

- (51) **International Patent Classification:**
B25J 9/16 (2006.01) **G05B 19/423** (2006.01)
- (21) **International Application Number:**
 PCT/EP2015/057735
- (22) **International Filing Date:**
 9 April 2015 (09.04.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
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- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,

HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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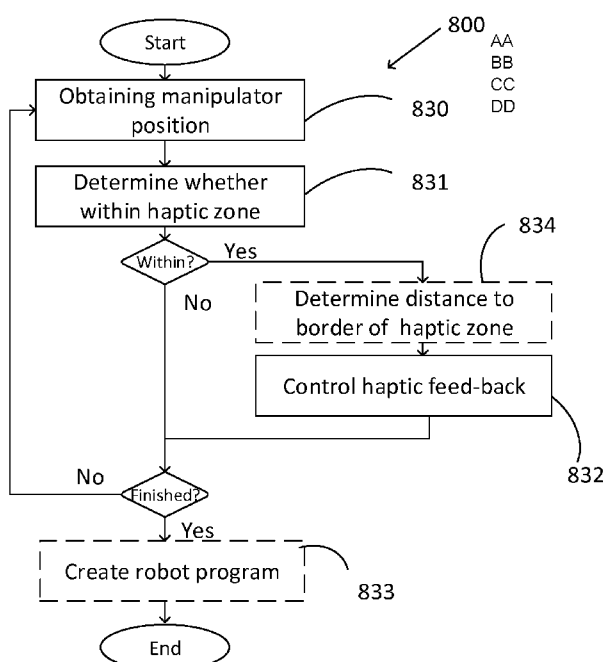
— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

- (54) **Title:** AN INDUSTRIAL ROBOT AND A METHOD FOR LEAD-THROUGH PROGRAMMING OF AN INDUSTRIAL ROBOT

Fig 8



(57) **Abstract:** The present disclosure relates to an industrial robot comprising a manipulator movable about a plurality of axes and a robot controller for controlling the movements of the manipulator. The robot controller is arranged to support manual programming of the industrial robot by means of lead-through of the manipulator while obtaining the positions of the manipulator. The robot controller is arranged to, for each obtained position of the manipulator in relation to at least one of the axes, determine whether the obtained position is within at least one pre-defined haptic zone associated to the axis and providing a haptic feed-back when determined that the obtained position is within the haptic zone. The present disclosure further relates to a method for lead-through programming of an industrial robot.

An industrial robot and a method for lead-through programming of an industrial robot

TECHNICAL FIELD

The present disclosure relates to an industrial robot comprising a manipulator movable

5 about a plurality of axes and a robot controller for controlling the movements of the manipulator, wherein the robot controller is arranged to support manual programming of the robot by means of lead-through of the manipulator while measuring the positions of the manipulator.

10 The present disclosure further relates to a method for lead-through programming of an industrial robot comprising a manipulator movable about a plurality of axes and a robot controller.

BACKGROUND

15 Traditionally, a robot controller of an industrial robot is provided with servo controllers for controlling the positions of motors driving the motion of the manipulator. Each servo controller is configured to calculate control signals to one motor arranged to drive an axis of the manipulator in at least one direction in accordance with a pre-stored program. The servo controller is configured to continuously calculate the control signals based on a position error,
20 which is determined as a difference between an actual value representing a measured position of the axis and a reference or set-point value as given by the pre-stored program. During normal operation, the gain of the servo controller is set to a high value such that the robot is stiff, preferably in all directions and orientations.

25 WO 2010/088959 discloses a method for programming an industrial robot comprising a manipulator movable about a plurality of axes and a robot controller for controlling the movements of the manipulator. The robot controller is further configured to switch between a position control mode and a floating control mode in which the manipulator has a reduced stiffness. When operating in the position control mode, the operation of the manipulator is
30 controlled in accordance with the pre-stored program. When switched to the floating control mode, wherein the manipulator has the reduced stiffness, the programming of the robot by means of lead-through of the robot is enabled or facilitated. The lead-through programming

involves manually leading the manipulator to a sequence of desired positions and recording the axis positions of the manipulator at each desired manipulator position and finally creating a robot program based on the sequence of recorded axis positions of the manipulator.

5

SUMMARY

One object with the present invention is to improve the operation of the robot when operating in a floating control mode.

10 The present disclosure relates to an industrial robot. The industrial robot comprises a manipulator movable about a plurality of axes and a robot controller for controlling the movements of the manipulator. The robot controller is arranged to support manual programming of the industrial robot by means of lead-through of the manipulator while obtaining the positions of the manipulator. The robot controller is arranged to, for each
15 obtained position of the manipulator in relation to at least one of the axes, determine whether the obtained position is within at least one pre-defined haptic zone associated to the axis. The robot controller is arranged to provide a haptic feed-back when determined that the obtained position is within the haptic zone.

20 A haptic feed-back is herein intended to have a broad meaning including any vibrational and/or resilient sensation. In line therewith, a haptic zone is intended to mean a zone wherein the operator experiences any vibrational and/or resilient sensation.

The working range for an axis may for example be limited by a mechanical stop such as a pin.

25 The mechanical stop may be such that it cannot withstand too large mechanical stresses. If introducing a haptic zone adjacent the mechanical stop, it is prevented that the mechanical stop will be damaged during manual programming of the industrial robot. Further, when operating the industrial robot according to a robot program created by the manual programming, it is ensured that the manipulator is operating such that the axis positions are
30 kept at a distance from the mechanical stops. Thus, the operation of the industrial robot can be controlled by defining the haptic zone(s). Thereby, the industrial robot can be controlled

to operate in ranges wherein there is less wear. Accordingly, maintenance of the industrial robot may be reduced.

In one option, the haptic feedback is provided by an increase in stiffness, in the axis
5 associated with the haptic zone.

In one option, the at least one pre-defined haptic zone associated to the axis is defined in relation to at least one end position of the axis.

10 In one option, the obtained position is an angular position.

In one option, the robot controller comprises for each axis a servo controller arranged to control a motor for driving the manipulator, wherein the servo controller is arranged to operate in a first mode of operation outside the haptic zone and a second mode of operation
15 within the haptic zone. When operating within the haptic zone, the servo controller may then be arranged to control the motor to provide the haptic feed-back.

When operating within the haptic zone, the servo controller has in one option an increased servo gain. Thereby, a resilient sensation is obtained.
20

When operating within the haptic zone, the servo controller has in one option as input a reference value corresponding to the border of the haptic zone. Thereby, a resilient sensation is obtained.

25 In order to further enhance the effect of obtaining a resilient sensation, when operating within the haptic zone, the servo controller has in one option a variable proportional gain value, which is increasing with the distance to the border of the haptic zone.

In one option, at least when operating within the haptic zone, the servo controller has a
30 derivative part.

In one option, the robot controller is configured to switch between a position control mode and a floating control mode in which the manipulator has a reduced stiffness in at least one of the axes, wherein in the floating control mode the manual programming of the robot is enabled by means of lead-through of the manipulator.

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In one option, the industrial robot comprises a switch arrangement for manual switch between the position control mode and the floating control mode.

The present disclosure further relates to a robot control system for control of a manipulator
10 movable about a plurality of axes. The robot control system comprises a data processing device and a memory having a computer program (P) stored thereon. The computer program comprises program code which, when executed by the data processing device causes the data processing device to repeatedly perform the following steps. A position of the manipulator in relation to at least one of the plurality of axes is obtained. Then it is
15 determined whether the obtained position is with at least one haptic zone associated to the axis. Thereafter a haptic feed-back of the manipulator is controlled when it is determined that the obtained position is with the at least one haptic zone.

The present disclosure further relates to a method for lead-through programming of an
20 industrial robot comprising a manipulator movable about a plurality of axes and a robot controller. The method comprises repeating the following steps. A manipulator position is obtained to which the manipulator has been manually moved in relation to at least one of the plurality of axes. Then, it is determined whether the obtained manipulator position is with at least one haptic zone associated to said at least one of the plurality of axes.
25 Thereafter, a haptic feed-back of the manipulator is controlled when it is determined that the obtained manipulator position is within the at least one haptic zone.

In one option, the method further comprises a step of thereupon creating a robot program based on the obtained positions of the manipulator.

30

In one option, the method further comprises a step of when determined that the obtained manipulator position is within the at least one haptic zone, determining a distance between

the obtained manipulator position and a border of the haptic zone. The haptic feed-back of the manipulator is then dependent on the distance to the border and the haptic feed-back is increasing with increased distance.

5

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure will now be described by way of examples with references to the accompanying schematic drawings, of which:

Fig. 1 illustrates one example of an industrial robot comprising a manipulator and a robot
10 controller.

Fig. 2 is a block scheme illustrating one example of a robot controller of an industrial robot.

Figs 3a and 3b are diagrams illustrating examples of servo controllers of a robot controller when operating in a floating control mode within a haptic zone.

Fig 4 is a diagram illustrating an example of a servo controller of a robot controller when
15 operating in the floating control mode outside the haptic zone.

Fig 5 illustrates one example of an operator control device of an industrial robot.

Fig 6 illustrates one example of a manipulator of an industrial robot.

Fig 7 is a block scheme illustrating one example of a robot control system for control of a manipulator.

20 Fig 8 is a flow chart illustrating one example of a method for lead-through programming of a robot.

DETAILED DESCRIPTION

Hereinafter, embodiments of the present disclosure will be described in detail with
25 reference to the accompanying drawings, wherein for the sake of clarity and understanding of the invention some details of no importance are deleted from the drawings. Moreover,

the drawings shall not be considered drawn to scale as some features may be exaggerated in order to more clearly illustrate the disclosure.

In Fig 1, an industrial robot 100 comprises a manipulator 300 movable about a plurality of
5 axes and a robot controller 200 for controlling the movements of the manipulator. The robot controller 200 is arranged to support manual programming of the robot by means of lead-through of the manipulator while obtaining the positions of the manipulator. The lead-through programming involves manually leading the manipulator to a sequence of desired positions and recording the axis positions of the manipulator at each desired manipulator
10 position. Finally, the robot controller creates a robot program based on the sequence of recorded axis positions of the manipulator. While manually programming the industrial robot, the robot controller 200 is arranged to, for each obtained position of the manipulator in relation to at least one of the axes, determine whether the obtained position is within at least one pre-defined haptic zone associated to the axis and providing a haptic feed-back
15 when determined that the obtained position is within the haptic zone.

In different embodiments, the obtained axis positions are angular positions.

The at least one pre-defined haptic zone associated to one of the axes may be defined in
20 relation to at least one end position of the axis. For example, at least one of the axes may have an angular working range from 0 to 90°. One haptic zone of this axis may then for example be in a range from 88° to 90°. Consequently, the manipulator is operated outside the haptic zone of this axis when the angular position of the axis is smaller than 88°. Further, the border of the haptic zone is at 88°. Yet further, the manipulator is operated within the
25 haptic zone of this axis when the angular position of the axis is larger than 88°. A corresponding haptic zone may be defined at the other end of the working range of the axis. In other embodiments, at least one of the axes has a working range in two or three dimensions. Then, a haptic zone may be defined for each of the dimensions at one or each end of the working range.

30

The working range may for example be limited by a mechanical stop such as a pin. The mechanical stop may be such that it cannot withstand too large mechanical stresses. When

introducing a haptic zone adjacent the mechanical stop, it is prevented that the mechanical stop will be damaged during manual programming of the industrial robot. Further, when operating the industrial robot according to the created robot program, it is ensured that the manipulator is operating such that the axis positions are kept at a distance from the mechanical stops. Thus, the operation of the industrial robot can be controlled by defining the haptic zone(s). Thereby, the robot can be controlled to operate in ranges wherein there is less wear. Accordingly, maintenance of the industrial robot may be reduced.

In different embodiments, the haptic feedback is provided by an increase in stiffness in the axis associated with the haptic zone.

The robot controller 200 may be configured to switch between a position control mode and a floating control mode in which the manipulator has a reduced stiffness in at least one of the axes. In the floating control mode the manual programming of the industrial robot as disclosed above is enabled by means of lead-through of the manipulator.

In the illustrated example, the industrial robot comprises an operator control device 500. The operator control device may comprise a switch arrangement for manual switch between the position control mode and floating control mode.

The robot controller 200 comprises in one example for each axis or each dimension a servo controller arranged to control a motor for driving the manipulator.

In Fig 2, an example of a robot controller 200 is illustrated. The robot controller is arranged to control the movements of a manipulator of an industrial robot. The robot controller comprises in one example for each axis a servo controller arranged to control a motor for driving the manipulator. In one example, the robot controller is configured to switch between a position control mode and a floating control mode in which the manipulator has a reduced stiffness in at least one of the axes. In the floating control mode the manual programming of the robot is enabled by means of lead-through of the manipulator.

The robot controller is arranged to support manual programming of the industrial robot by means of lead-through of the manipulator while obtaining axis positions of the manipulator.

The robot controller 200 comprises in accordance with this illustrated example a first module 240 configured to receive information related to manipulator positions to which a

manipulator has been manually moved in relation to at least one of a plurality of axes. The robot controller comprises further a second module 241 configured to determine whether the obtained manipulator position is within at least one haptic zone associated to said at least one of the plurality of axes. The industrial robot controller comprises further a third module 242 configured to control a haptic feed-back of the manipulator when it is

determined that the obtained manipulator position is within the at least one haptic zone associated to said at least one of the plurality of axes. In different embodiments, the third module 242 configured to control a haptic feed-back of the manipulator comprises for each axis or each dimension a servo controller arranged to control a motor so as to obtain the haptic feed-back.

The industrial robot controller comprises in the illustrated example an optional fourth module 243 for determining where in the haptic zone the obtained manipulator position associated to said at least one of the plurality of axes is. The fourth module 243 thus determines how long distance into the haptic zone said at least one of the plurality of axes has moved. In other words, the fourth module determines the distance to a border of the haptic zone for the at least one axis when the axis is in the haptic zone. The third module for providing haptic feed-back may then be configured to provide the haptic feed-back also based on the distance to the border of the haptic zone for the at least one axis.

In Figs 3a-3b and 4, a robot controller comprises for each axis, or each dimension of the axis, a servo controller 250, 250', 250'' arranged to control a motor 251 for driving the manipulator. Thus, each axis, or dimension of the axis, is connected to a servo controller 250, 250', 250'' arranged to control a corresponding motor 251. Each servo controller is arranged to operate in a first mode of operation outside the haptic zone (Fig 4) and a second mode of operation within the haptic zone (Figs 3a and 3b). When operating within the haptic zone, the servo controller is arranged to control the motor to provide the haptic feed-back.

The servo controller 250, 250', 250'' is in one example formed as a P-regulator. The servo controller 250, 250', 250'' is in one example formed as a PD-regulator. The servo controller 250, 250', 250'' is in one example formed as a PID-regulator.

- 5 The servo controller of figs 3a-3b and 4 is fed with a reference or set-point value. The reference or set-point value corresponds to a reference position of the manipulator. The reference or set-point value will be discussed more in detail below.

10 The reference or set-point value is compared to an actual output value. The actual output value corresponds to an actual position of the manipulator axis. The actual position is in one example obtained as a measured position of the motor or a measured position of the manipulator axis or a combination thereof. In one example, at least one sensor is mounted so as to obtain the actual position of the manipulator axis. The at least one sensor may be adapted to sense the position of the manipulator axis and/or the position of the motor. In
15 one example the actual manipulator axis position is obtained as a current or voltage provided by the motor 251.

An error signal e is formed based on a difference between the reference or set-point value and the actual output value. The error signal e is multiplied with a gain K_p . In the illustrated
20 examples, the error signal e is multiplied with the gain K_p in a gain element 252, 252', 252''. The servo controller 250, 250', 250'' then feeds a torque control signal TC to a drive unit 253. The drive unit 253 is configured to provide the motor 251 with current in dependence on the torque control signal TC . The torque control signal TC is based on the error signal e multiplied with the gain K_p .

25

In the illustrated embodiments, when operating within and/or outside the haptic zone, the servo controller has optionally a derivative element 254. The derivative element 254 controls speed. In the illustrated example the derivative element is operating on the actual output value. An output from the derivative element 254 is in the illustrated example
30 subtracted from the signal from the gain element 252, 252', 252''. In optional embodiments, when operating within and/or outside the haptic zone, the servo controller has optionally a speed control gain element 255 configured to provide a speed control gain K_v . In the

illustrated example, the speed control gain element 255 is in the signal path formed directly before the drive unit 253. In a not illustrated example, the speed control gain element 255 may be formed in the signal path directly after the derivative element 254.

- 5 In the illustrated embodiments of Figs 3a and 3b, when operating within the haptic zone, the servo controller 250, 250' has a reference or set-point value corresponding to the border of the haptic zone. Thus the error signal e provided to the gain element 252 represents a distance between the border of the haptic zone and the actual output value representing the actual position of the manipulator axis.

10

In the illustrated embodiments of Figs 3a and 3b, when operating within the haptic zone, the servo controller 250, 250' has an increased servo gain K_p in relation to the servo gain of the servo gain when operating outside the haptic zone. Thus the servo gain K_p of the servo gain element 252, 252' is larger than the servo gain K_p of the servo gain element 252'' when
15 operating outside the haptic zone.

In the embodiments illustrated in relation to Fig 3a, when operating in within the haptic zone, the servo controller 250' has a constant proportional gain value. Thus, the servo gain K_p value of the servo gain element 252 is constant. Thereby, the output from the servo gain
20 element 252 is proportional to the input.

In the embodiments illustrated in relation to Fig 3b, when operating in within the haptic zone, the servo controller 250' has a variable proportional gain value, which is increasing with the distance to the border of the haptic zone. Thus the servo gain K_p value of the servo
25 gain element 252' is increasing with the distance to the border of the haptic zone. In one example, the servo gain K_p value is selected such that the output from the servo gain element 252' is increasing exponentially in relation to the input.

In the illustrated embodiments of Fig 4, when operating outside the haptic zone, the servo
30 controller 250'' has a reference or set-point value which is mirroring the actual output value related to the axis position. Thus, the actual output value related to the axis position is used as the reference or set-point value. Thus the error signal e provided to the gain element 252

is characteristically aiming to be close to zero at least when operating the manipulator slowly.

In the illustrated embodiments of Fig 4, when operating outside the haptic zone the servo controller has optionally a servo gain K_p of the servo gain element 252'' close to zero.

In using the servo controller 250, 250', 250'' when acting outside the haptic zone(s), the manipulator is made compliant and easy to move by hand. It is easy to move the manipulator along a desired path. The programmer can grasp a tool of the manipulator and lead the tool to desired positions and with desired orientations. The programmer may push or pull any part of the manipulator in order to move the tool to the desired position. When the programmer stops the movement, the manipulator will stay in the desired position, since there is no resilience outside the haptic zone(s). When however, one of the manipulator axes reaches a border of a haptic zone, the reference or set-point value is altered to be the value of the border of the haptic zone. Further, the servo gain K_p is set to a value substantially higher than outside the haptic zone. The servo gain K_p is set to a value such that the manipulator becomes resilient when entering the haptic zone. This may be even more enhanced by making the servo gain variable and increasing as the manipulator axis moves longer into the haptic zone. In one example the servo gain is dependent on the direction of movement of the position of the manipulator axis.

In Fig 5, an example of an operator control device 500 for a robot controller is illustrated. The operator control device 500 is for example a portable operator control device. A robot operator uses the operator control device for manually controlling the robot, for example to jog the robot. The operator control device may also be used for monitoring robot program, changing certain variables in the program, starting, stopping and editing the program.

The operator control device 500 comprises operator control means, for example a joystick 512 and/or a set of buttons 511. The operator control device comprises further in the illustrated example a visual display unit 510. The operator control device comprises in the illustrated example safe equipment 513. The operator control device is connected to the robot controller either via a cable or wirelessly.

The operator control device 500 comprises in the illustrated example a switch arrangement 514 for manual switch between the position control mode and the floating control mode.

Thus, the switch arrangement 514 is configured to be operated by an operator for switching the robot controller between the position control mode and the floating control mode. In

5 this embodiment the switch arrangement 514 is arranged on the operator control device in the form of a pushbutton. Alternatively, the switch arrangement may be provided on the manipulator. Alternatively, the switch arrangement can be a soft button displayed on the display unit 510, or as an alternative on a menu displayed on the display unit 510.

10 In one example, the operator control device makes it possible for a user to select in which axes, or dimensions of the axes, the manipulator shall be stiff and in which axes the manipulator shall be soft when the robot is in the floating control mode. By the axes of the manipulator are meant the rotational axes of the manipulator.

15 For example, when the user operates the switch arrangement 514 so that the robot controller is switched to the floating control mode, a menu is displayed on the display unit 510 showing options regarding in which axes the manipulator shall be soft in the floating control mode.

20 In an alternative embodiment, all axes of the manipulator are displayed on the display unit 510 and it is possible to select which axes to be soft in the floating control mode. Further it is possible to select haptic zones for the axis which are soft in the floating control mode.

Information related to the selected axes is transferred from operator control device to the robot controller. The information may comprise information related to which axes are soft in
25 the floating control mode and possible haptic zones associated to the soft axes.

In one embodiment of the invention, the manipulator is provided with a device (not shown) for generating information on in which direction a programmer intends to move the manipulator during programming of the robot. The device is, for example, a set of buttons
30 each representing a Cartesian direction or orientation, or a handgrip unit including a sensor sensing directions of forces or torques from a user. The device is, for example, a space mouse sensing forces in three degrees of freedom and torques in three degrees of freedom.

The device is in communication with the robot controller and transfers information on the intended direction to the robot controller. The device is to be used when programming a heavy robot having large static friction. For small and medium sized manipulators it might not be necessary to use the device. The device can be mounted anywhere on the

manipulator.

In Fig 6, an example of a manipulator 300 is illustrated. The manipulator is movable about a plurality of axes. In the illustrated example, the manipulator 300 has three main axes and three wrist axes. The manipulator comprises a stationary foot 601, usually referred to as the base of the robot. The base 601 supports a stand 602, which is rotatable about a first axis (not shown). A first arm 603 is rotatable mounted to the stand 602. The first arm 603 is in the example rotatable about a second axis 607. A second arm 604 is rotatable mounted to the first arm 603. The second arm 603 is in the example rotatable about a third axis 606. The second arm 604 supports a wrist unit 605. The wrist unit 605 is rotatable about a fourth, a fifth and a sixth axis 608. The wrist supports a tool 609, or a work object, in which an operating point, called TCP (tool centre point) may be defined. A robot path of the operating point is to be programmed.

When operating in position control mode the manipulator is stiff in all axes. When operating in the floating control mode the manipulator is soft, i.e. has a low stiffness, in at least one of the axes. The position control mode is the default mode used during normal operation of the robot. In the following the term soft is used synonymously with having a reduced stiffness.

In Fig 7, a robot control system 700 for control of a manipulator movable about a plurality of axes is illustrated. The robot control system 700 comprises a data processing device 720 and a memory 721 having a computer program stored thereon. The computer program comprises program code which, when executed by the data processing device 720, causes the data processing device 720 to repeatedly perform the following steps. The position of the manipulator in relation to at least one of the plurality of axes is obtained. The robot control system receives the obtained position from the manipulator via manipulator interface 722, if the robot control system is not integrated with the manipulator. The data processing device then determines whether the obtained position is within at least one haptic zone associated to the axis. The data processing device then controls a haptic feed-

back of the manipulator when it is determined that the obtained position is within the at least one haptic zone. Signals for control of the haptic feed-back are in one example wherein the robot control system is not integrated with the manipulator transferred to the manipulator via the manipulator interface 722. The robot control system further comprises an operator interface 723 for communication with an operator control device. Examples of operator control devices are disclosed in relation to fig 5.

In fig 8, a method 800 for lead-through programming of an industrial robot comprising a manipulator movable about a plurality of axes and a robot controller is illustrated. The method comprises a step of measuring 830 a manipulator position to which the manipulator has been manually moved in relation to at least one of the plurality of axes. The method further comprises a step of determining 831 whether the obtained manipulator position is with at least one haptic zone associated to said at least one of the plurality of axes. The method further comprises a step of controlling 832 a haptic feed-back of the manipulator when it is determined that the obtained manipulator position is within the at least one haptic zone.

In the illustrated example, the method further comprises a step of thereupon creating 833 a robot program based on the obtained positions of the manipulator.

In one optional example, when determined 831 that the obtained manipulator position is within the at least one haptic zone, the method comprises further a step of determining 834 a distance between the obtained manipulator position and a border of the haptic zone, wherein the haptic feed-back of the manipulator is dependent on the distance to the border and wherein the haptic feed-back is increasing with increased distance.

CLAIMS

1. An industrial robot (100) comprising
 - a manipulator (300) movable about a plurality of axes and
 - a robot controller (200) for controlling the movements of the manipulator, wherein

5 the robot controller is arranged to support manual programming of the industrial robot by means of lead-through of the manipulator while obtaining the positions of the manipulator and wherein the robot controller is arranged to, for each obtained position of the manipulator in relation to at least one of the axes, determine whether the obtained position is within at least one pre-defined haptic zone associated to the

10 axis and providing a haptic feed-back when determined that the obtained position is within the haptic zone.
2. An industrial robot (100) according to claim 1, wherein the at least one pre-defined haptic zone associated to the axis is defined in relation to at least one end position of
- 15 the axis.
3. An industrial robot (100) according to any of the preceding claims, wherein the obtained position is an angular position.
- 20 4. An industrial robot according to any of the preceding claims, wherein the robot controller (200) comprises for each axis a servo controller (250, 250', 250'') arranged to control a motor (251) for driving the manipulator, wherein the servo controller (250, 250', 250'') is arranged to operate in a first mode of operation outside the haptic zone and a second mode of operation within the haptic zone.
- 25 5. An industrial robot according to claim 4, wherein when operating within the haptic zone, the servo controller is arranged to control the motor to provide the haptic feed-back.
- 30 6. An industrial robot according to claim 4 or 5, wherein when operating within the haptic zone, the servo controller has an increased servo gain.

7. An industrial robot according to any of the claims 4-6, wherein when operating within the haptic zone, the servo controller has as input a reference value corresponding to the border of the haptic zone.
- 5 8. An industrial robot according to any of the claims 4-7, wherein when operating in within the haptic zone, the servo controller has a variable proportional gain value, which is increasing with the distance to the border of the haptic zone.
9. An industrial robot according to any of the claims 4 to 8, wherein at least when
10 operating within the haptic zone, the servo controller has a derivative part.
10. An industrial robot according to any of the preceding claims, wherein the haptic
feedback is provided by an increase in stiffness, in the axis associated with the haptic
zone.
- 15 11. An industrial robot according to any of the preceding claims, wherein the robot
controller is configured to switch between a position control mode and a floating
control mode in which the manipulator has a reduced stiffness in at least one of the
axes, wherein in the floating control mode the manual programming of the robot is
20 enabled by means of lead-through of the manipulator.
12. An industrial robot according to claim 11, further comprising a switch arrangement
(514) for manual switch between the position control mode and the floating control
mode.
- 25 13. A robot control system (700) for control of a manipulator (300) movable about a
plurality of axes, said robot control system comprising a data processing device (720)
and a memory (721) having a computer program (P) stored thereon, the computer
program comprising program code which, when executed by the data processing
30 device (720), causes the data processing device (720) to repeatedly perform the steps
of

- obtaining a position of the manipulator in relation to at least one of the plurality of axes,
- determining whether the obtained position is with at least one haptic zone associated to the axis, and
- 5 - controlling a haptic feed-back of the manipulator when it is determined that the obtained position is with the at least one haptic zone.

14. A method (800) for lead-through programming of an industrial robot comprising a manipulator movable about a plurality of axes and a robot controller, said method
10 comprising repeating the steps of

- obtaining (830) a manipulator position to which the manipulator has been manually moved in relation to at least one of the plurality of axes,
- determining (831) whether the obtained manipulator position is with at least one haptic zone associated to said at least one of the plurality of axes, and
- 15 -controlling (832) a haptic feed-back of the manipulator when it is determined that the obtained manipulator position is within the at least one haptic zone.

15. A method according to claim 14, further comprising a step of thereupon creating (833) a robot program based on the obtained positions of the manipulator.

20 16. A method according to claim 14 or 15, further comprising a step of when determined that the obtained manipulator position is within the at least one haptic zone, determining (834) a distance between the obtained manipulator position and a border of the haptic zone, wherein the haptic feed-back of the manipulator is
25 dependent on the distance to the border and wherein the haptic feed-back is increasing with increased distance.

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Fig 1

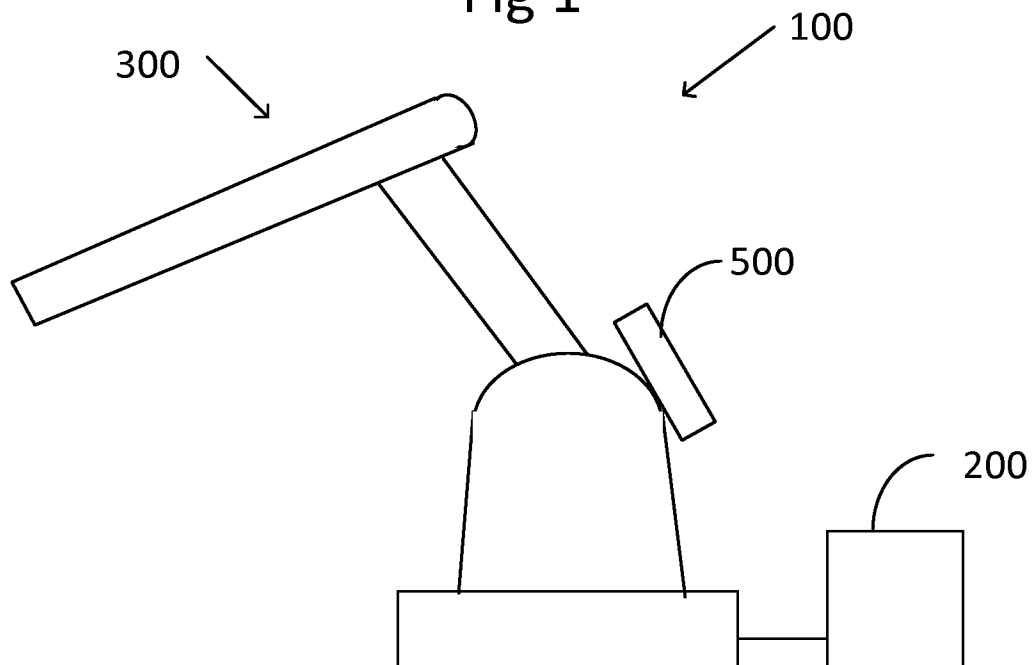


Fig 2

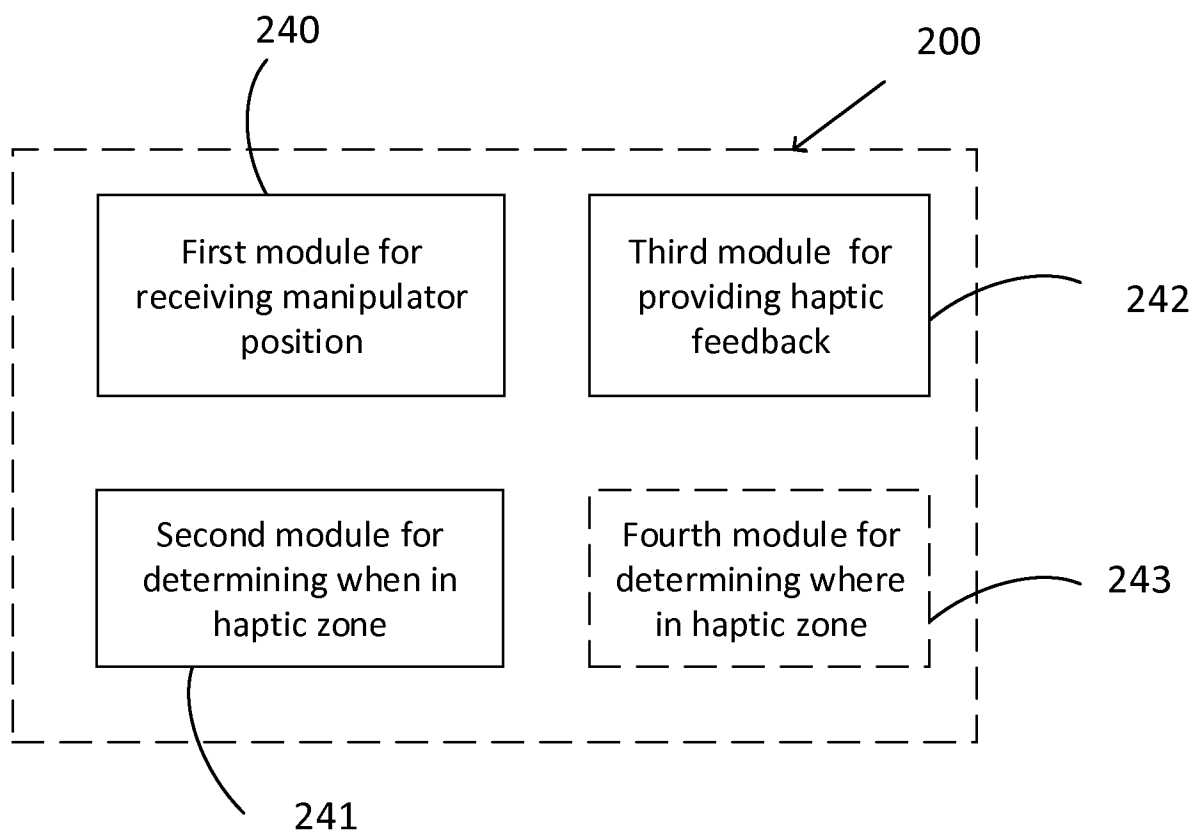


Fig 3a

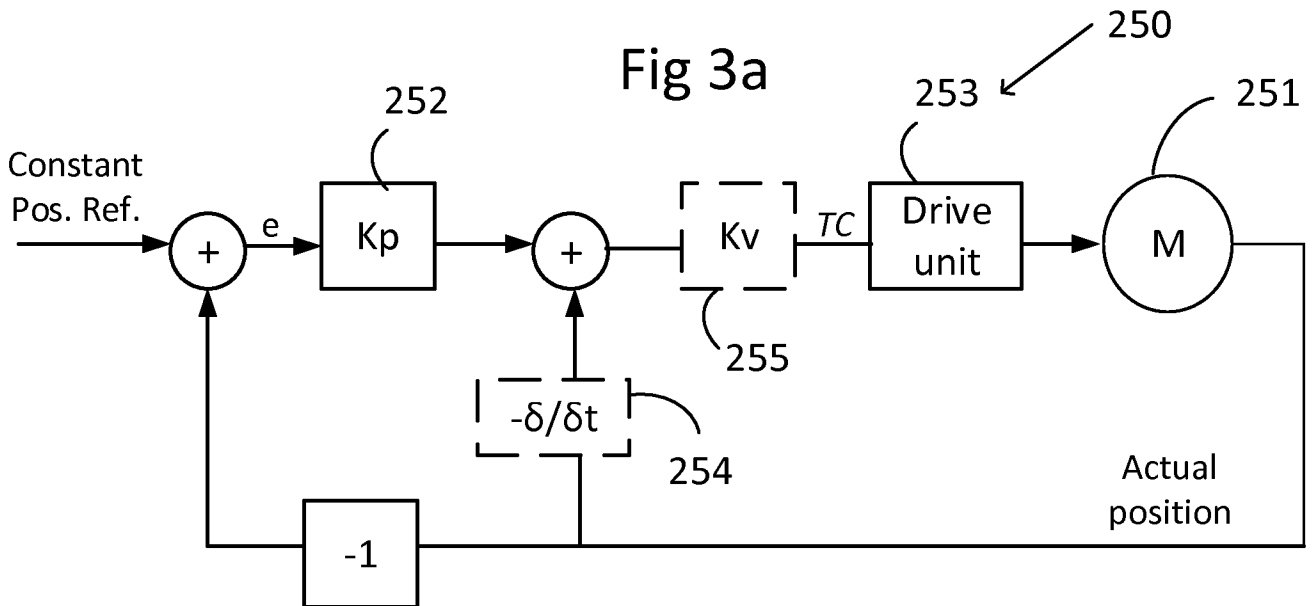


Fig 3b

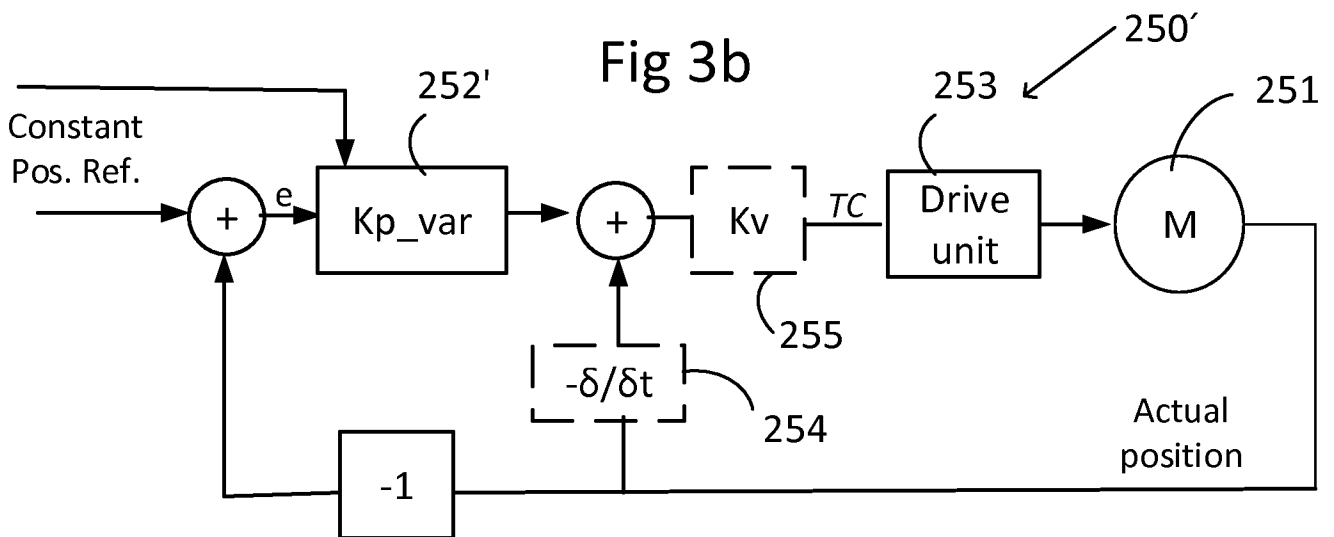


Fig 4

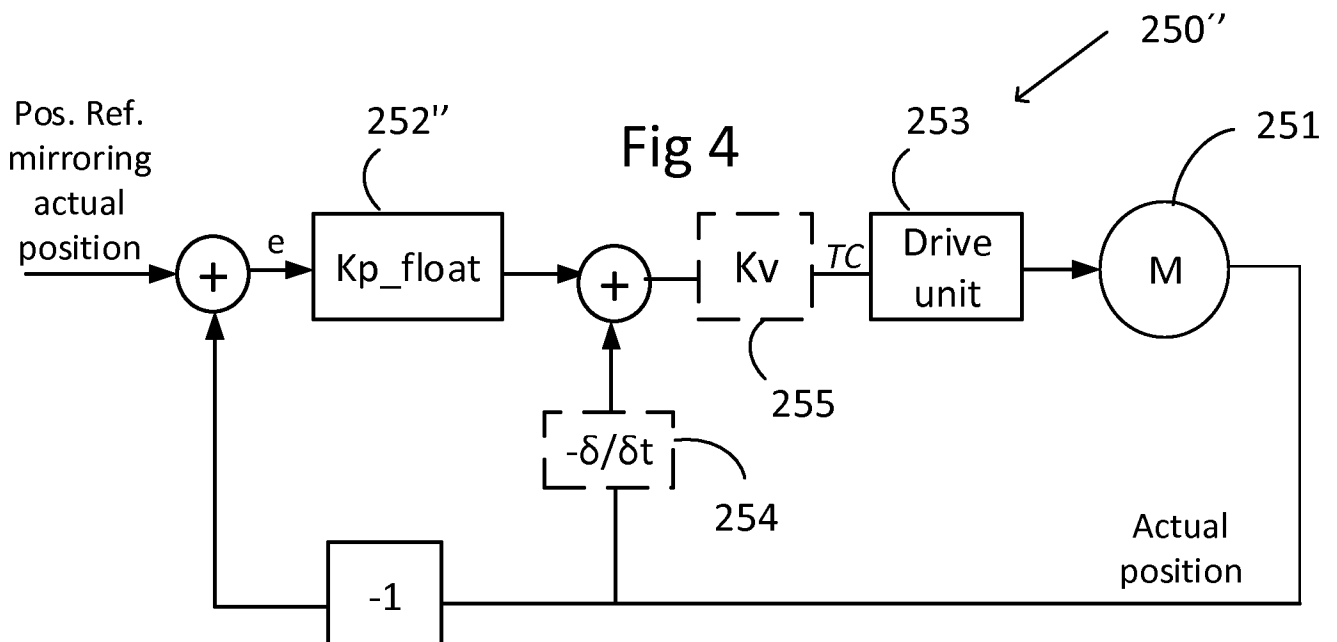


Fig 5

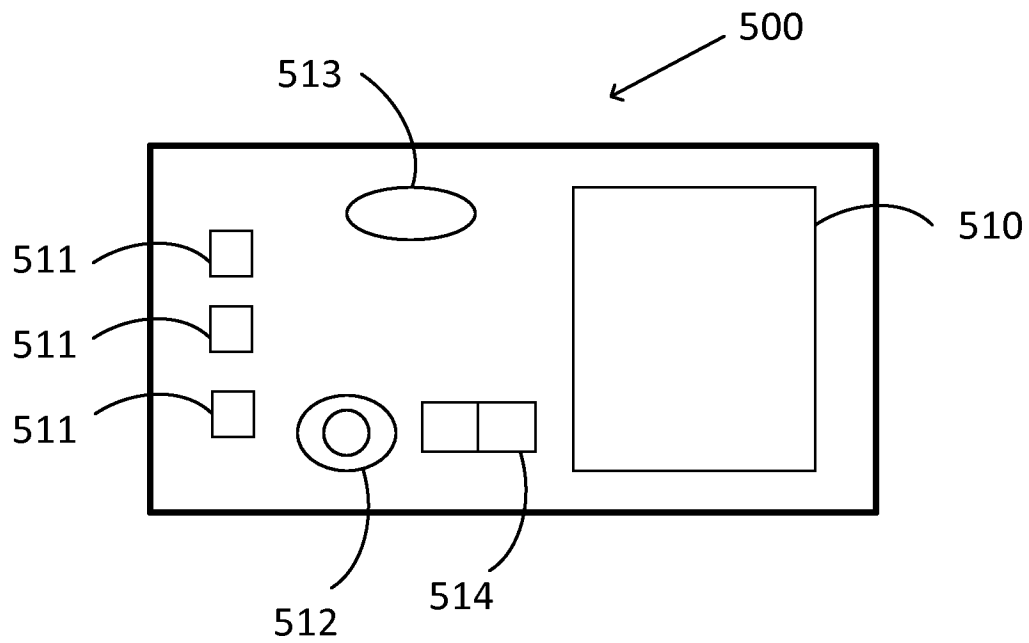
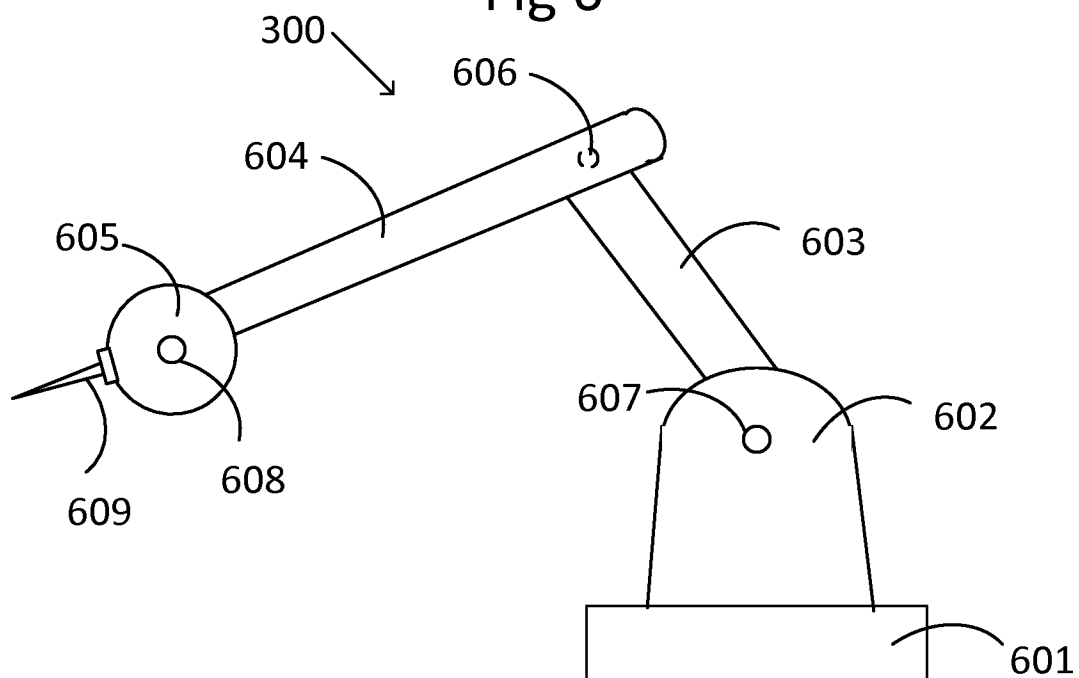
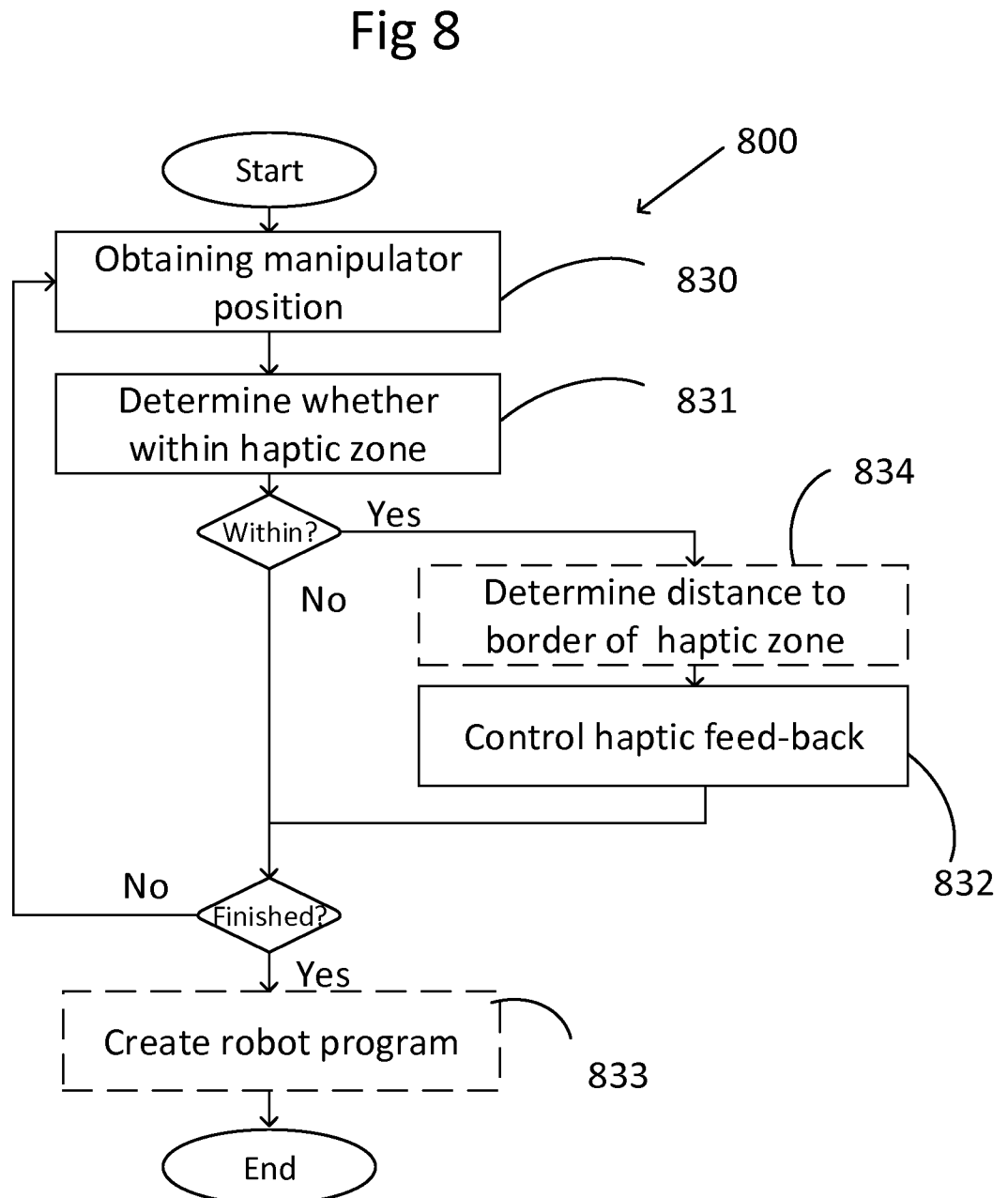
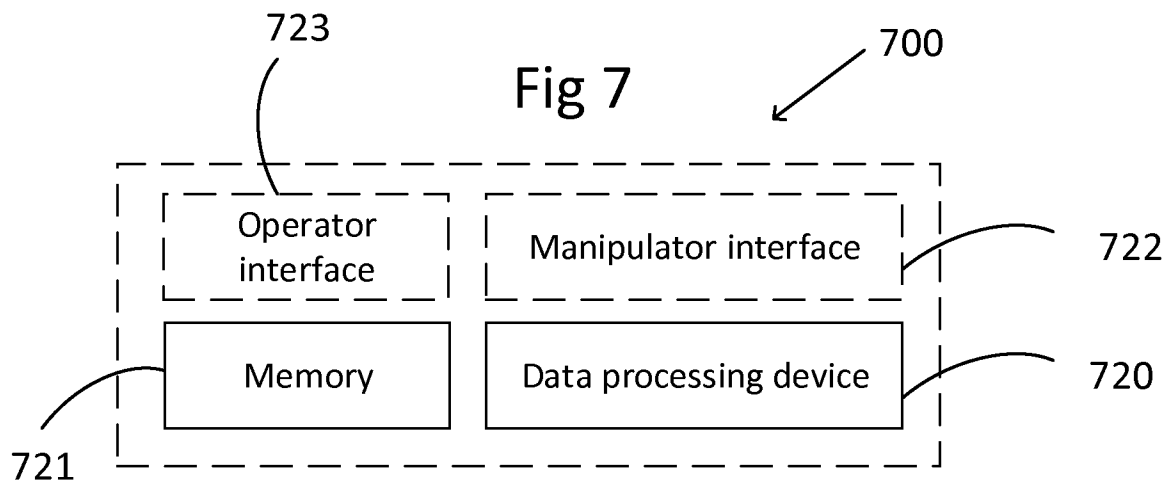


Fig 6



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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/057735

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25J9/16 G05B19/423
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B25J G05B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2011 206886 A (YASKAWA ELECTRIC CORP) 20 October 2011 (2011-10-20) paragraphs [0001] - [0012], [0031] - [0053] -----	1-16
X	US 2007/120512 A1 (ALBU-SCHAFER ALIN [DE] ET AL) 31 May 2007 (2007-05-31) paragraphs [0007] - [0019] -----	1,3-5, 10,11, 13-16
A	WO 2011/153569 A1 (KEBA AG [AT]; MITTERMAYER CHRISTOPH [AT]) 15 December 2011 (2011-12-15) page 11, line 20 - page 21, line 27 ----- -/--	1-16



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See patent family annex.

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Date of the actual completion of the international search

4 December 2015

Date of mailing of the international search report

15/12/2015

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/057735

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 02/060653 A2 (ACROBOT COMPANY LTD [GB]; HARRIS SIMON JAMES [GB]; DAVIES BRIAN LAWREN) 8 August 2002 (2002-08-08) page 8, line 21 - page 11, line 11 page 19, line 5 - page 38, line 5 -----	1-16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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