of associated environment sensor information and device control instructions, said autonomous control information configured to facilitate generating autonomous device control signals from
15 autonomous environment sensor information representing an environment associated with an autonomous device, said autonomous device control signals configured to cause the autonomous device to take at least one autonomous action, said autonomous control information comprising a representation of an
20 artificial intelligence model derived from the one or more sets of associated environment sensor information and device control instructions.

8. A system for deriving autonomous control information, the system
25 comprising at least one processor configured to:

receive one or more sets of associated environment sensor information and device control instructions, wherein each set of associated environment sensor information and device control
30 instructions comprises:

environment sensor information representing an environment associated with an operator controllable device; and

5 associated device control instructions configured to cause the operator controllable device to simulate at least one action taken by at least one operator experiencing a representation of the environment generated from the environment sensor information;

10 derive autonomous control information from the one or more sets of associated environment sensor information and device control instructions, said autonomous control information configured to facilitate generating autonomous device control signals from
15 autonomous environment sensor information representing an environment associated with an autonomous device, said autonomous device control signals configured to cause the autonomous device to take at least one autonomous action, said autonomous control information comprising a representation of an
20 artificial intelligence model derived from the one or more sets of associated environment sensor information and device control instructions.

25

+

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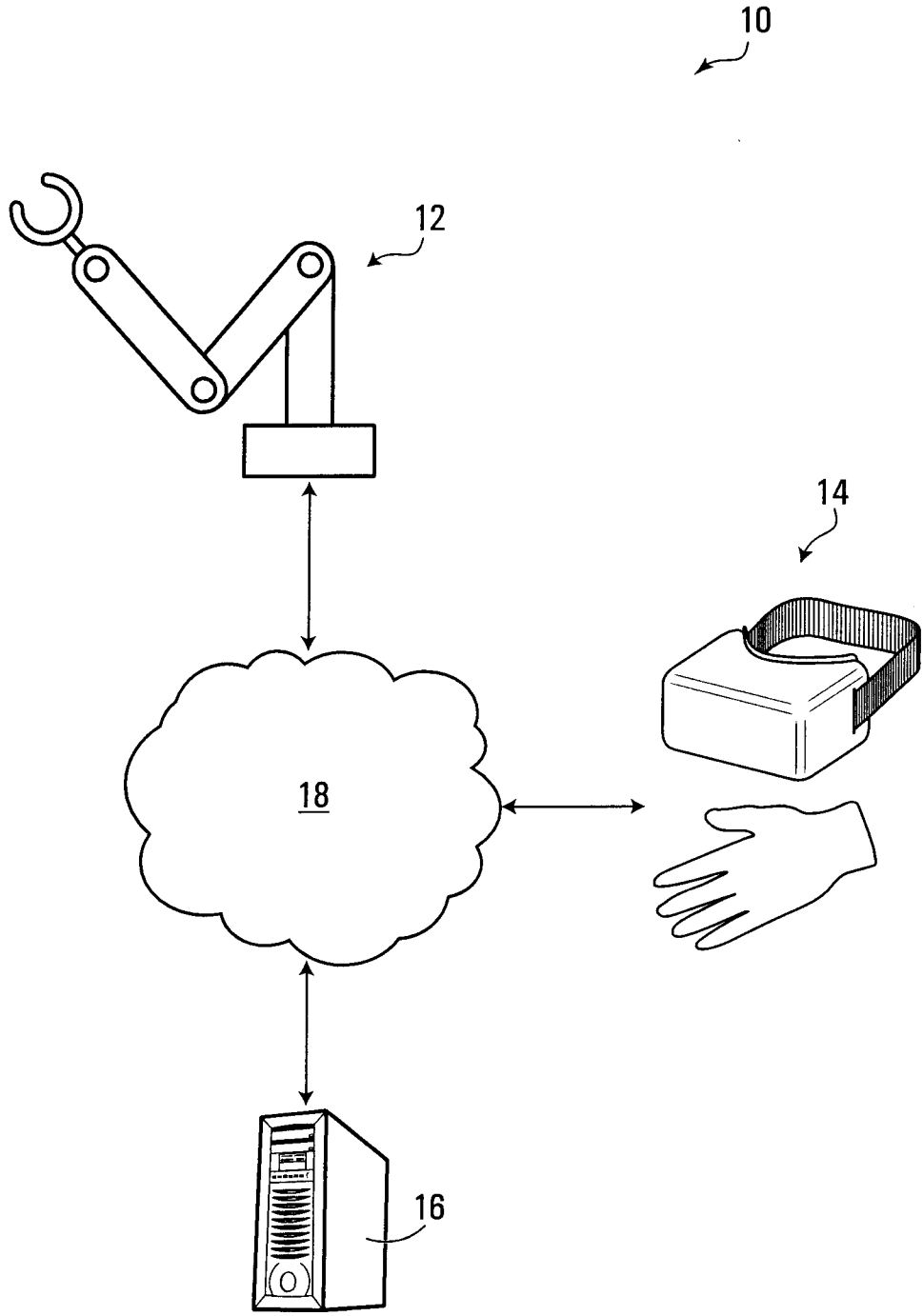


FIG. 1

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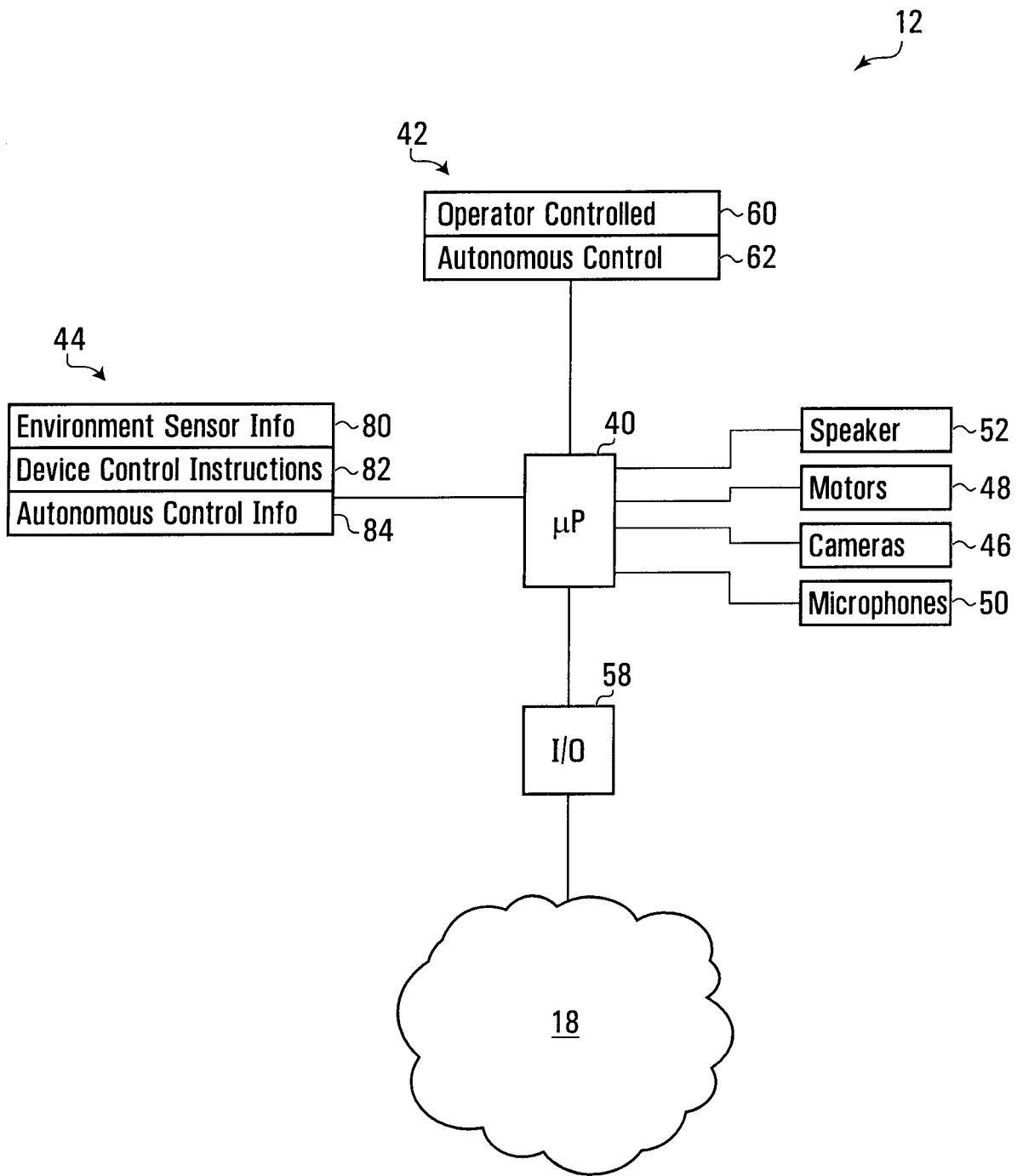


FIG. 2

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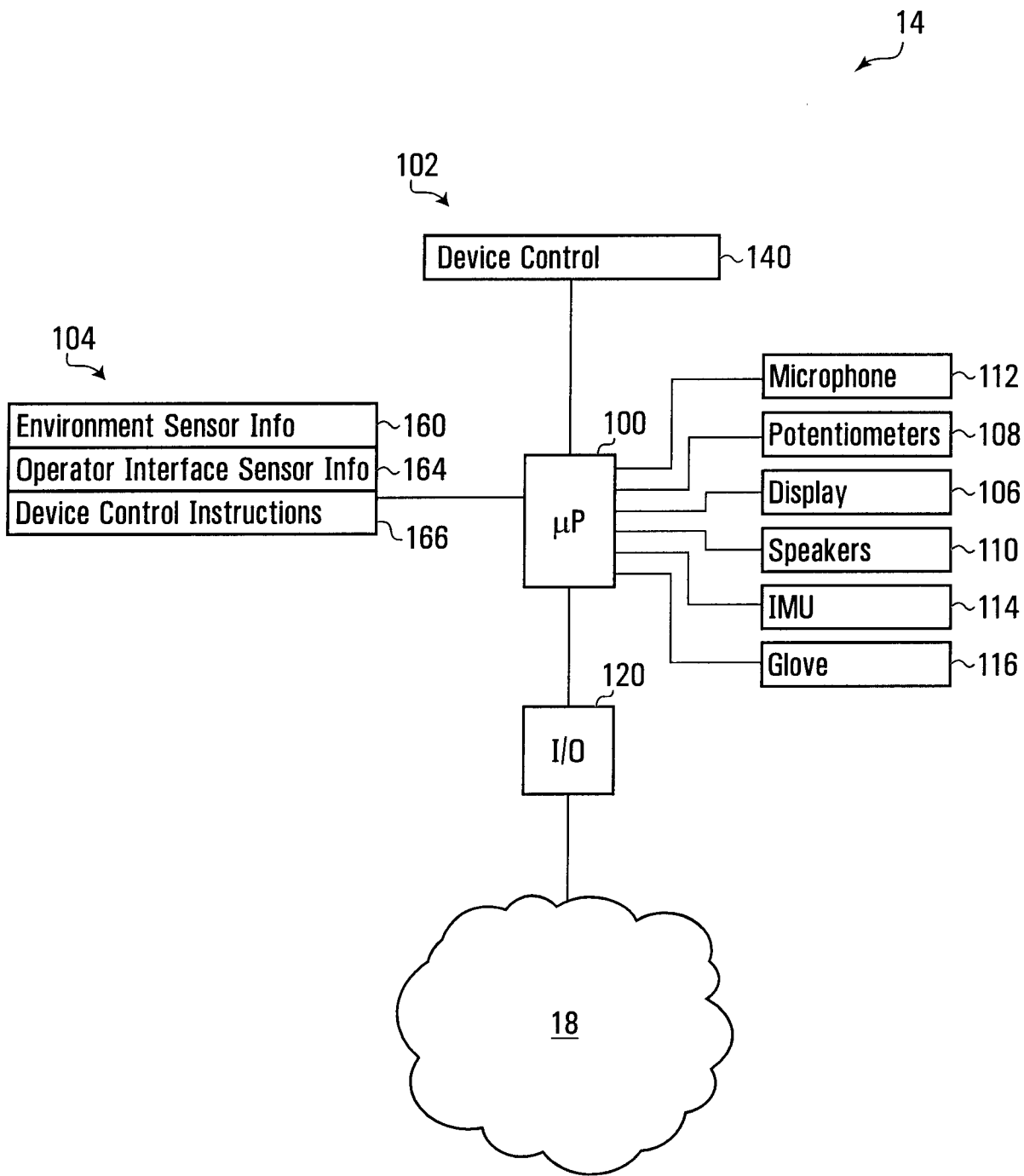


FIG. 3

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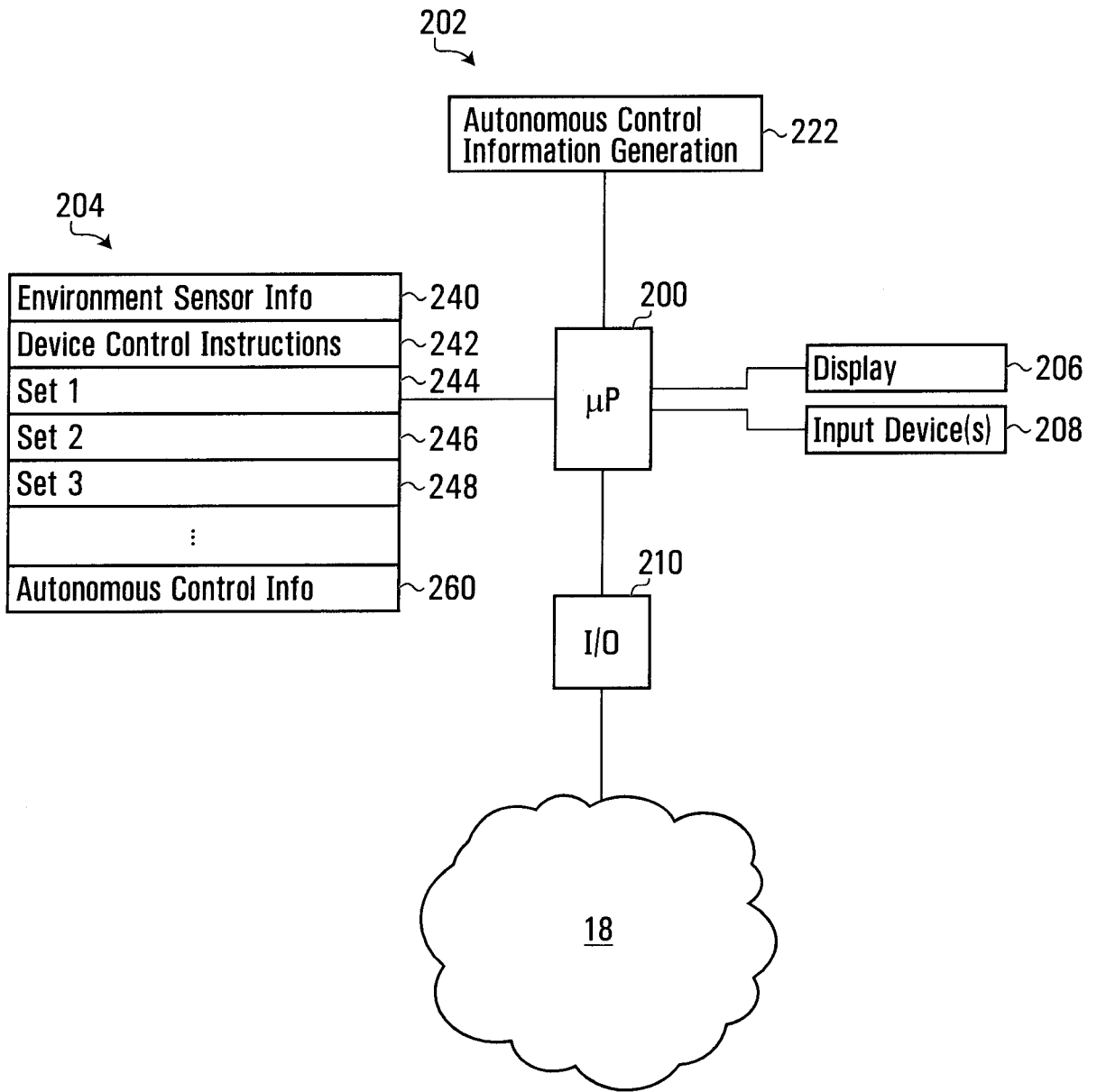


FIG. 4

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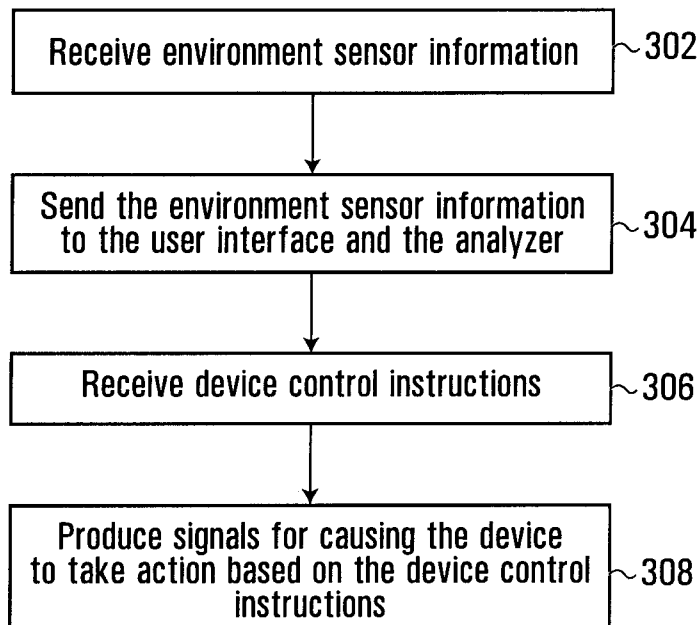


FIG. 5

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Device Environment Frame Record

350
↙



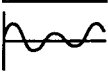
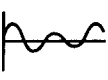
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354	↪	Right Image	
356	↪	Left Audio	
358	↪	Right Audio	
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362	↪	Motor 2 Position	0
364	↪	Motor 3 Position	0
366	↪	Motor 4 Position	0
368	↪	Motor 5 Position	0
370	↪	Motor 6 Position	0
372	↪	Time	2014112512000000

FIG. 6

+

400

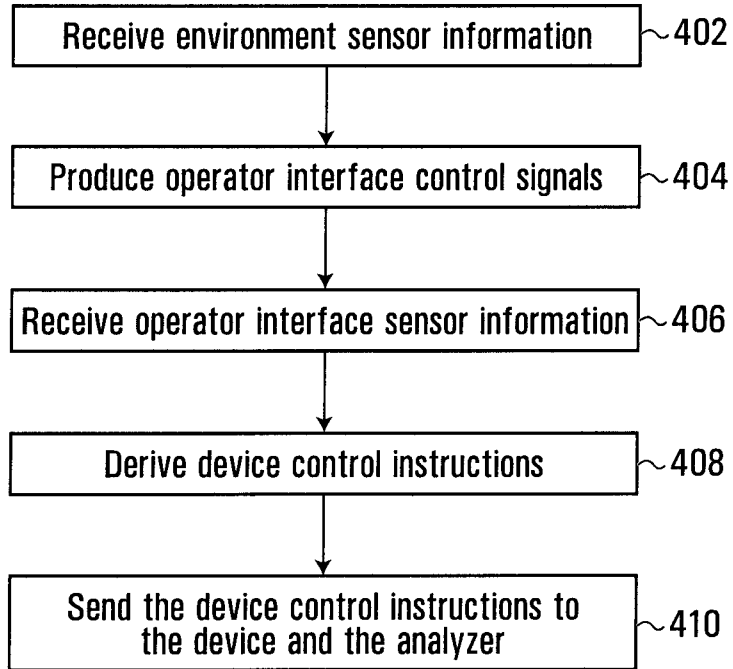


FIG. 7

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Operator Interface Sensor Frame Record

450
↙

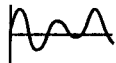
452	↪	Operator Audio	
462	↪	IMU x-axis	20
464	↪	IMU z-axis	10
454	↪	Potentiometer 1	10
456	↪	Potentiometer 2	10
458	↪	Potentiometer 3	10
466	↪	Glove	5
468	↪	Time	2014112512000001

FIG. 8

+

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500

Device Control Instructions Frame Record



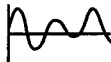
502	→	Speaker	
504	→	Motor 1	10
506	→	Motor 2	10
508	→	Motor 3	10
510	→	Motor 4	20
512	→	Motor 5	10
514	→	Motor 6	15
516	→	Time	2014112512000001

FIG. 9

+

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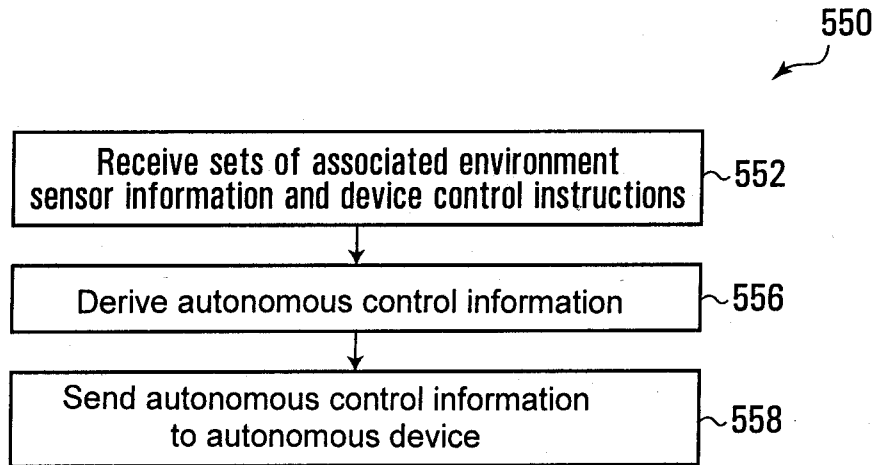


FIG. 10

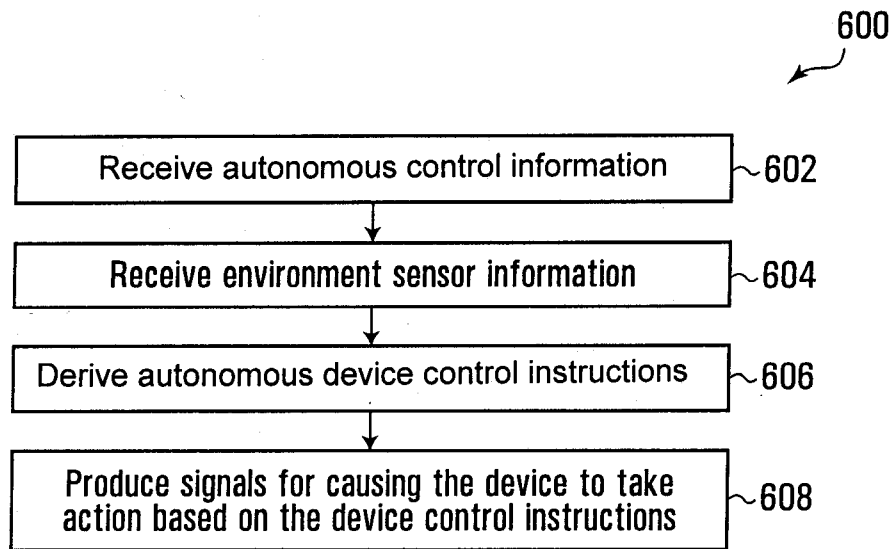


FIG. 11

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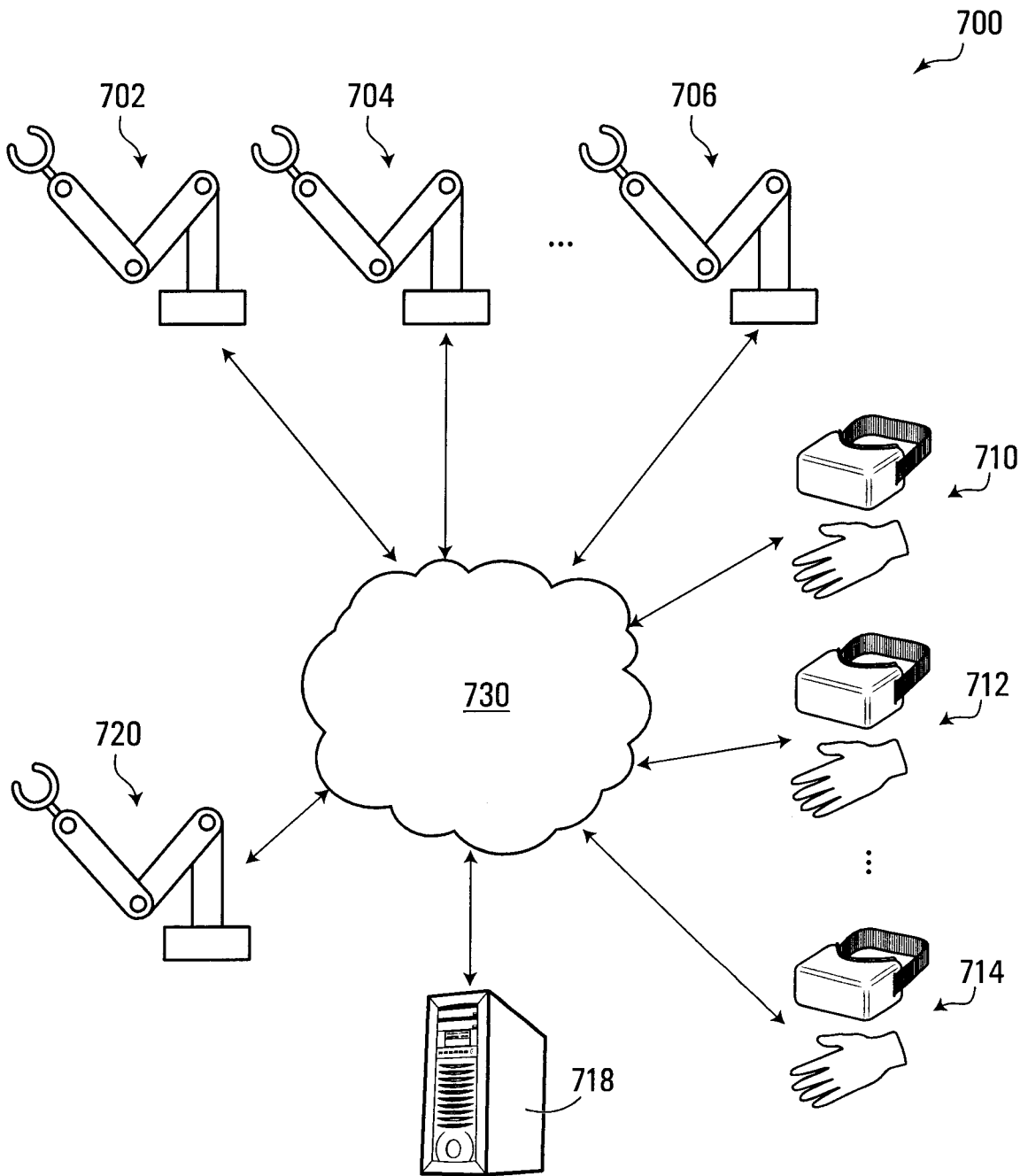
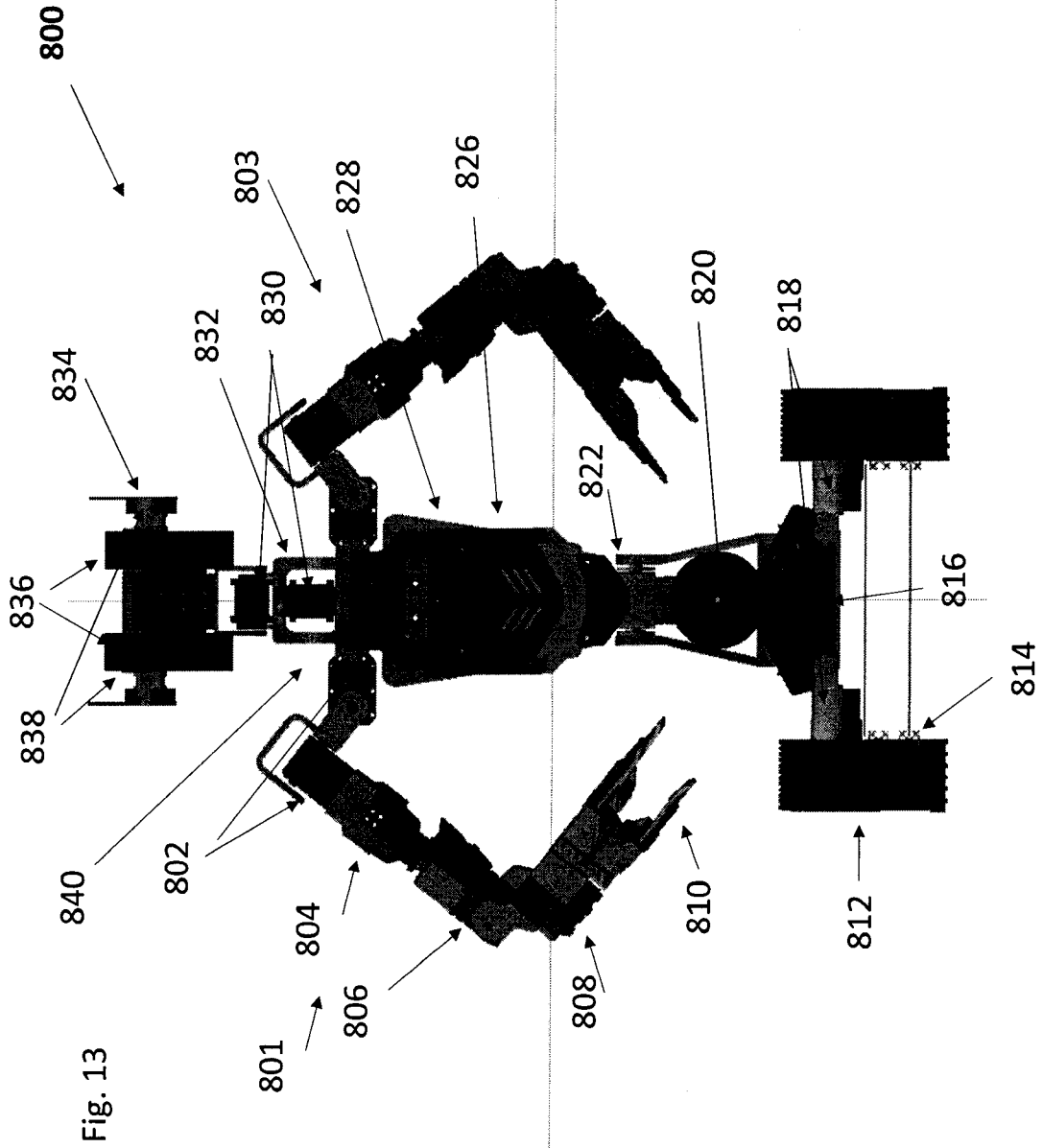


FIG. 12

+



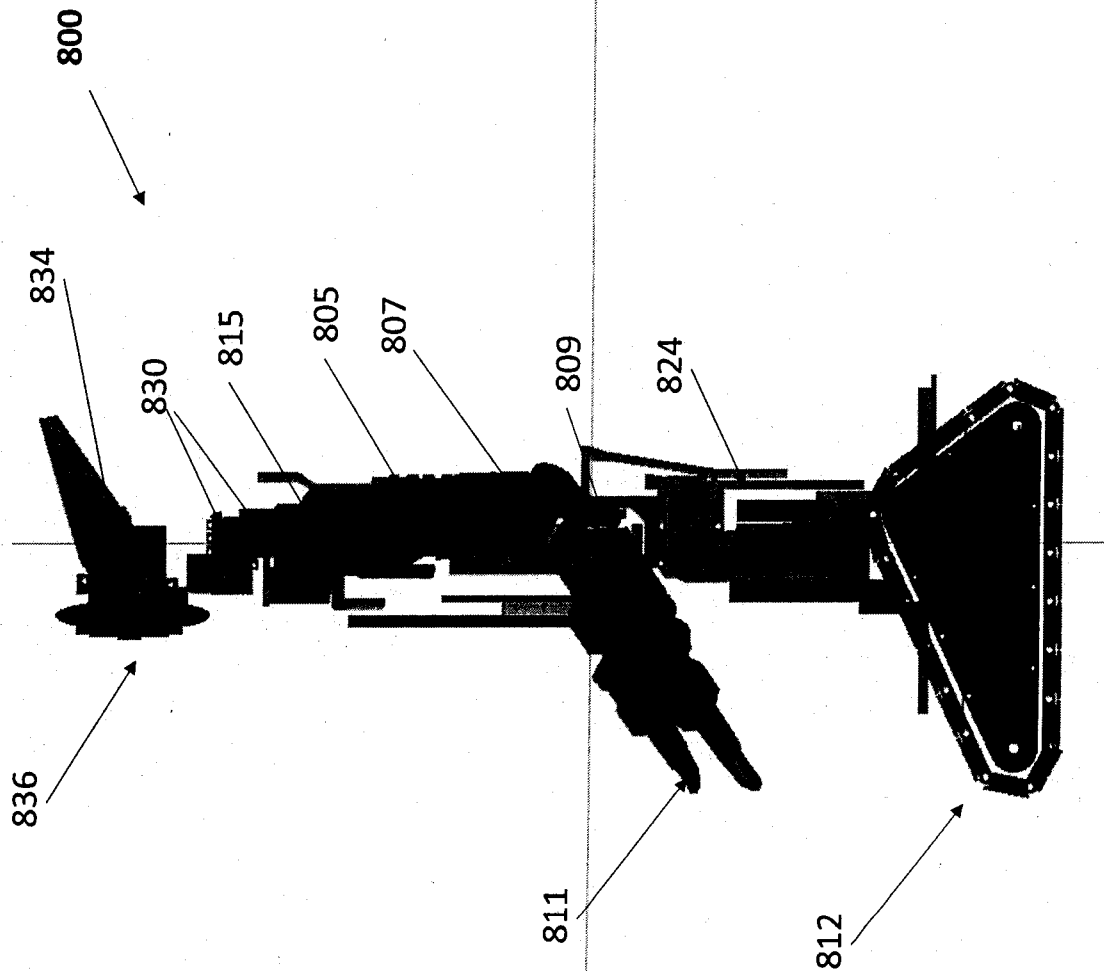


Fig. 14



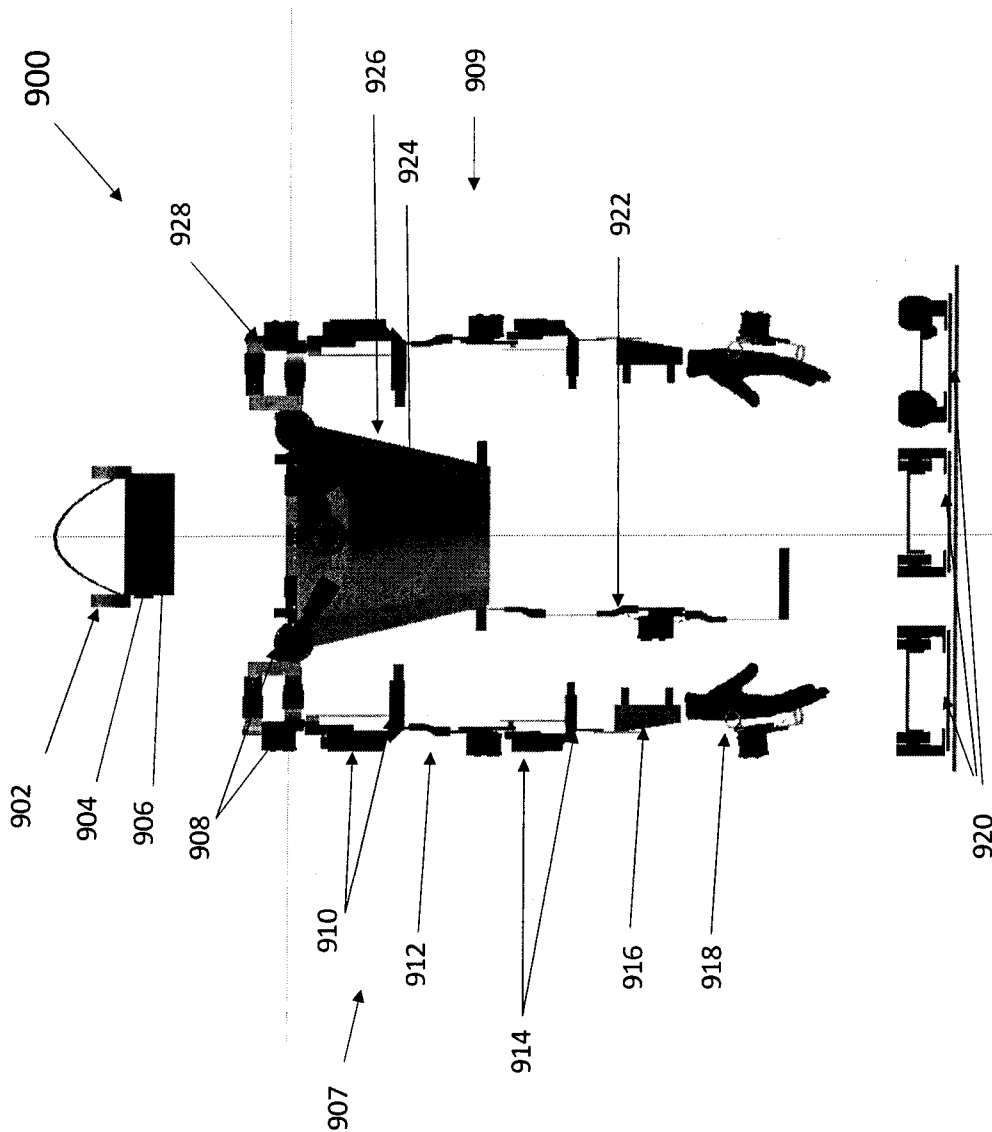


Fig. 15

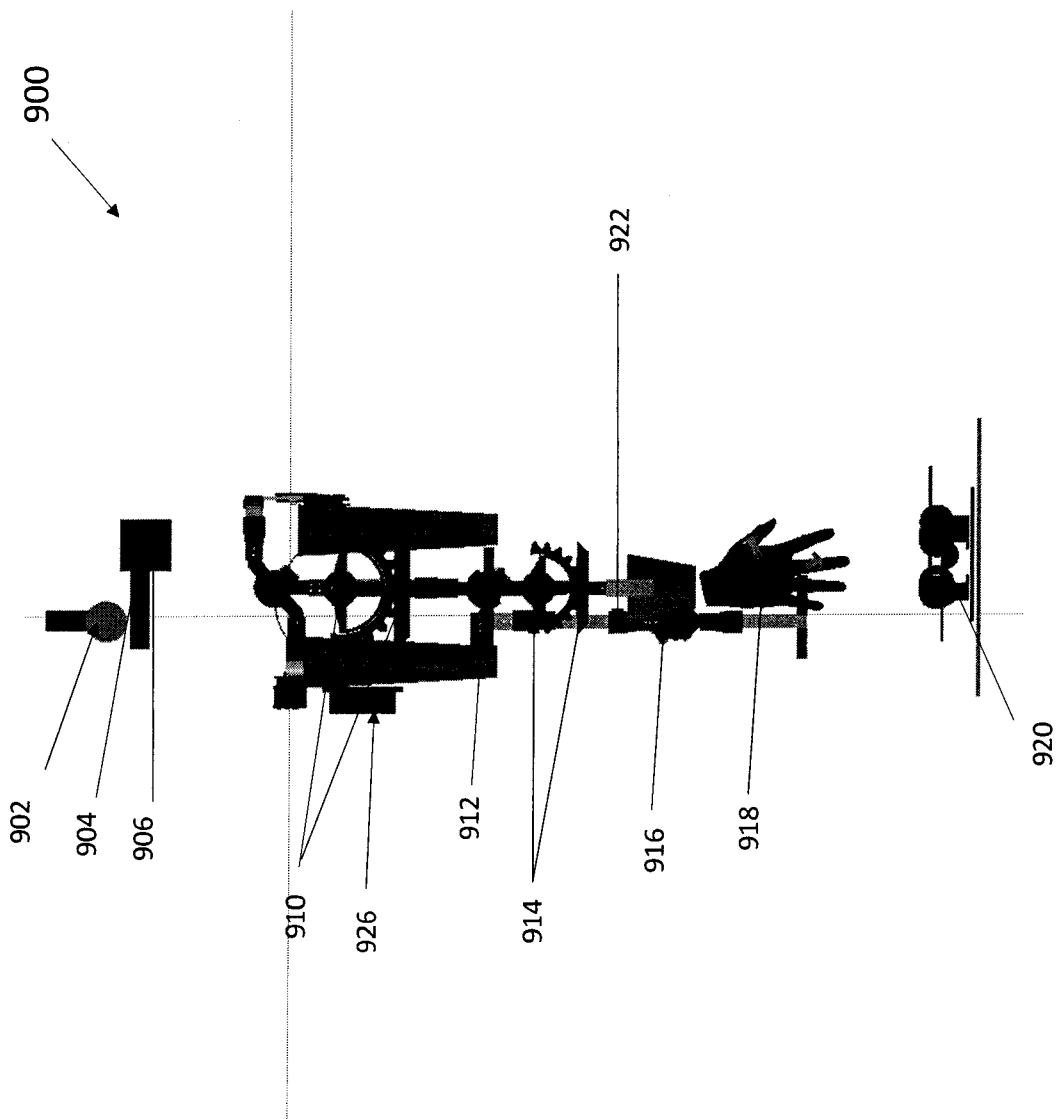


Fig. 16

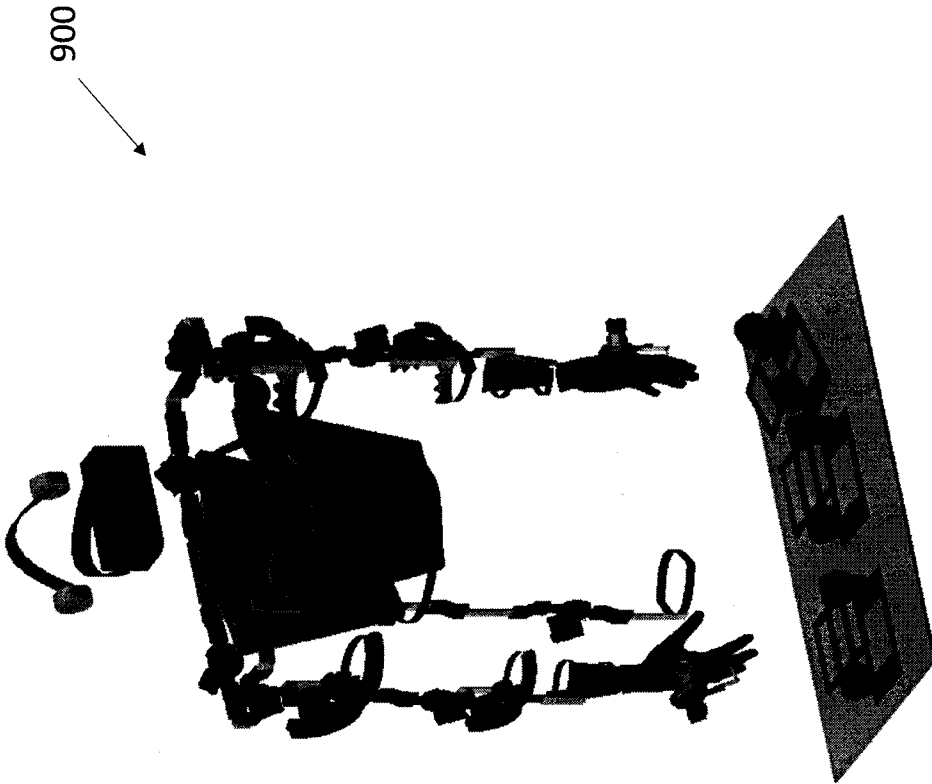


Fig. 17

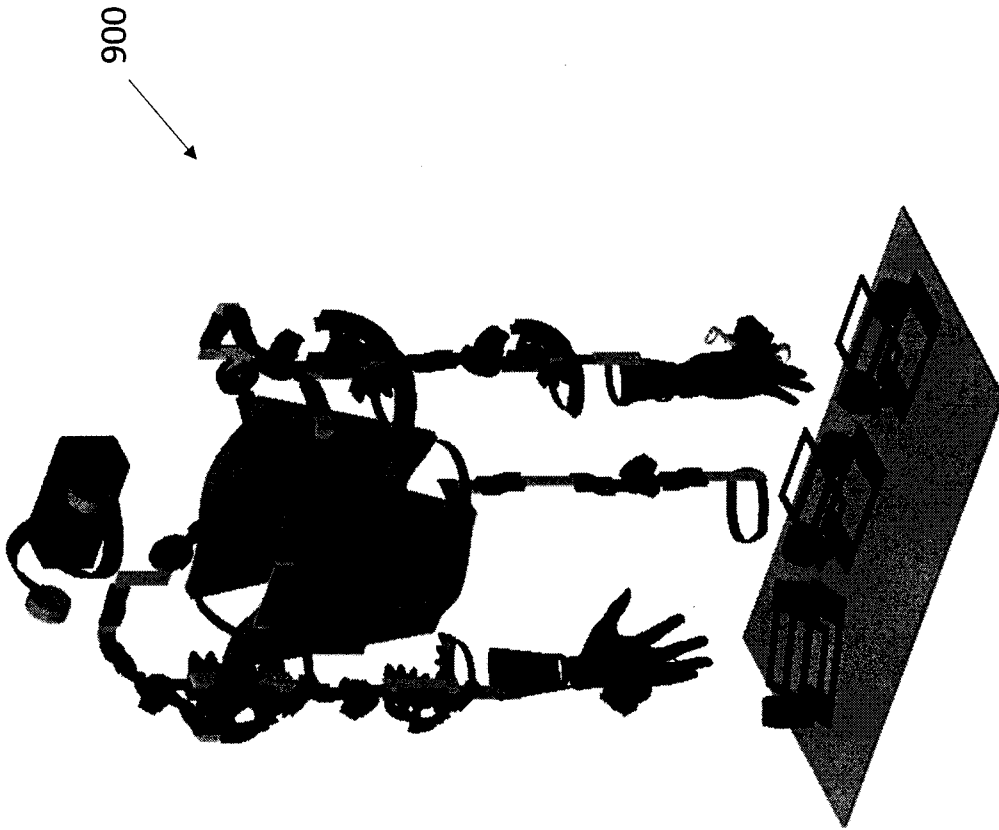


Fig. 18

10

