

Robot and Method for Operating a Robot

The invention relates to a robot and to a method for operating a robot.

5 The object of the invention is to provide a robot and a method for operating a robot, so that feedback regarding contact events of the robot, in particular a robot manipulator, with an environment is made possible for a user. In particular, the feedback is to enable improved "teach-in" programming of the robot.

10 The invention results from the features of the independent claims. Advantageous refinements and embodiments are the subject matter of the dependent claims. Additional features, application possibilities and advantages of the invention result from the following description and from the explanation of exemplary embodiments of the invention represented in the figures.

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A first aspect of the invention relates to a robot comprising the following: a system for ascertaining information KE on mechanical contact events of the robot with an environment, a transformation unit for transforming the ascertained information KE into feedback information FI reflecting this information KE, and a lighting means, disposed on the robot, in particular on a robot manipulator of the robot, for outputting light signals L(FI) that are dependent on the feedback information FI.

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In the present case, the expression "contact events of the robot" relates to mechanical contacts and is understood to have a broad meaning in the present case. The expression covers, for example, mechanical contacts with an object of the environment or with a person operating the robot, or a contact event of the robot with itself. Contacts of a robot can, in principle, be desirable or undesirable. Desirable contacts occur, for example, when an object is handled according to a program by the robot or with so-called "teach-in" programming, in which a person guides, in particular, a robot manipulator and, as a result, the robot learns, for example, poses and positions of the robot manipulator. Undesirable mechanical contacts occur in an unplanned or random manner.

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A contact event can be described physically by a plurality of parameters. Advantageously, a contact event is described by parameters such as the current position and/or the pose of the

robot on which the contact occurs, the position on the robot on which the contact forces and/or moments act, a magnitude and a direction of the acting forces and/or moments, speeds and/or accelerations of the robot that occur during the contact event, material deformations of the robot that occur, and the like. The information KE is advantageously based on
5 measurements/estimations of such parameters describing a contact and/or on variables derived therefrom. The information KE is therefore advantageously multidimensional. The information KE moreover advantageously comprises predictions of possible future contact events, which are ascertained based on a current state of the robot and a corresponding prediction model. For this purpose, the system for ascertaining information KE
10 advantageously comprises a prediction computer on which a corresponding prediction model runs.

The transformation unit transforms the information KE into feedback information FI, which, in turn, is output in the form of light signals $L(FI)$ by the lighting means. The transformation
15 of the information KE into the feedback information FI advantageously occurs by way of a predefined transformation matrix or by way of a predefined transformation function.

Advantageously, the transformation, carried out by the transformation unit, of information KE into feedback information FI is dependent on a current work mode of the robot. For example,
20 if the robot is in a "teach-in" programming mode, an accordingly associated first transformation rule can be executed by the transformation unit, for example, while, in an "execution of a program" mode, an accordingly associated second transformation rule is executed by the transformation unit.

25 By outputting light signals $L(FI)$, intuitive, that is, easy-to-understand, light feedback regarding the contact that has just occurred is provided in the respective context to a user of the robot, in particular while carrying out a "teach-in" programming of the robot.

The system for ascertaining information KE, the transformation unit and the lighting means
30 are advantageously controlled by a control program. The control program is additionally defined by corresponding control and regulation parameters. By accordingly specifying the control program or of the currently associated control and regulation parameters, the current feedback behavior of the robot is defined. By changing the control program and/or changing

the associated control and regulation parameters, the feedback behavior of the robot can be changed accordingly.

Advantageously, the system comprises at least one sensor means for ascertaining measurement data regarding the contact events and for ascertaining/estimating information KE that is based on the measurement data. Advantageously, the information KE comprises one or more of the following (measurement) variables: forces, moments, pressures, voltages, currents, associated action points/surfaces, and the like. In principle, the information KE can comprise any information and data describing a contact of the robot with an external object.

Advantageously, the information KE moreover comprises a current state of the robot (position, pose, speed, acceleration, and the like of the individual parts of the robot, a work mode of the robot, a current program step in a control program of the robot, and the like) during the action of an external contact. Advantageously, the feedback information FI additionally codes the current state of the robot. The user is thus able to determine based on the output light signals L(FI) whether the robot is, for example, in the "teach-in" programming mode, for example in that the output light color codes this mode.

An advantageous refinement of the robot is characterized in that the lighting means is designed and configured to control the light intensity and/or the light color and/or a modulation of the light intensity and/or a modulation of the light color and/or a (light) pattern of the output light signals L(FI) and/or a number of light sources of the lighting means as a function of the feedback information FI. For this purpose, the lighting means includes appropriate control electronics. The lighting means comprises one or more light sources. The light sources can be, for example, light emitting diodes LEDs, halogen lamps, incandescent lamps, and the like.

The light sources can, in particular, be designed to emit light of different color spectra or different light colors. The lighting means advantageously comprises a combination of at least one light source comprising a light guide, into which the light source couples light on the input side, and from which light is outcoupled into an environment on the output side. Here, the feedback information FI codes the light signals L(FI) to be output.

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An advantageous refinement of the robot is characterized in that the transformation unit is designed and configured in such a manner that the transformation of the ascertained information KE into the feedback information FI reflecting the information KE is provided in the form of a lookup table or in the form of a transformation matrix. In this refinement,

information KE is thus transformed by means of a lookup table or a transformation matrix into feedback information FI.

5 An advantageous refinement of the robot is characterized in that the transformation unit is designed and configured in such a manner that the transformation of the ascertained information KE into the feedback information FI reflecting the information KE is provided in the form of a function/an algorithm. Advantageously, the lookup table or the transformation matrix is dependent on the current state of the robot and/or on the current work mode of the robot.

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An advantageous refinement of the robot is characterized in that the transformation unit is designed and configured in such a manner that a pattern in the ascertained information KE is transformed into patterns of feedback information FI which reflect these patterns. The term "pattern" used in this connection relates, in particular, to recognizable patterns/characteristics in the parameters describing the contact events, for example, to a characteristic time profile of one or more of the parameters describing the information KE. Here, in addition, the term "pattern" advantageously takes into consideration the current state and/or the current work mode of the robot. Such a "parameter pattern" can characterize, for example, a chronological sequence of one or more parameter(s) in the description of a contact event. Especially when the pattern is characterized by multiple parameters, a suitable transformation of the information KE into corresponding feedback information FI (with or without taking into consideration the current state of the robot and/or the current work mode of the robot) enables intuitive feedback regarding complex contact processes.

25 An advantageous refinement of the robot is characterized in that the transformation unit is designed and configured in such a manner that the collected information KE is categorized into categories, wherein characteristic feedback information FI is associated with each category.

30 An advantageous refinement of the robot is characterized in that the information KE is categorized based on a time profile and/or of an amplitude and/or of a frequency of the respective information KE. Advantageously, during the categorization, the current state and/or the work mode of the robot are additionally taken into consideration.

An advantageous refinement of the robot is characterized in that one of the predefined categories represents a collision of the robot with the environment. Depending on the work mode of the robot, such a collision can occur, for example, during a "teach-in" process or during an autonomous execution of a control program which controls the robot.

5 Advantageously, the output of light signals in red color is associated with this category, which represents a collision of the robot with the environment.

Advantageously, one of the predefined categories represents a robot error ascertained by the robot. Advantageously, the output of light signals in orange or yellow color is associated with
10 this category, which represents a robot error.

Advantageously, one of the predefined categories represents a normal state, that is, a state without error. Advantageously, the output of light signals in green color is associated with this category, which indicates a normal state of the robot.

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The optical output unit advantageously comprises one or more light emitting diodes. The optical output unit can comprise light strips, light guides, light guiding elements, and the like. Advantageously, the optical output unit comprises an annular luminous surface, which emits light in a planar and homogeneous manner. Advantageously, the optical output unit has a
20 circular lighting surface which emits homogeneous light in a flat manner.

An advantageous refinement of the robot is characterized in that the robot comprises a data interface to a data network (for example, Internet, LAN, Local Area Network), and the robot is configured and designed to load control programs for controlling the robot from the data
25 network. Advantageously, for this purpose, the robot comprises a data interface and a corresponding program memory. Advantageously, the control programs are made available to a control unit of the robot by a central provider in the respective data network. The data network is advantageously a wired data network, a radio data network or a combination thereof.

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Advantageously, the robot is configured and designed to load control and regulation parameters for the control programs from the data network. The control and regulation parameters define the specific application of the corresponding control program. The control

and regulation parameters are, in particular, adapted to the problem to be solved. Advantageously, for this purpose, the robot comprises a corresponding data memory.

5 Advantageously, the robot is configured and designed to load control and regulation parameters for the control programs via a manual input interface of the robot (for example, a man-machine interface available in the area of the robot) and/or via a "teach-in process," in which the robot is guided manually, that is, it is moved by the application of a force by a user. Moreover, both the manual input interface and a "teach-in process" carried out by the robot enable a correction or adaptation of the control and regulation parameters loaded from the data
10 network.

Advantageously, the robot is configured and designed so that the loading of control programs and/or of associated control and regulation parameters from the data network is controlled by a remote station, which is likewise connected to the data network. Such remote stations can
15 be, for example, tablet PCs, smartphones, notebooks, personal computers (PCs), and the like. Advantageously, a remote station is operated by a central provider.

Advantageously, the robot is configured and designed to transmit control programs that are present locally in the robot and/or associated control and regulation parameters upon request
20 from a participant in the data network and/or autonomously, for example, when a predefined condition is present, to other participants in the data network. In principle, such a "participant" can be any computer and/or memory unit configured for this data exchange.

Advantageously, the robot is configured and designed to start control programs that are loaded
25 locally in the robot with the associated control and regulation parameters from a remote station, which is likewise connected to the data network. Such remote stations can be, for example, tablet PCs, smartphones, notebooks, personal computers, etc. Advantageously, a remote station is operated by a central provider.

30 Advantageously, the remote station and/or the manual input interface on the robot comprise a man-machine interface which is designed and configured to input control programs and/or associated control and regulation parameters, and/or to select control programs and/or associated control and regulation parameters from a plurality of available control programs and/or associated control and regulation parameters.

Advantageously, the man-machine interface enables inputs via a "drag and drop" input on a touchscreen, a guided input dialog, a keyboard, a computer mouse, a haptic input interface, virtual reality goggles, an acoustic input interface, body tracking, based on electromyography data, based on electroencephalography data, via a neuronal interface to the brain of the operator or a combination thereof.

Advantageously, the man-machine interface is designed and configured to output audiovisual, haptic, olfactory, tactile, electrical feedback or a combination thereof.

An additional aspect of the invention relates to a method for operating a robot, comprising the following steps: ascertaining information KE on mechanical contact events of the robot with an environment, transforming the ascertained information KE into feedback information FI reflecting this information KE, and outputting light signals L(FI) that are dependent on the feedback information FI by a lighting means, disposed on the robot, in particular on a robot manipulator of the robot.

An advantageous refinement of the method is characterized in that at least one sensor means ascertains measurement data regarding the contact events of the robot and ascertains/estimates information KE that is based on the measurement data. Advantageously, the sensor means moreover ascertains the information KE as a function of the current state and/or the current work mode of the robot.

Advantageously, the contact information variables comprise one or more of the following variables: forces, moments, pressures, voltages, currents, associated action points/surfaces, and the like.

Advantageously, the lighting means controls the light intensity and/or the light color and/or a modulation of the light intensity and/or a modulation of the light color and/or a pattern of the output light signals L(FI) and/or a number of light sources of the lighting means as a function of the feedback information FI. The "pattern of the output light signals" advantageously relates to a spatial, planar and/or temporal arrangement of light signals to be output. Thus, for example, certain surface elements of the lighting means can output light signals of a certain color at certain times.

An advantageous refinement of the method is characterized in that the transformation unit provides the transformation of the ascertained information KE into the feedback information FI reflecting the information KE in the form of a lookup table, so that the transformation occurs
5 by means of the lookup table.

An advantageous refinement of the method is characterized in that the transformation unit provides the transformation of the ascertained information KE into the feedback information FI reflecting the information KE in the form of a function/an algorithm. The above-mentioned
10 term "reflecting" is understood to apply to the entire description in general as "dependent on," that is, the feedback information FI generated by the transformation is dependent on the information KE.

An advantageous refinement of the method is characterized in that the transformation unit
15 categorizes the collected information KE into categories, wherein characteristic feedback information FI is associated with each category. Advantageously, the categorization of the information KE occurs based on a progression over time and/or of an amplitude and/or of a frequency of the respective information KE.

20 An advantageous refinement of the method is characterized in that the robot comprises a data interface to a data network, and the robot is configured and designed to load one or more control programs from the data network.

An advantageous refinement of the method is characterized in that the robot loads control and
25 regulation parameters for control programs from the data network.

An advantageous refinement of the method is characterized in that the robot loads control and regulation parameters for the control programs that are present locally in the robot via a local input interface and/or by way of a teach-in process, in which robots are manually guided.
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An advantageous refinement of the method is characterized in that the loading of control programs and/or of associated control and regulation parameters from the data network into the robot is controlled by a remote station, which is likewise connected to the data network.

An advantageous refinement of the method is characterized in that control programs that are present locally in the robot are started with the associated control and regulation parameters from a remote station, which is likewise connected to the data network.

- 5 Advantages and advantageous refinements as well as corresponding explanations of the method result from an appropriate and analogous application of the explanations provided above with respect to the robot according to the invention.

10 An additional aspect of the invention relates to a computer system comprising a data processing device, wherein the data processing device is designed in such a manner that a method, as described above, is carried out on the data processing device.

15 An additional aspect of the invention relates to a digital memory medium having electronically readable control signals, wherein the control signals can cooperate with a programmable computer system in such a manner that a method, as described above, is carried out.

20 An additional aspect of the invention relates to a computer program product having program code stored on a machine-readable medium for carrying out the method, as described above, when the program code is executed on a data processing device.

25 An additional aspect of the invention relates to a computer program having program codes for carrying out the method, as described above, when the program runs on a data processing device. For this purpose, the data processing device can be designed as any computer system known from the prior art.

30 Additional advantages, features and details result from the following description in which — where applicable with reference to the drawing — at least one exemplary embodiment is described in detail. Identical, similar and/or functionally equivalent parts are denoted by identical reference numerals.

In the drawings:

Fig. 1 shows a highly schematic representation of the design of the proposed robot,

Fig. 2 shows a highly schematic flow chart of a proposed method.

Fig. 1 shows a highly diagrammatic representation of the design of a robot including a robot manipulator, comprising: a system 101 for ascertaining information KE on mechanical contact events of the robot manipulator with an environment, a transformation unit 102 for transforming the ascertained information KE into feedback information FI reflecting this information KE, and a lighting means 103, disposed on the robot manipulator, for outputting light signals that are dependent on the feedback information FI. The system 101 comprises, in particular, sensors for detecting forces and moments acting externally on the robot manipulator. In particular, the transformation unit 102 is designed as an arithmetic unit, wherein the transformation is accordingly predefined as a transformation matrix. The lighting means 103 comprises at least three light emitting diodes of different colors, serving as light sources, each feeding light into a light guide. The light guides each outcouple the light on the output side in a planar manner. The output-side outcoupling points of the light conductors are arranged adjacent to one another.

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Fig. 2 shows a highly diagrammatic flow chart of a proposed method for operating a robot, comprising the following steps: ascertaining 201 information KE on mechanical contact events of the robot with an environment, transforming 202 the ascertained information KE into feedback information FI reflecting this information KE, and outputting 203 light signals that are dependent on the feedback information FI by a lighting means, disposed on the robot, in particular on a robot manipulator of the robot.

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Although the invention has been further illustrated and explained in detail using preferred exemplary embodiments, the invention is not limited to the disclosed examples, and other variations can be derived therefrom by a person skilled in the art, without departing from the scope of protection of the invention. Therefore, it is clear that numerous variation options exist. It is likewise clear that embodiments mentioned by way of example in fact only represent examples that should in no way be construed to constitute a limitation, for example, of the scope of protection, of the application options or of the configuration of the invention. Instead, the above-provided description and the description of the figures make it possible for a person skilled in the art to specifically implement the exemplary embodiments, wherein the person skilled in the art, having knowledge of the disclosed idea of the invention, can carry out numerous modifications, for example, with regard to the function or the arrangement of individual elements mentioned in an exemplary embodiment, without departing from the

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scope of protection which is defined by the claims and their legal equivalents, such as, for example, further explanations in the description.

Claims

1. A robot, comprising:
 - a system (101) for ascertaining information KE on mechanical contact events of the robot with an environment;
 - a transformation unit (102) for transforming the ascertained information KE into feedback information FI reflecting this information KE; and
 - a lighting means (103), disposed on the robot, in particular on a robot manipulator of the robot, for outputting light signals L(FI) that are dependent on the feedback information FI.
2. The robot according to claim 1,
 - wherein the system (101) comprises at least one sensor means for ascertaining measurement data regarding the contact events and for ascertaining/estimating information KE that is based on the measurement data.
3. The robot according to any one of claims 1 to 2,
 - wherein the lighting means is designed and configured to control the light intensity and/or the light color and/or a modulation of the light intensity and/or a modulation of the light color and/or a pattern of the output light signals and/or a number of light sources of the lighting means as a function of the feedback information FI.
4. The robot according to any one of claims 1 to 3,
 - wherein the transformation unit is designed and configured in such a manner that the transformation of the ascertained information KE into the feedback information FI is provided in the form of a lookup table.
5. The robot according to any one of claims 1 to 4,
 - wherein the transformation unit is designed and configured in such a manner that the transformation of the ascertained information KE into the feedback information FI is provided in the form of a function/an algorithm.
6. The robot according to any one of claims 1 to 4,

wherein the transformation unit is designed and configured in such a manner that patterns of the ascertained information KE are transformed into feedback information FI reflecting these patterns.

7. The robot according to any one of claims 1 to 4,

wherein the transformation unit is designed and configured in such a manner that the collected information KE is categorized into categories occurs, characteristic feedback information FI being associated with each category.

8. The robot according to claim 7,

wherein the categorization of the information KE occurs based on a time profile and/or of an amplitude and/or of a frequency of the respective information KE.

9. A method for operating a robot, comprising the following steps:

- ascertaining (201) information KE on mechanical contact events of the robot with an environment;
- transforming (202) the ascertained information KE into feedback information FI reflecting this information KE; and
- outputting (203) light signals L(FI) that are dependent on the feedback information FI by a lighting means, disposed on the robot, in particular on a robot manipulator of the robot.

10. The method according to claim 9,

wherein the lighting means controls the light intensity and/or the light color and/or a modulation of the light intensity and/or a modulation of the light color and/or a pattern of the output light signals and/or a number of light sources of the lighting means as a function of the feedback information FI.