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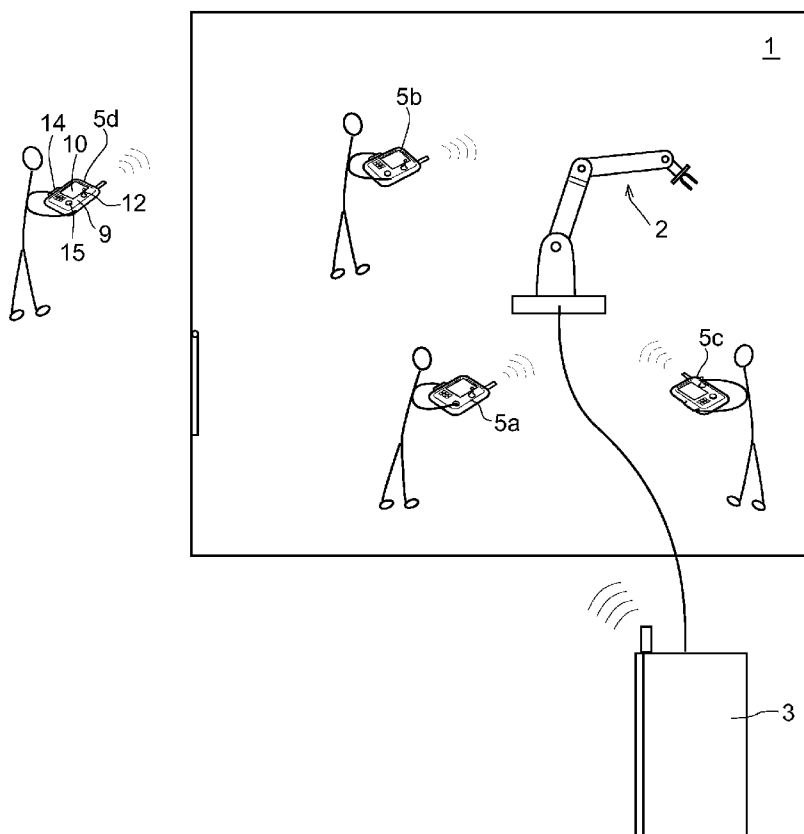
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(54) Title: AN INDUSTRIAL ROBOT SYSTEM WITH MORE THAN ONE TPU



(57) Abstract: An industrial robot system comprising an industrial robot including a manipulator (2) and a control unit (3) for controlling the manipulator, and a plurality of portable operator control devices (5a-d), called TPUs, for manually operating the robot. Each TPU comprises a manually operated enabling device (14), which upon activation enables manual movement of the robot by the TPU. The control unit comprises a safety system, which upon connection enables the enabling device of the TPU. The system is adapted to simultaneously connect the TPUs to the safety system of the control unit. One of the TPUs, called a Master TPU, is given a master authority. The control unit receives information from all TPUs about whether the enabling device of the TPU is activated or deactivated, and permits manual movement of the robot by the Master TPU if the received information indicates that the enabling devices for all TPUs connected to the safety system are simultaneously activated. The system does not permit manual movement of the robot by any other TPU than the Master TPU.

5 **AN INDUSTRIAL ROBOT SYSTEM WITH MORE THAN ONE TPU**

FIELD OF THE INVENTION

10 The present invention relates to an industrial robot system including an industrial robot comprising at least one manipulator and a control unit for controlling the manipulator, and at least two portable operator control devices, called TPU:s. The invention also relates to a method for controlling such a robot system.

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PRIOR ART

20 An industrial robot is programmed to carry out work along an operating path. In order to program or teach the robot the work, the robot is manipulated to positions along the desired operating path. These positions are stored as instructions in a memory in the control unit. During operation of the robot, the program instructions are executed, thereby making the robot operate as desired.

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30 The person controlling a robot is denoted an operator. In the following the words user and operator are used synonymously. An industrial robot can be operated in different operation modes. For example, when the robot is put in manual operation mode, the robot is controlled by means of a portable operator control device, generally denoted a Teach Pendant Unit, and called hereafter a TPU. The TPU is used for manually controlling the robot, for example to teach or program the robot to follow an operating path. The TPU may also be used for monitoring the robot program, changing certain variables in the program, starting, stopping and editing the program. When the robot is

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switched to automatic mode, it is no longer possible to manually move the robot with the joystick. However, it is still possible to start and stop the robot program.

- 5 A TPU comprises operator control means, for example a joystick, a ball, a set of buttons or any combination thereof, a visual display unit, and safety equipment for protecting a user against injury during manual control of the robot, such as an enabling device and a stop device, for example an emergency
10 stop button, or a conditional stop button. The enabling device is for example a switch or a push button, which has to be pressed by the operator to enable manual control of the robot by the TPU. For safety reasons the TPU normally is provided with either an emergency stop button, which makes it possible for the
15 operator to unconditionally stop the robot at any time by pushing the button, or a conditional stop button, which makes it possible for the operator to conditionally stop the robot. The TPU is either wirelessly or physically connected to the control unit through a cable. If the TPU is wirelessly connected to the control
20 unit, the TPU communicates with the control unit via a data link.

- During a login procedure the operator is logged in to the control unit of the robot and the TPU is connected to the control unit.
25 Further, the TPU is connected to the safety system of the robot. To connect the TPU to the safety system of the robot includes activating the enabling function of the robot, which means to put the enabling device of the TPU into function. Thus, when the enabling function is activated, the enabling device of the TPU is
30 enabled and it is possible to move the robot, for example by means of the joystick, when the enabling button of the TPU is pressed.

- To connect the TPU to the safety system of the robot also includes
35 activating the emergency stop function of the robot, which for example means to put the emergency stop button of

the TPU into function for the robot. When the emergency stop function of the TPU is activated, the emergency stop button of the TPU is enabled and it is possible to emergency stop the robot by pushing the emergency stop button. If the emergency stop function of the TPU is deactivated the emergency stop button of the TPU is disabled and nothing happens when the emergency stop button is pressed.

When the operator no longer desires to control the robot, he has to disconnect the TPU from the control unit of the robot by sending a logout order from the TPU to the control unit. The logout order logs out the operator from the control unit and deactivates the safety system of the TPU, which means that the safety equipment of the TPU is disabled.

For security reasons the manipulator is often placed into a robot cell. The robot cell is usually an enclosed area, for example a fence having a gate encloses the robot cell. The safety regulation for the robot specifies that the TPU must be connected to the safety system of the robot when the TPU is inside the robot cell, and to avoid accidents and unintended emergency stops of the robot, the safety equipment of the TPU should be out of function as long as the TPU is outside the robot cell.

Sometimes it is necessary to be more than one user in the cell at the same time. If only one TPU is present in the robot cell, it is only the user with the TPU who has control over the robot and thus over what is happening in the cell. This could be very dangerous for the other users present in the cell. For example, if the user is testing a robot installation it can be very dangerous for the other users to be in the cell because of movements of the mechanical arms of the robot.

OBJECTS AND SUMMARY OF THE INVENTION

The object of the present invention is to improve the safety in a robot cell when more than one person is present in the cell at the same time.

According to one aspect of the invention this object is achieved with an industrial robot system as defined in claim 1.

10 According to the invention the robot system comprises an industrial robot including at least one manipulator and a control unit for controlling the manipulator, and at least two TPU:s, which are adapted to be simultaneously connected to the safety system of the control unit and one of the TPU:s is a Master TPU,
15 and the control unit is adapted to receive information from all TPU:s, which are simultaneously connected to the safety system, about whether the enabling device of the TPU is activated or deactivated, to permit manual movement of the robot by the Master TPU, if the received information indicates that the enabling devices for all TPU's connected to the safety system are
20 simultaneously activated, to not permit manual movement of the Master TPU if the information received indicates that at least one of the enabling devices is deactivated, and to not permit manual movement of the robot by any other TPU than the Master TPU.
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The invention makes it possible for two or more TPU:s to be simultaneously connected to the safety system of the robot control unit. This means that all users in the robot cell could be provided with a TPU connected to the safety system. To increase
30 the safety, only one user is the master and is allowed to move the robot. The other users are not allowed to move the robot, only to affect the safety system. To allow any movement of the robot, all users in the cell must simultaneously activate the enabling device, for example by pressing the enabling button. If one
35 of the users releases the enabling button, i.e. deactivate the

enabling device; the Master TPU is no longer allowed to move the manipulator. Accordingly, the safety for the other users in the cell is increased.

- 5 The number of TPU:s simultaneously connected to the control unit may vary from time to time, in dependence on the number of users in the robot cell. Of course, the system also allows one TPU having master authority to be alone in the cell, and to control the movement of the manipulator, independent of any other
10 TPU.

Preferably, the control unit is adapted to receive information from one or more of the TPU:s about which of the simultaneously connected TPU:s has the master authority and accordingly
15 is the Master TPU. Thus, it is possible for the users to decide which of the TPU:s is to be the Master TPU. For example, which of the TPU:s in the cell is to be Master TPU could be negotiated at login to the control unit. Alternatively, it is decided beforehand which TPU is the Master TPU and this information is previously
20 stored in the control unit.

According to an embodiment of the invention, the safety equipment comprises an emergency stop device and the control unit is adapted to receive information of from all TPU:s, which are
25 simultaneously connected to the safety system, about whether the emergency stop device of the TPU is activated or deactivated, and to emergency stop the robot, if the received information indicates that the emergency stop device of at least one of the TPU's, connected to the safety system, is activated. This
30 embodiment further increases the safety in a cell with more than one user, since it makes it possible to provide all the users with a TPU having an functioning emergency stop device, which works independently of the emergency stop devices of the other TPU:s. Thus, it is possible for all the users in the cell to emergency
35 stop the robot.

According to an embodiment of the invention, the control unit is adapted to upon order change authorities between the TPU:s, so that the Master TPU does no longer have a master authority and another of the TPU:s connected to the safety system instead becomes the Master TPU and have the master authority. In some situations it is a desire to switch the manual control of the robot to another user in the cell. This embodiment makes it possible to change authorities between the TPU:s so that another of the TPU:s in the cell instead becomes the Master TPU.

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According to an embodiment of the invention, the system allows TPU:s connected to the safety system to be assigned at least two different levels of authority, wherein the highest level of authority is a master authority. For example, the master authority allows the user to start and stop a robot program, and to move the robot by means of the joystick. For example, a second level of authority allows the user to view data, but not to control the robot. Due to the connection to the safety system, the safety equipment of the TPU is enabled and thereby the enabling device and the emergency stop device are in function.

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According to an embodiment of the invention, the system is adapted to allow a remote TPU to be connected to the control unit, but not to the safety system. The remote TPU is assigned a third level of authority. When a TPU is connected to the control unit, it is to be understood that a communication link is established between the TPU and the control unit. For example, the third level of authority may allow the user to communicate with the control unit and to view data from the control unit, but not to control the movements of robot, or to affect the safety system. This embodiment makes it possible to connect a TPU located outside the robot cell to the control unit and allows the user of the TPU to view data from the control unit. However, for safety reasons, the remote TPU is not allowed to affect the movements of the manipulator, to emergency stop the robot, or to enable or disable movement of the manipulator. It would be very danger-

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ous if a TPU located outside the robot cell were allowed to control the movements of the manipulator if there are other users inside the robot cell.

5 According to an embodiment of the invention, the control unit is adapted to check whether a move command, received from one of the TPU:s, is issued by the Master TPU, and to move the robot according to the move instruction if the move command is issued by the Master TPU, and to not move the robot if the move
10 command is issued by a TPU which is not the Master TPU. In order to improve the safety, each received move command is checked to find out whether it was issued by the Master TPU or not. If a move command is not issued by the Master TPU, the command is not executed.

15 According to an embodiment of the invention, the control unit comprises a storage area for storing the identity and authority of the TPU:s and the control unit is adapted to receive and store information about the identity and authority from each TPU connected to the control unit. Preferably, the control system is
20 adapted to store the new authorities of the TPU:s in the storage area, upon the order to change the authorities between the TPU:s. Thus, the control unit will always have an updated authority matrix, which makes it easy keep track on which TPU:s
25 are connected to the control unit at the moment and the authorities of the connected TPU:s.

According to an embodiment of the invention, the control unit is adapted to receive move commands from the TPU:s, wherein
30 each move command includes information about the identity of the TPU that issued the move command, to check whether the identity, included in the move command, is equal to the stored identity of the Master TPU, and to move the robot according to the move instruction if the identity included in the move command is equal to the identity of the Master TPU, and to not move
35 the robot if the identity included in the move command is not

equal to the identity of the Master TPU. Each move command issued by a TPU should contain the identity of the TPU, and the control unit checks whether a move command received from one of the TPU:s, is issued by the Master TPU, by comparing the
5 identity contained in the received move command with the identity of the Master TPU stored in the authority matrix.

The invention is applicable for TPU:s, which are physically connected to the control unit by means of cables as well as for wire-
10 lessly connected TPU:s. However, due to the risk for twisted cables, when more than one TPU is in the cell at the same time, it is to prefer to if the TPU:s are wirelessly connected to the control unit.

15 According to one aspect of the invention this object is achieved with a method as defined in claim 12.

According to a further aspect of the invention, the object is achieved by a computer program directly loadable into the internal memory of a computer or a processor, comprising software
20 code portions for performing the steps of the method according to the appended set of method claims, when the program is run on a computer.

25 According to another aspect of the invention, the object is achieved by a computer readable medium having a program recorded thereon, when the program is to make a computer perform the steps of the method according to the appended set of method claims, and the program is run on the computer.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained more closely by the description of different embodiments of the invention and with reference
35 to the appended figures.

Fig. 1 shows an industrial robot system according to an embodiment of the invention.

5 Fig. 2 shows schematically a block diagram of a robot control unit according to an embodiment of the invention.

Fig. 3 shows an example of an enabling circuit.

10 Fig. 4 shows an example of an emergency stop circuit.

Fig. 5 shows schematically a block diagram of a TPU according to an embodiment of the invention.

15 Figs. 6a-d show flow diagrams of a method for controlling an industrial robot system, according to an embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

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Figure 1 shows an industrial robot system comprising an industrial robot located within a robot cell 1 surrounded by a safety arrangement, for example a fence or a photo-electric trip device. A robot cell is a defined safe area surrounding the manipulator. Within the robot cell certain safety rules are applied. One safety rule is for example that the safety equipment of the TPU must function within the robot cell. The robot system includes a manipulator 2, a control unit 3 for controlling the manipulator, and a plurality of portable operator control devices 5a-d, in the following denoted TPU:s (Teach Pendant Unit) for teaching and manually operating the manipulator. The TPU:s are communicating with the control unit 3 via a wireless data link. It should be noted that in another embodiment of the invention, the TPU:s are connected to the control unit 3 by means of cables.

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Each TPU 5a-d comprises a portable box 9 including a display screen 10, function keys, a joystick 12, an enabling device 14 and an emergency stop device 15. The TPU also includes an antenna for wireless communication with the control unit 3. The function keys permit the operator to select various states for the control system. The joystick 12 is used for controlling the movement of the manipulator when the robot is in manual operation mode. The enabling device 14 comprises a button, which has to be pressed down by the operator to enable control of the robot by the TPU. When the operator releases the button of the enabling device 14, the robot can no longer be operated by the TPU. The emergency stop button 15 causes an emergency stop upon activation. The enabling device 14 and the emergency stop device 15 is a part of the safety equipment of the TPU.

In figure 1, there are four operators, each equipped with a TPU 5a-d connected to the control unit 3. It is to be understood that connected to the TPU means that the operator has been logged in to the control unit 3 and is able to communicate with the control unit 3 and to send and receive data from the control unit. Three of the TPU:s 5a-c are located inside the robot cell and one TPU 5d is located outside the cell.

For safety reasons, the number of TPU:s allowed to be simultaneously connected to the control unit, or to the safety system, could be limited.

In this embodiment of the invention, the robot system allows a TPU to be assigned three different levels of authorities: master authority, safety authority, and remote authority. The master authority is the highest level of authority and allows the TPU to be connected to the safety system of the control unit, i.e. allows enabling of the safety equipment of the TPU, and allows the operator to manually operate the robot, for example to move the manipulator with the joystick, and to start and stop robot programs. The safety authority is a lower level of authority, and al-

lows the TPU to be connected to the safety system of the control unit, to communicate with the control unit and view data from the control unit, but not to manually operate the robot. The remote authority is the lowest level of authority, and allows the user to
5 communicate with the control unit and view data from the control unit, but does not allow the operator to manually operate the robot, and it does not allow the TPU to be connected to the safety system of the control unit, which means that the safety equipment of the TPU does not function.

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According to the safety rules, a TPU located outside the robot cell must have the Remote authority, and a TPU located inside the robot cell must have either the Master authority or the Safety authority. However, only one of the TPU:s located inside the cell
15 is allowed to have the Master authority, the other TPU:s inside the cell must have the safety authority. In this embodiment of the invention it is possible to change the authority so that another of the TPU:s connected to the safety system become the Master TPU. For example, the operator communicates a desired
20 authority to the control system during a login procedure. Which one of the TPU:s is the master could be negotiated at the login procedure.

The control unit is adapted to receive and store information
25 about which of the simultaneously connected TPU:s has master authority and accordingly is Master TPU, to change the authority of the Master TPU to a lower level of authority, and to change the authority of another of the connected TPU: to the master authority. The TPU:s continuously send information about the
30 status of the enabling devices, i.e. information about whether the enabling devices are activated or not, and information about the status of the emergency stop devices, i.e. information about whether the emergency stop devices are activated or not.

35 Figure 2 shows by means of a block diagram a robot control unit 3a according to an embodiment of the invention. The robot con-

trol unit includes communication means (not shown) for communicating with the TPU:s, a processor unit 20, such as a central processing unit (CPU) for executing software modules of the invention and stored robot programs, memory means 22, including
5 a storage area 24 for storing an authority matrix, a login module 26 for handling login of the TPU:s to the control unit, a logout module 27 for handling logout of the TPU:s from the control unit, a TPU authority handler 28, which updates the authority matrix upon order of change of authority, and checks whether a move
10 command is issue by a TPU having the authority therefore, and a safety system 30.

Each TPU has a unique identity, which, for example, is transferred to the control unit together with the desired authority
15 upon login to the control unit. The authority matrix is a list including the identity of all TPU:s, which are connected to the control unit, and the authority of the TPU:s. The login handler 26 receives the identity and authority of the TPU during the login procedure and stores the identity and authority of the TPU in the
20 authority matrix. The logout handler 27 removes the identity and authority of the TPU from the authority matrix upon receiving a logout order and disconnects the TPU from the safety system 30. The login handler 26 is also adapted to check whether the user is authorized to login to the control system or not based on
25 stored information about authorization of the users.

The authority handler 28 is adapted to, upon order from the TPU:s, change the authorities between two of the TPU:s, one of which is the Master TPU, so that the Master TPU does no longer
30 have the master authority, and the other TPU instead becomes the Master TPU and accordingly has the master authority. The authority handler receives information from at least one of the two TPU:s about the change of authorities and the identity of the new Master TPU, and based thereon updates the authority matrix with the new authorities. In order to increase the safety, it is
35 advantageous if one of the two TPU:s, which are changing au-

thorities, sends an change order to the control unit and the other TPU sends a confirmation of the change to the control unit before the authorities are changed.

5 The authority handler 28 is also adapted to receive move commands from the TPU:s, wherein the move commands includes information about the identity of the TPU that issued the move command, to check whether the identity, included in the move command, is equal to the identity of the Master TPU, as stored
10 in the authority matrix, and to allow the robot to move according to the move instruction, if the identity included in the move command is equal to the identity of the Master TPU, and to not allow the robot to move if the identity included in the move command is not equal to the identity of the Master TPU. A move command
15 is for example a move command issued by the joystick 12, an order to start running a robot program including move instructions, or an order to stop running the robot program. The authority handler sends information to the CPU about whether or not the move command is allowed to be executed or not.

20 The safety system 30 of the control unit includes an enabling module 31, an emergency stop module 32, an enabling chain 33, and an emergency stop chain 34. The enabling module and the emergency stop module holds information about which TPU:s
25 are connected to the safety system. The enabling module continuously, or repeatedly within a certain time frame, receives information from all the TPU:s, which are simultaneously connected to said safety system, about whether the enabling devices of the TPU:s are activated or deactivated. The enabling
30 module generates an enabling signal ED indicating whether manual movement of the robot is permitted or not. The enabling signal ED is transferred to the enabling chain 33. The enabling signal ED enables manual movement of the manipulator if the received information indicates that the enabling devices for all
35 TPU's connected to the safety system are simultaneously activated and does not enable manual movement of the manipulator

if the information received indicates that at least one of the enabling devices connected to the safety system is deactivated. Information about the enabling signal ED is also communicated to the CPU. If the authority handler has allowed a move command, and the enabling signal enables manual movement, the CPU executes the move command; otherwise the move command is not executed.

An example of the enabling chain 33 is shown in figure 3. The enabling chain 33 comprises a switch 36 that is opened or closed in dependence on the enabling signal EC. The enabling chain 33 is connected to the motors M of the robot. When the enabling chain is broken, the brakes are applied to the motors and the robot no longer controls the motors. The enabling chain has to be activated before any user is allowed to operate the robot by the TPU. The enabling chain is for example activated when manual operation mode of the robot is selected. Activation of the enabling chain means that manual operation of the robot is enabled. Accordingly, when the enabling chain is activated, the enabling devices of the TPU:s connected to the safety system is operatable. If the enabling circuit has been activated, the enabling chain 33 is opened or closed in dependence on whether the enabling signal ED enables manual movement of the robot or not. Accordingly, it is only possible to operate the robot by means of the Master TPU if the enabling devices for all TPU's connected to the safety system are simultaneously activate by the users.

The emergency stop module 32 continuously receives information from all the TPU:s, which are simultaneously connected to the safety system, about whether the emergency stop devices of the TPU:s are activated or deactivated. The emergency stop module generates an emergency stop signal EV, indicating whether the robot should be emergency stopped or not. The emergency stop signal ES indicates that the robot shall be emergency stopped, if the emergency stop device of at least one

of the TPU's, connected to the safety system, is activated, and indicates that the robot shall not be emergency stopped if non of the emergency stop device connected to the safety system is activated. The emergency stop signal ES is transferred to the emergency stop chain 34. An example of the emergency stop chain 34 is shown in figure 34. The emergency stop chain 34 comprises a switch 38 that is opened or closed in dependence on the emergency stop signal EV. The emergency stop chain 34 is connected to the brakes B of the robot. When emergency stop chain 34 is broken, the brakes are applied to the motors.

In this embodiment of the invention, the login handler 26, the logout handler 27, the authority handler 28, the enabling check module 31, and the emergency stop check module 32 are software modules. Alternatively they can be implemented in hardware or a combination of software and hardware.

Figure 5 shows by means of a block diagram a TPU 5a-d according to an embodiment of the invention. The TPU includes communication means (not shown) for communicating with the control unit 3, a central processor unit 40, memory means 42, an authority handler 44, and a safety circuit 46. The authority handler 44 handles authority issues, such as to communicate the desired authority to the control unit during the login procedure, to send an order about a change of the authority to the control unit, and to accept or deny a request regarding change of authority received from another TPU. The authority handler 44 also handles the communication with the operator regarding selection of level of authority and change of level of authority. The safety equipment includes a safety circuit 46 comprising the emergency stop button 15 and the enabling device 14, which both are switches. The safety circuit 46 is closed when the enabling device 14 is activated and the stop button 15 is not activated.

Figure 6a-e are a flow diagrams illustrating a method and a computer program for coupling a wireless TPU to a robot con-

troller, according to an embodiment of the present invention. It will be understood that each block of the flow diagram can be implemented by computer program instructions, which are executed by the central processing unit 20 of the control unit. A presumption is that a communication link has been established between the TPU:s and the control unit. The method according to the invention is event driven, which means that a certain sequence of method steps are executed based on a certain event. The events are for example: a login command is received from one of the TPU:s, a move command is received from one of the TPU:s, an emergency stop order is received from one of the TPU:s, an order to change authority is received from one of the TPU:s, and a logout command is received from one of the TPU:s. In the following it will be described, with reference to the flow diagrams 6a-e, what will happen in the control unit when those events occurs.

Figure 6a shows the login procedure. When the operator picks up the TPU and begins to use it, he enters information about his identity and a desired level of authority to the system. The TPU sends a login command to the control unit including a request to connect the TPU to the control unit, the identity of the operator, a password, the identity of the TPU, and the desired level of authority of the TPU. The control unit receives the login command, block 50, and checks if the operator is authorized to be logged in to the control unit, block 52. If the check reveals that the operator is authorized and the password is correct the operator is logged in to and connected to the control unit, block 54. If the desired authority is the master authority, the authority handler 28 of the control unit checks whether any other TPU connected to the control unit already has been assigned the master authority. If so, the TPU is denied the master authority and is informed about that. If no other TPU has the master authority, or if a lower level of authority is claimed, the identity of the TPU and the level of authorization are stored in the authority matrix, block 56.

If the level of authority is a remote authority the login procedure is finished, otherwise the TPU is connected to the safety system, block 58, 60. Upon connection to the safety system, the identity of the TPU is communicated to the safety system. The safety system enables the safety equipment of the TPU, which means that the enabling device and the emergency stop device of the TPU is functioning, block 62. The safety equipment of a TPU with a remote authority does not function, i.e. it is not possible to emergency stop the robot by activating the emergency stop button on the TPU, and it is not possible to enabling motion of the manipulator by activating the enabling button.

Figure 6b shows a procedure for handling move commands from the TPU:s. The control unit continuously receives information about the status of the enabling devices from all TPU:s connected to the safety system, block 70. The status includes enabling device activated or deactivated. When the control unit receives a command from any of the TPU:s, block 72, the control system is adapted to perform a check whether the TPU is allowed to issue this type of command or not according to its authority, block 74. Each command received from the TPU includes the identity of the TPU that issued the command. Information of the authority of the TPU, which issued the command, is found in the authority matrix. If the check shows that the TPU does not have the authority to issue the command, the command is ignored and the TPU is informed thereof, block 76.

For example, if the control system receives a command involving a movement of the manipulator, or any other command, which is only allowed to be issued by the Master TPU, the command is ignored if the authority check shows the TPU does not have the master authority, block 76. If the enabling devices for all TPU:s connected to the safety system are activated, the enabling chain of the safety system is closed, block 78, 80, which means that it is possible to move the manipulator. If any of the

enabling devices of the TPU:s connected to the safety system is deactivated, the enabling chain remains open and the move command is not executed. If the command involves a movement of the manipulator, if the command included the identity of the master TPU, and the enabling devices for all TPU:s connected to the safety system are activated, the move command is executed, block 82.

Figure 6c shows a procedure for an emergency stop command from one of the TPU:s. The control unit continuously receives information about the status of the emergency stop devices from all TPU:s connected to the safety system, block 90. The status includes emergency stop activated or deactivated. The control system is adapted to detect whether the received status indicates that the emergency stop device of any of the TPU:s connected to the safety system is activated, block 92. If the control unit detects that one or more of the emergency stop device are activated, the emergency stop chain is closed and the robot is emergency stopped.

Figure 6d shows a procedure for handling an order for changing the authority of two TPU:s. In this example, a TPU having a safety authority wants to change to the master authority, and the TPU having the master authority wants to change to the safety authority. It is also possible to order a change from a remote authority to a safety authority and vice versa. The control unit receives a request for changing the authority to master authority from a TPU having a safety level of authority, block 96. The control unit sends an inquiry to the Master TPU about the change, block 98. The master TPU can choose to grant or deny the request. The control system receives the answer from the Master TPU, block 100. If the Master TPU grants the request, the new authorities are stored in the authority matrix. If the Master TPU denies the request, the authorities are not changed.

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- Figure 6e shows a logout procedure. When the control system receives a logout command from the TPU, block 110, the control system removes the identity and authority of the TPU from the authority matrix, block 112. Further, the control system disconnects the TPU from the safety system and logs out the operator from the control system, block 114. The safety equipment of the TPU does no longer function and the operator can no longer view data from the control unit.
- 10 According to an embodiment of the invention, the robot system is adapted to emergency stop the robot and log out all TPU:s from the control unit if an error occurs with a TPU connected to the safety system. Thereafter, all the TPU:s have to log in again to the control unit.
- 15 The term comprises/comprising when used in this specification is taken to specify the presence of stated features, integers, steps or components. However, the term does not preclude the presence or addition of one or more additional features, integers, steps or components or groups thereof.
- 20 The present invention is not limited to the embodiments disclosed but may be varied and modified within the scope of the following claims. For example the number of TPU:s may vary in dependence on the number of operators.
- 25

CLAIMS

1. An industrial robot system comprising:
an industrial robot including at least one manipulator (2)
5 and a control unit (3) for controlling the manipulator, and
at least two portable operator control devices (5a-d), called
hereafter TPU:s, for manually operating the robot, each TPU
comprising safety equipment including a manually operated
enabling device (14), which upon activation enables manual
10 movement of the robot by means of the TPU, and the control
unit comprises a safety system (33,34) which upon connection
enables the safety equipment of the TPU, **characterized in** that
the system is adapted to simultaneously connect said TPU:s to
the safety system of the control unit, wherein one of the TPU:s
15 is given a master authority, called hereafter a Master TPU, and
the control unit is adapted
to receive information from all TPU:s, which are simultane-
ously connected to said safety system, about whether the ena-
bling device of the TPU is activated or deactivated,
20 to permit manual movement of the robot by the Master TPU
if said received information indicates that the enabling devices
for all TPU's connected to the safety system are simultaneously
activated,
to not permit manual movement of the Master TPU if said
25 information received indicates that at least one of the enabling
devices is deactivated, and
to not permit manual movement of the robot by any other
TPU than the Master TPU.
- 30 2. The industrial robot system according to claim 1, wherein
said safety equipment comprises an emergency stop device (15)
and the control unit is adapted
to receive information of from all TPU:s, which are simulta-
neously connected to said safety system, about whether the
35 emergency stop device of the TPU is activated or deactivated,
and

to emergency stop the robot, if said received information indicates that the emergency stop device of at least one of the TPU's, connected to the safety system, is activated.

5 3. The industrial robot system according to claim 1 or 2,
wherein the control unit is adapted to upon order change au-
thorities between the TPU:s, so that the Master TPU does no
longer have a master authority and another of the TPU:s con-
10 nected to the safety system instead becomes the Master TPU
and have the master authority.

4. The industrial robot system according to claim 3, wherein the
control unit is adapted to receive information from at least one
of the TPU:s about the change of authorities and the identity of
15 the new Master TPU.

5. The industrial robot system according to any of the previous
claims, wherein the system allows TPU:s connected to the
safety system to be assigned at least two different levels of au-
20 thority, wherein the highest level of authority is master authority.

6. The industrial robot system according claim 5, wherein the
system is adapted to allow a remote TPU to be connected to the
control unit, but not to the safety system, and to assign the re-
25 mote TPU a third level of authority.

7. The industrial robot system according to any of the previous
claims, wherein the control unit is adapted
to check whether a move command, received from one of
30 the TPU:s, is issued by the Master TPU, and
to move the robot according to the move instruction if the
move command is issued by the Master TPU, and to not move
the robot if the move command is issued by a TPU which is not
the Master TPU.

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8. The industrial robot system according to any of the previous claims, wherein the control unit comprises a storage area (24) for storing the identity and authority of the TPU:s, and the control unit is adapted to receive and store information about the identity and authority for each TPU connected to the control unit.

9. The industrial robot system according to claim 3 and 8, wherein the control system is adapted to upon said order to change the authorities between the TPU:s store the new authorities of the TPU:s in said storage area.

10. The industrial robot system according to claim 8 or 9, wherein the control unit is adapted

15 to receive move commands from the TPU:s, wherein the move commands include information about the identity of the TPU that issued the move command,

to check whether the identity, included in the move command, is equal to the stored identity of the Master TPU, and

20 to move the robot according to the move instruction if the identity included in the move command is equal to the identity of the Master TPU, and to not move the robot if the identity included in the move command is not equal to the identity of the Master TPU.

25 11. The industrial robot system according to any of the previous claims, wherein the TPU:s are adapted to communicate wirelessly with the control unit.

30 12. A method for controlling an industrial robot system including an industrial robot comprising at least one manipulator and a control unit for controlling the manipulator, and at least two portable operator control devices, called hereafter TPU:s, for manually operating the robot, each TPU comprising safety equipment

35 including a manually operated enabling device, which upon activation enables manual movement of the robot by means of the

TPU, and the control unit comprises a safety system which upon connection enables the safety equipment of the TPU, **characterized in** that the method comprises:

- 5 connecting the TPU:s to said safety system so that they are simultaneously connected to the safety system,
- receiving information about which of the connected TPU:s has master authority and accordingly is Master TPU,
- receiving information from all TPU:s, which are simultaneously connected to said safety system, about whether the enabling device of the TPU is activated or deactivated,
- 10 receiving a move command from one of the connected TPU:s,
- deciding whether the move command is issued by the Master TPU or not,
- 15 executing the move command if the move command is issued by the Master TPU and said received information indicates that the enabling devices for all TPU's connected to the safety system are simultaneously activated, otherwise not executing the move command.

20

13. A method according to claim 12, wherein said safety equipment comprises an emergency stop device and the method further comprises:

- 25 receiving information of from all TPU:s, which are simultaneously connected to said safety system, about whether the emergency stop device of the TPU is activated or deactivated, and
- executing an emergency stop of the robot, if said received information indicates that the emergency stop device of at least one of the TPU's connected to the safety system is activated.

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- 14. The method according to claim 13, wherein the method comprises receiving an order to change the authorities between the TPU:s, and based thereon changing the authorities so that the Master TPU does no longer have the master authority and an-

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other of the TPU:s connected to the safety system instead becomes the Master TPU and have the master authority.

5 15. The method according to any of claims 12-14, wherein the method comprises receiving information about the identity and authority of the TPU:s connected to the control unit and saving the identity and authority of the connected TPU:s.

10 16. The method according to claim 14 and 15, wherein said order to change the authorities comprises information of the identity of the new Master TPU, and the method comprises: changing the authority of the Master TPU to a lower level of authority, changing the authority of the new Master TPU to the master authority, and storing the new authorities.

15 17. The method according to claim 16, wherein said move commands include information about the identity of the TPU that issued the move command, and the method comprises checking whether the identity, included in the move command, is equal to the stored identity of the Master TPU, and moving the robot according to the move instruction if the identity included in the move command is equal to the identity of the Master TPU, and to not move the robot if the identity included in the move command is not equal to the identity of the Master TPU.

25 18. The method according to any of claims 12-17, wherein the TPU:s are assigned at least two different levels of authority, wherein the highest level of authority is the master authority.

30 19. The method according to claim 18, wherein the TPU:s are assigned at least three different levels of authority, wherein the lowest level of authority is a remote authority, which allows the TPU to view data from the control unit, but not to be connected to the safety system.

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20. A computer program directly loadable into the internal memory of a computer, comprising software for performing the steps of any of claims 12-19.
- 5 21. A computer readable medium, having a program recorded thereon, where the program is to make a computer perform the steps of any of claims 12-19, when said program is run on the computer.

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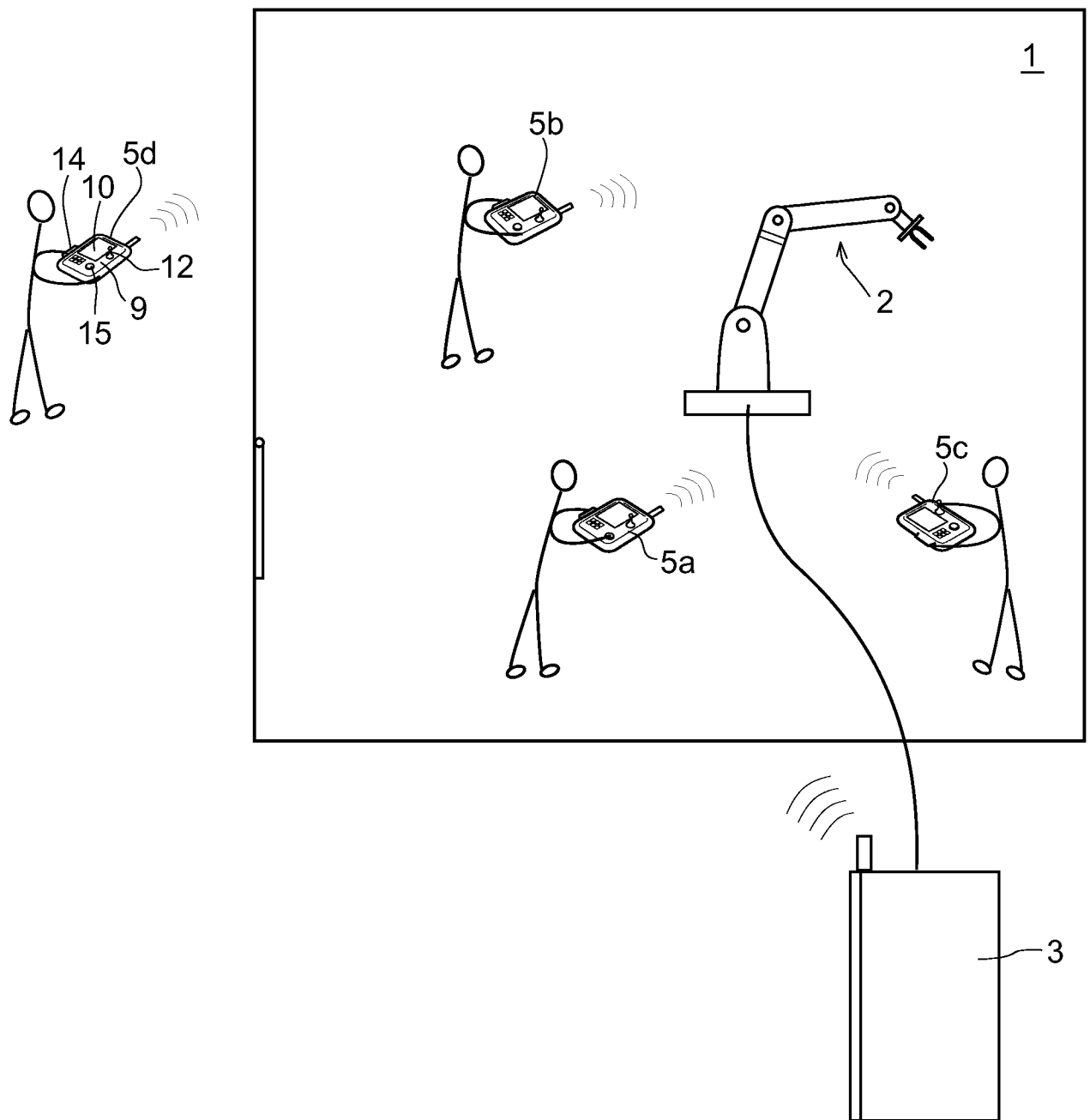


Fig. 1

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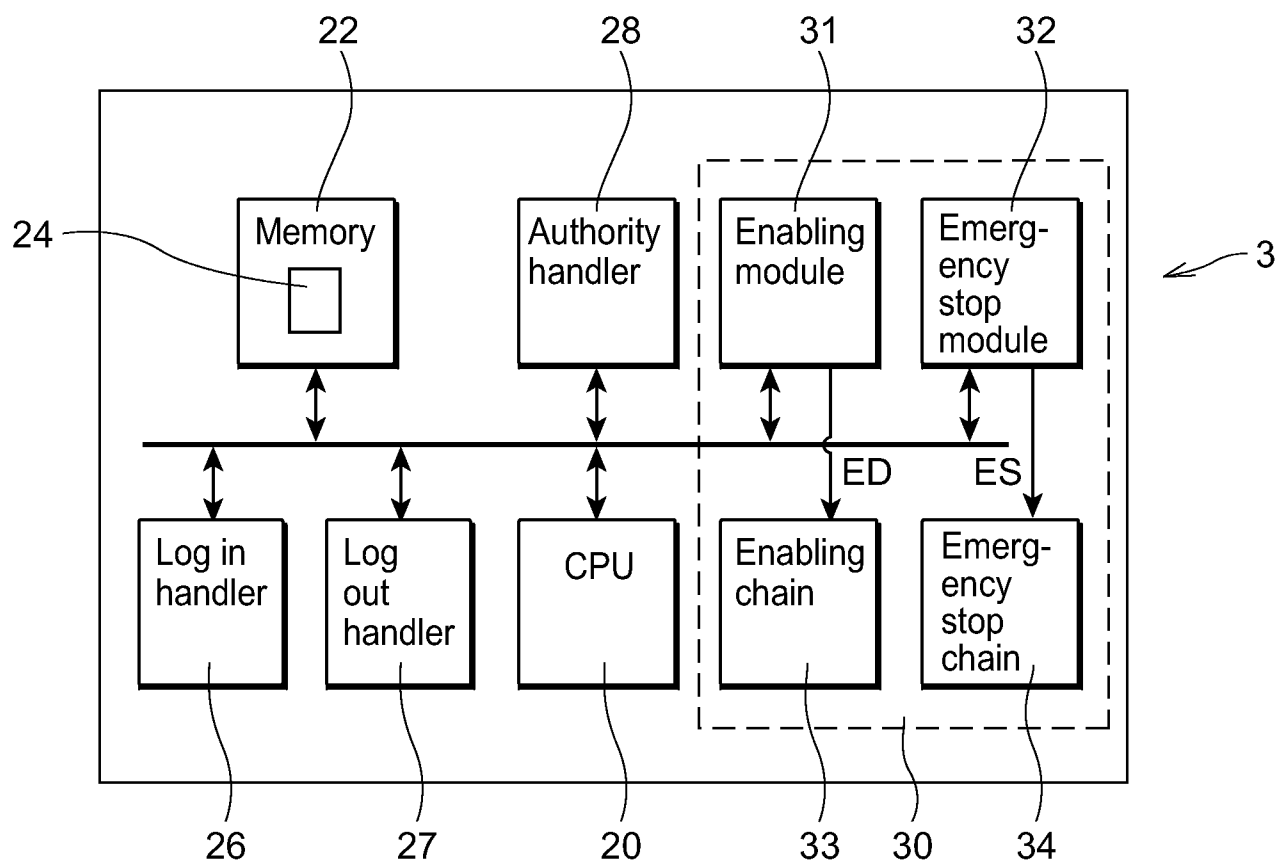


Fig. 2

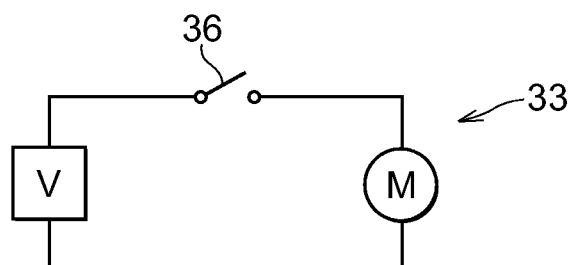


Fig. 3

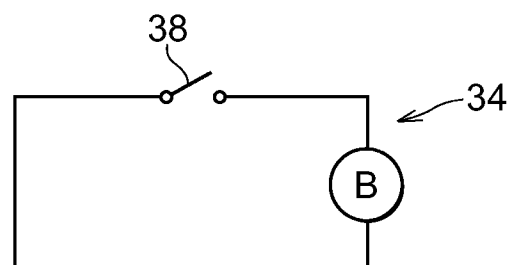


Fig. 4

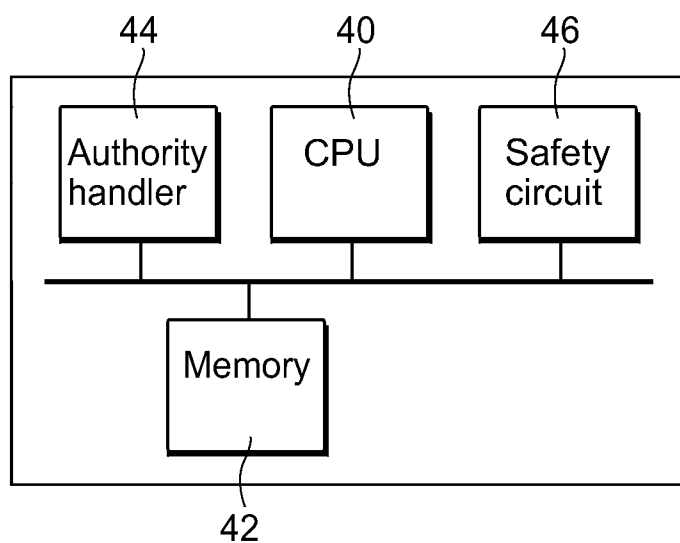


Fig. 5

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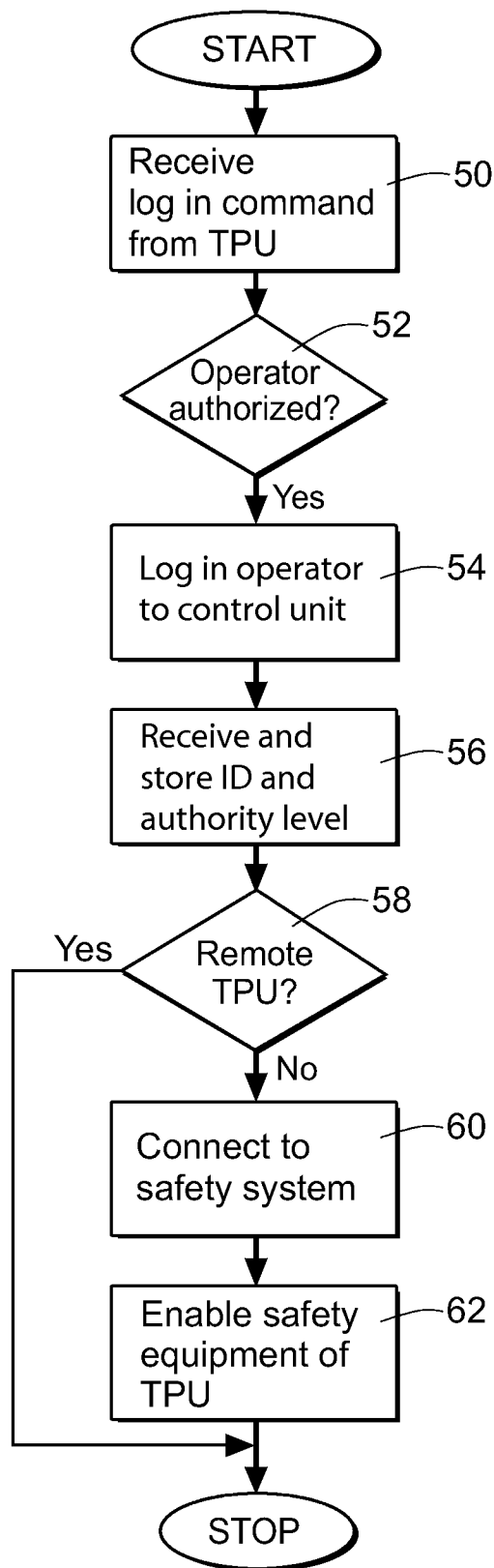


Fig. 6a

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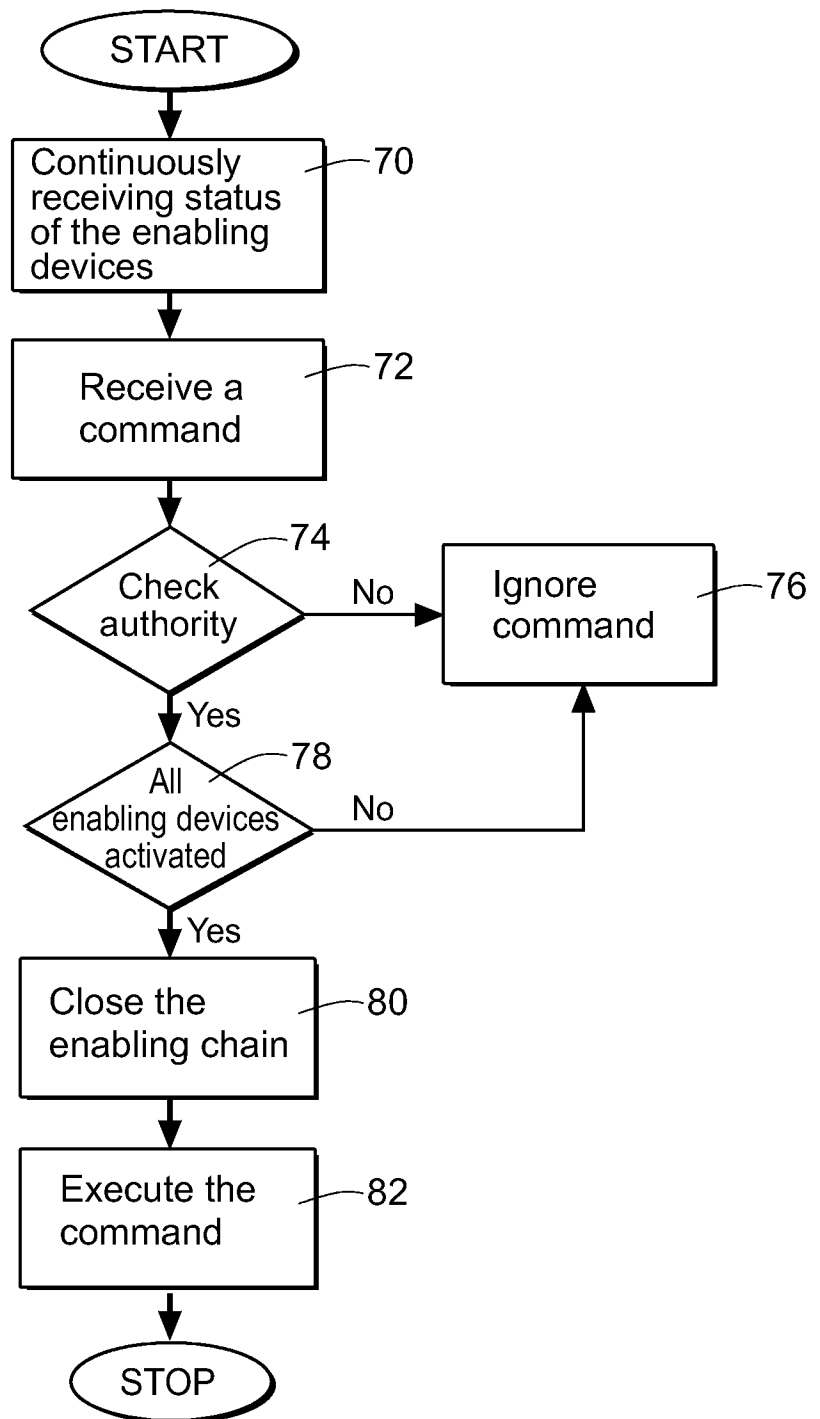


Fig. 6b

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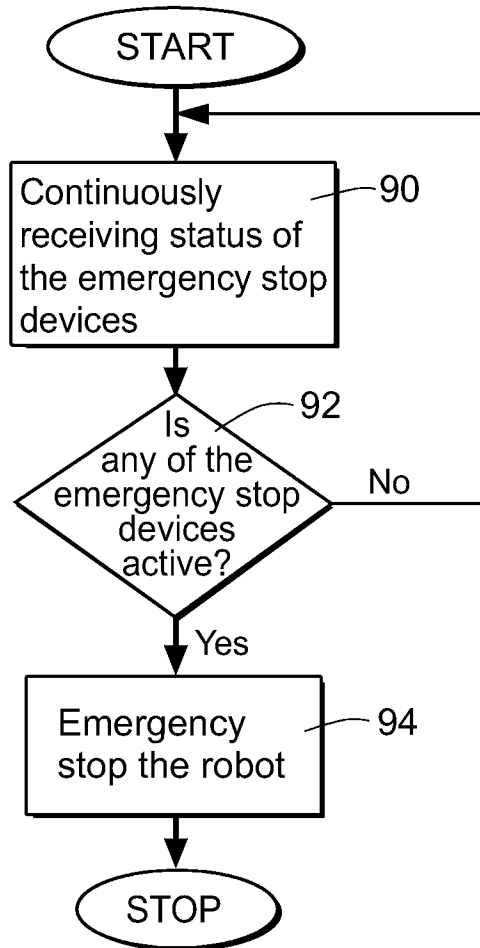


Fig. 6c

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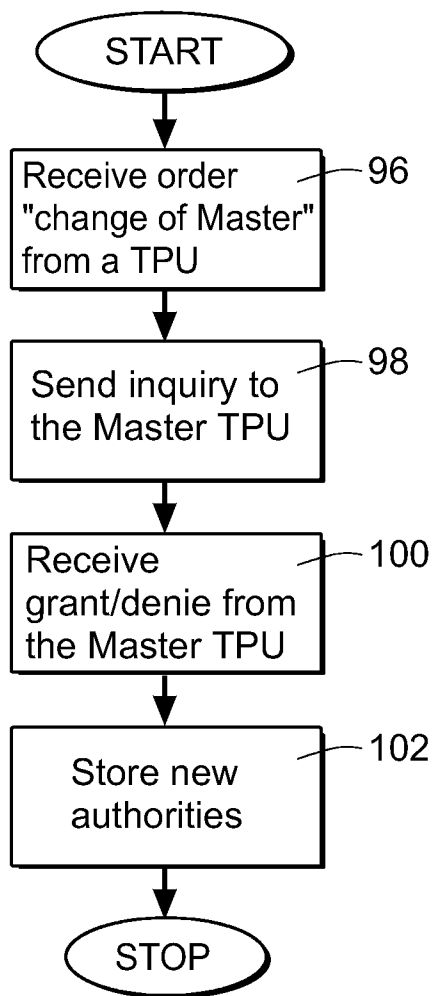


Fig. 6d

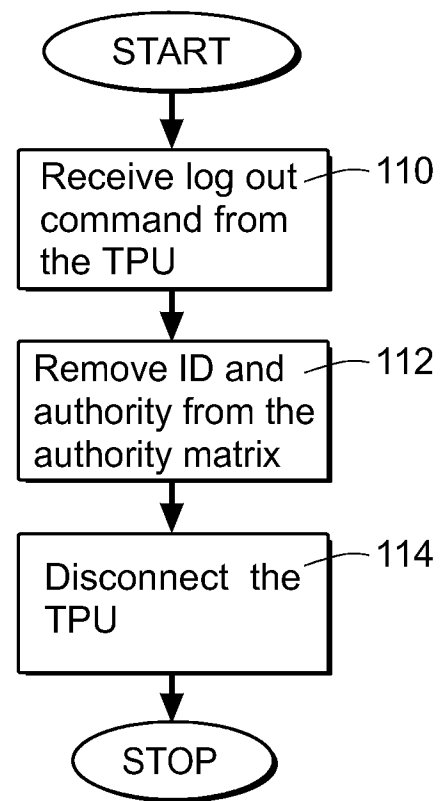


Fig. 6e

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2006/067793

A. CLASSIFICATION OF SUBJECT MATTER
 INV. B25J13/06 B25J19/06

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

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 practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 514 650 A (KABUSHIKI KAISHA YASKAWA DENKI) 16 March 2005 (2005-03-16) abstract; figures 1,2 column 3, line 50 - column 4, line 6 column 4, line 20 - line 24 column 4, line 35 - line 41	1
Y A		2,5,6,11 12
Y	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 12, 5 December 2003 (2003-12-05) & JP 2005 118967 A (YASKAWA ELECTRIC CORP), 12 May 2005 (2005-05-12) abstract	2
A		13
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

E earlier document but published on or after the international filing date

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

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

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

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

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

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

* & * document member of the same patent family

Date of the actual completion of the international search

15 January 2007

Date of mailing of the international search report

26/01/2007

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2006/067793

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2005/065894 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD; IKEDA, TATSUYA; MORITA, KUNIT) 21 July 2005 (2005-07-21) the whole document	5,6
A		3,4, 7-10,12, 14-19
P,Y	-& EP 1 598 152 A (MATSUSHITA ELECTRIC INDUSTRIES CO., LTD) 23 November 2005 (2005-11-23) figures 1,15,16 paragraphs [0061], [0064] paragraph [0067]	5,6
Y	US 2005/052148 A1 (CARLSON ERIK ET AL) 10 March 2005 (2005-03-10) abstract; figure 1	11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2006/067793

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 20,21
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

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

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 20,21

Article 17(2)(a)(ii) PCT: the international search authority considers that the subject-matter of the claims 20 and 21 is to such an extent unclear that a meaningful search cannot be carried out for these claims.

In claim 20, the computer program is only defined in that it is directly loadable into the internal memory of a computer and in that it comprises a software suitable for performing the steps of any of the claims 12 to 19.

No information in the application allows to understand how a single software could be capable of performing all the steps of claim 12.

The subject-matter of claim 21 is also not clear since claim 21 does not contain any technical feature regarding the computer readable medium itself. The medium is only defined in that it has a specific program recorded thereon, which is possible for any medium which has a sufficient storage capacity.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2006/067793

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1514650	A	16-03-2005	WO 03086716 A1	23-10-2003
			JP 2003311665 A	05-11-2003
			US 2005209734 A1	22-09-2005
JP 2005118967	A	12-05-2005	NONE	
WO 2005065894	A	21-07-2005	CN 1705540 A	07-12-2005
			EP 1598152 A1	23-11-2005
			JP 2005193338 A	21-07-2005
			US 2006106471 A1	18-05-2006
EP 1598152	A	23-11-2005	CN 1705540 A	07-12-2005
			JP 2005193338 A	21-07-2005
			WO 2005065894 A1	21-07-2005
			US 2006106471 A1	18-05-2006
US 2005052148	A1	10-03-2005	EP 1449007 A1	25-08-2004
			WO 03036324 A1	01-05-2003