(19) DANMARK

(10) **DK/EP 3556709 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: *B 66 C 13/04 (2006.01)* *B 66 C 13/18 (2006.01)* *B 66 C 13/40 (2006.01)* *B 66 C 13/46 (2006.01)* *B 66 C 23/00 (2006.01)*

(45) Oversættelsen bekendtgjort den: **2020-04-06**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2020-03-25**

(86) Europæisk ansøgning nr.: **19150837.3**

(86) Europæisk indleveringsdag: **2019-01-08**

(87) Den europæiske ansøgnings publiceringsdag: **2019-10-23**

(30) Prioritet: **2018-04-19 IT 201800004719**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

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(54) Benævnelse: **SYSTEM TIL AUTOMATISK BEVÆGELSE AF EN LEDDELT ARM, SÆRLIGT PÅ EN LASTEKRAN**

(56) Fremdragne publikationer:
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DESCRIPTION

Technical field of the invention

[0001] The present invention refers to a system for automatically moving an articulated arm, particularly of an articulated crane. The term "articulated arm" means a system provided with a plurality of bodies, consecutively connected to each other, capable of forming an open kinematic chain with a plurality of translative and/or rotative degrees of freedom in the space.

Prior art

[0002] Systems enabling other systems having plural degrees of freedom, to perform previously stored movements, are known. Such systems provide to manually perform a desired movement, store it and then automatically re-perform it. Such mode is particularly useful when identical movements must be cyclically repeated (consider for example the transport of items from a first area to a second area in a yard, in an industrial area, or similar).

[0003] Overhead cranes are often used in a yard for example. An overhead crane comprises a U-inverted frame movable along a track (first degree of freedom), and a trolley transversally movable along the frame (second degree of freedom). Therefore, the absolute position of the trolley depends on the absolute position of the frame and on the position of the trolley with reference to the frame. The absolute position of the trolley is matched by only one configuration of the overhead crane and consequently it can be simply registered and reproduced a sequence of movements.

[0004] With reference to complex articulated arms, for example in the presence of an articulated crane, the position of an end-effector of the crane can be obtained by different configurations of the crane itself. Therefore, simply registering a manual movement and repeating it do not cause the end-effector to follow the same movements. Indeed, if in the start position the crane has a configuration different from the one it had in a step of storing the movement of the end-effector, just simply repeating the movements performed in the storing step will not enable the end-effector to reach the same stored final position.

[0005] Systems according to the known art are described in documents JP 2001 130892 A, EP 2 725 183 A1, JP H10 219731 A and JP 2000 355957 A.
Document JP 2001 130892 A discloses a system for automatically moving an articulated arm, comprising: said articulated arm, comprising a plurality of bodies consecutively connected to each other in order to form an open kinematic chain with an end-effector, having a plurality of translative and/or rotative degrees of freedom and a plurality of actuators for moving said bodies; a plurality of sensors associated to said bodies adapted to supply signals indicative of linear or angular positions such to enable to determine the (relative) coordinates of the end-

effector; a user interface device configured for commanding the articulated arm by an operator; a control unit comprising a memory module and operatively connected to said actuators, said sensors and said user interface device, said control unit being configured for performing: a step of storing a movement of the end-effector, which comprises: receiving movement instructions of the end-effector from the user interface device; actuating the actuators so that the end-effector performs a sequence of movements corresponding to the movement instructions; detecting during the movement, in a plurality of subsequent sampling instances distanced from each other of a sampling time, the signals from said sensors; determining, based on the signals from the sensors, the (relative) coordinates of the end-effector in each sampling instant; and storing in the memory module the absolute coordinates of the end-effector determined in each sampling instant and the actuators used for moving the end-effector between each determined absolute coordinate and the absolute coordinate determined in the following sampling instant.

Summary of the invention

[0006] Therefore, it is an object of the present invention to provide a system for automatically moving an articulated arm, particularly of an articulated crane, having a plurality of degrees of freedom, wherein particularly the same absolute position of the end-effector can be obtained by plural configurations of the articulated arm itself.

[0007] This and other objects are obtained by a system for automatically moving an articulated arm according to claim 1.

[0008] The dependent claims define possible advantageous embodiments of the invention.

Brief description of the figures

[0009] For better understanding the invention and appreciating the advantages, some exemplifying non-limiting embodiments thereof will be described in the following with reference to the attached figures, wherein:

Figure 1 is a side view of an articulated crane;

Figure 2 is a schematic illustration of an example of the steps of storing the movements of an articulated arm, based on the invention;

Figure 3 is a schematic illustration of an example of the steps of re-performing the movements of the articulated arm, based on the invention;

Figure 4 is a schematic illustration of a further example of the steps of re-performing the movements of the articulated arm, based on the invention;

Figure 5 is a schematic illustration of a further example of the steps of re-performing the movements of the articulated arm, based on the invention;

Figure 6 is a schematic illustration of a further example of the steps of re-performing the movements of the articulated arm, based on the invention.

Detailed description of the invention

[0010] The present description will illustratively refer to an articulated crane. However, the present invention finds an application in the movements of articulated arms of other types, such as for example robotic arms, or aerial work platforms (PLE).

[0011] Referring to the attached Figure 1, it shows an example of a possible articulated arm, particularly an articulated crane, for example a hydraulic loading crane (commonly known as "loader crane"), generally indicated by the reference 101.

[0012] The crane 101 comprises a column 102 pivoting about its axis, and one or more possibly extendable arms 103', 103". The possibility of extending the arms, if provided, is obtained by a plurality of extensions 104 reciprocally translatingly movable in order to modify the axial length of a respective arm. In the example of Figure 1, only the second arm 103" is extendable by moving the extensions 104. In the following description, the first arm 103', devoid of extensions, will be indicated by the term "main arm", while the second arm 103", provided with the extensions 104, will be indicated by the term "secondary arm". The free end 105 of the last extension of the secondary arm 103" is commonly known as end-effector. A hook 106 movable for example by a rope winch 107 can be provided at the end-effector 105.

[0013] For sake of simplicity, it is illustratively assumed the presence of only one extension 104, neglecting the movements of the hooks 106, so that the crane 101 has the following degrees of freedom:

1. 1) rotation of the column 102 about its axis;
2. 2) rotation of the main arm 103' with respect to the column 102 about an axis perpendicular to the plane on which the column 102 and main arm 103' lie;
3. 3) rotation of the secondary arm 103" with respect to the main arm 103' about an axis perpendicular to the plane on which the main arm 103' and secondary arm 103" lie;
4. 4) translation of the extension 4 with respect to the secondary arm 103".

[0014] The above described crane therefore provides an open kinematic chain, having a plurality of sequentially connected bodies (column, main arm, secondary arm, extensions) and a free end (end-effector).

[0015] The above cited degrees of freedom are matched by the movement of an element of the articulated arm with respect to another one (degrees of freedom 2, 3, 4) or with respect to a reference (degree of freedom 1). In order to perform such movements, the crane 101 comprises a plurality of actuators, at least one actuator corresponding to a specific degree of freedom. With reference to Figure 1, a first hydraulic jack 108, moving the main arm 103' with respect to the column 102, a second hydraulic jack 109, moving the secondary arm 103" with respect to the main arm 103', and an actuator 110 moving the column 102 with respect to a stationary reference, are shown. Obviously, further actuators (not shown in the figures), for example of a hydraulic-type, for moving the extensions 104, are present. Obviously, even though the actuators of the cranes are normally of a hydraulic-type, generally it is possible to provide actuators of a different kind (electric or pneumatic, for example) in the articulated arms.

[0016] The crane 101 comprises a plurality of sensors capable of enabling to determine the absolute coordinates of the end-effector 105, particularly the Cartesian coordinates thereof. For example, it is assumed that the origin of a Cartesian coordinate system, coincides with the base of the column 102, so that the absolute coordinates of the end-effector 105 are expressable by three values: x, y, z.

[0017] According to a possible embodiment, with reference to the crane 101, the plurality of sensors can include, for example:

1. 1) an angular sensor for measuring the rotation of the column 102 about its axis;
2. 2) an angular sensor for measuring the rotation of the main arm 103'. This measured rotation can be absolute, in other words referred to a stationary reference such as the horizontal, or can be a relative rotation, with respect to the column 102;
3. 3) an angular sensor for measuring the rotation of the secondary arm 103". This measured rotation can be absolute, in other words referred to a stationary reference such as the horizontal, or can be a relative rotation, with respect to the main arm 103';
4. 4) a linear sensor for measuring the translation of the extension 104 with reference to the secondary arm 103".

[0018] For example, the sensors can include linear or angular encoders, inclinome-ters, magnetostrictive position sensors or similar. From the signals output by the above cited sensors, it is possible to determine, by geometrical relationships, the absolute coordinates of the end-effector 105.

[0019] The crane 101 comprises a control unit operatively connected to the actuators, for moving them, and to the sensors, for receiving signals indicative of the above cited magnitudes. Moreover, the control unit comprises a memory module, the operation thereof will be explained in the following.

[0020] In addition, it is provided a user interface device connected to the control unit for enabling an operator to manually move the crane and, possibly, to gain access to other functions. For example, the user interface device can comprise a remote control and the control unit can comprise a transmission module for communicating with this latter (a radio transmission module, for example). The operator, by acting on a joystick of the remote control for example, can visually move the end-effector 105 among subsequent positions. As said in the introductory part, since a position of the end-effector 105 can generally correspond to more than one configuration of the crane, also the movements of the end-effector 105 can be performed in different ways, in other words by sequentially moving several actuators. Consequently, predefined operative logics are generally provided, by which, based on a desired determined movement of the end-effector, corresponding actuators are selected to be operated for obtaining this movement.

[0021] Therefore, the control unit is configured so that, upon a movement instruction of the end-effector received from the user interface device, such movement is obtained as a function of a predetermined logic for actuating the actuators. For example, the actuating logics can be one for minimizing the oil flow rate required for actuating the actuators or can be one for minimizing the energy used for moving them. A further logic can be one of the minimum distance travelled by the end-effector for reaching the desired position. A further criterion. often used for example in combination with one of the above listed ones, consists of maintaining the actuators away from the stop position. The predetermined operative logics are per se known and therefore will not be specifically described.

[0022] Alternatively, the operator can decide which actuators to move: only one or more than one at a time, and consequently can obtain the desired movement of the end-effector.

[0023] By a system configured in this way, it is possible to store a sequence of movements manually imparted by the user interface device, and then automatically repeat the same by modes which will be described in the following.

[0024] The control unit is particularly configured to perform a step of storing a movement of the end-effector 105, comprising:

- receiving instructions of moving the end-effector 105 by the user interface device;
- actuating the actuators so that the end-effector 105 performs a sequence of movements corresponding to the movement instructions. The actuators can be moved based on a predetermined logic (for example for minimizing the flow rate or minimum travelled distance), or the operator himself/herself directly moves certain actuators, by the user interface device, so that the end-effector 105 performs determined movements in the space;
- sensing, during the movement, at a plurality of consecutive sampling instants spaced from each other by a sampling time, the signals from the sensors. The sampling time can be predefined or alternatively can be set by the operator. Preferably, the sampling time is less than one second, still more preferably is in the order of a one tenth of a

second;

- determining the absolute coordinates of the end-effector 105 at each sampling instant based on the signals from the sensors;
- storing in the memory module the absolute coordinates of the end-effector 105 determined at each sampling instant, and the actuators used for moving the end-effector 105 between each determined absolute coordinate and the absolute coordinate determined at the following sampling instant. It is observed that, in this step, with reference to the signals from the sensors, just the absolute coordinates of the end-effector are stored, and it is not required to store the configuration of the crane, also obtainable from the signals of the sensors. Moreover, with reference to the actuators, the memory stores only the used actuators, and it is not required to store neither the movement direction, nor the (angular or linear) travelled distance of the actuators themselves.

[0025] Consequently, the real trajectory followed by the end-effector 105, based on the manual instructions of the operator, is divided in a plurality of discrete points, each corresponding to a sampling instant, and further the actuators used in the trajectory segments defined by said following points, are stored.

[0026] Based on such stored information, therefore the control unit can act on the actuators in order to re-perform the stored movement, particularly by automatically moving the crane in the following way.

[0027] Particularly, the command unit is configured to implement a step of re-performing the movement stored upon an instruction of automatically re-performing the stored movement. For example, such step can be started by the operator by the user interface device.

[0028] Such step of re-performing the stored movement provides to divide the re-performing step into a plurality of partial re-performing periods, each delimited by two consecutive re-performing instants distanced by a re-performing partial time, which, according to a possible embodiment, is equal to the sampling time. Alternatively, the partial re-performing time could be different from the sampling time (it could be selectable by the operator, for example) and in this case the duration of the re-performing step will be different from the duration of the storing step. The re-performing step comprises, during each partial re-performing period:

- sensing, at the initial re-performing instant, the signals from the sensors;
- determining the effective absolute coordinates of the end-effector 105 and the configuration of the articulated arm based on the signals from the sensors. It is observed that, as opposed to the storing step, the step of re-performing the configuration of the articulated arm, is monitored. For example, with reference to Figure 1, it is possible to determine if the secondary arm 103" and main arm 103' are aligned to each other or if they form a determined relative angle;

- comparing the effective absolute coordinates of the end-effector 105 with the absolute coordinates of the end-effector 105 stored in each of the sampling instant. Preferably, such step is performed with a determined tolerance, in other words the effective absolute coordinates are considered equal to the stored absolute coordinates if the effective absolute coordinates are equal to the stored absolute coordinates plus or minus a determined dimensional tolerance;
- if the effective absolute coordinates of the end-effector 105 are equal (preferably plus or minus the above given tolerance) to one of the absolute coordinates of the end-effector stored during one of the sampling instants, actuating the stored actuators for moving the end-effector 105 towards the absolute coordinate stored at the following sampling instant. If the crane has the same configuration which it had in the corresponding position of the end-effector during the storing step, this passage is sufficient to reach the absolute coordinate stored at the following sampling instant;
- if it is determined based on the configuration of the crane that the end-effector 105 is not capable of reaching the absolute coordinate stored at the following sampling instant, preferably further actuating one or more additional actuators according to a predetermined operative logic. Such condition can also happen if, despite the absolute coordinate corresponds to the stored one, the crane has a different configuration. In this case, further movements will be required for reaching the absolute coordinate stored at the following sampling instant.

[0029] On the contrary, if the effective absolute coordinates of the end-effector 105 are not equal to one of the absolute coordinates of the end-effector, stored at one of the sampling instants, two different conditions can occur: the end-effector 105 lies along the stored trajectory, or the end-effector 105 lies outside the stored trajectory. Advantageously, the control unit is therefore configured to:

- determine the whole stored trajectory of the end-effector. This can be obtained for example as a polygonal chain joining the different stored absolute coordinates of the end-effector or by a (polynomial for example) interpolation of the same.
- If the effective absolute coordinate of the end-effector 105 lies in a segment of the trajectory comprised between a first and second absolute coordinates stored between two following sampling instants, actuate the stored actuators for moving the end-effector 105 between said two absolute coordinates stored between two following sampling instants;
- if the end-effector 105 is determined as not capable of reaching the second stored absolute coordinate based on the configuration of the crane, actuate one or more additional actuators according to a predetermined operative logic.

[0030] If the effective absolute coordinate of the end-effector 105 lies outside the stored trajectory, advantageously the control unit is configured to:

- calculate the point of the stored trajectory nearest to the effective absolute coordinate of the end-effector;
- actuate the actuators according to a predetermined operative logic for moving the end-effector to such point. Such nearest point can be both a beforehand stored point, and a not stored point being anyway comprised between two following stored points. According to one of the two conditions, it is therefore implemented one of the abovementioned modes.

[0031] Advantageously, the movements of the end-effector 105 between two following points, for example between two points whose absolute coordinates were stored, are performed preferably by a closed-loop control of the position of the end-effector (according to the logics P, PI, PD, PI, PID, for example), wherein the reference is the trajectory of the end-effector. For example, if the two desired end points are known, the reference trajectory between these points can be set equal to the segment joining such points.

[0032] From what discussed above it is assumed that the movement is re-performed during the same time used for the storing step.

[0033] However, it is also possible to re-perform the stored trajectory at a different speed, in other words so that the end-effector performs such stored trajectory in a re-performing total time greater or less than the total stored time (given by the summation of the sampling times).

[0034] Therefore, the control unit is advantageously configured to receive, as an input parameter, a total desired re-performing time. Such parameter can be supplied to the control unit by the user interface device, for example.

[0035] Particularly, the control unit is configured to:

- determine the stored trajectory of the end-effector. This step can be performed according to what was previously discussed;
- calculate on the stored trajectory, the equivalent absolute coordinates of the end-effector, corresponding to the absolute coordinates of the end-effector which were sensed during the movement storing step if the end-effector had performed the estimated trajectory in the desired re-performing total time;
- set the stored absolute coordinates of the end-effector equal to said equivalent absolute coordinates.

[0036] Consequently, the stored coordinates are effectively manipulated so that they are substituted with new equivalent coordinates which take into account that the movement re-performing step is done at a speed different from the speed of the storing step.

[0037] At this point, it is required to distinguish the case wherein the desired speed during the performing step is greater or less than the speed of the storing step.

[0038] Advantageously, the control unit is configured to:

- if the total desired re-performing time is greater than the total sampling time (in other words, if it is desired to decrease the performing speed), store, for each equivalent absolute coordinate, the actuators stored in the segment of the trajectory along which the equivalent absolute coordinate lies. Consequently, each equivalent absolute coordinate is matched by the actuators to be used (if the crane configuration enables that) during the re-performing step, which are the same ones stored for the trajectory segment along which the equivalent absolute coordinates lie. Therefore, it is possible to implement what was previously described;
- if the total desired performing time is less than the total sampling time (in other words if it is desired to increase the speed), store for each equivalent absolute coordinate the actuators used along the segment of the trajectory along which the equivalent absolute coordinate lies and along all the previous segments. In other words, since the speed increases, between two following equivalent absolute coordinates, additional segments of the stored trajectory can be included. So, the actuators stored for each equivalent absolute coordinate will be those stored for all the segments included between it and the previous equivalent absolute coordinate. Then, again, the following will be the same as previously described.

[0039] Some operative examples will be given for further explaining what was hereinbefore discussed.

[0040] Figure 2 illustrates the steps of storing a possible trajectory of an articulated arm. Particularly, the figure schematically shows the articulated arm having the column 102, the main arm 103', the secondary arm 103", and a single extension 104, terminating with the end-effector 105. The initial position of the end-effector 105 is indicated by the coordinates x1, y1, z1. The stored movements are the following:

- the elapse of the sampling time, from the position x1, y1, z1 (initial position) to the position x2, y2, z2. The absolute coordinates of both positions are stored. Based on the predetermined operative logic, for example, consisting of minimizing the oil flow rate, or based on a decision of the operator, the second position is reached by projecting the extension 104, which entails the actuation of a corresponding actuator, which is also stored (therefore Figure 2 shows, besides x1, y1, z1 and x2, y2, z2, also the reference 104 for indicating that during this elapse the extension 104 were moved). Storing the configuration of the arm is not required. For example, storing the angle included between the main arm 103' and secondary arm 103" is not required. Neither storing the direction and length of the movement of the actuator moving the extension 104 are required;

- the elapse of the sampling time from the second position x2, y2, z2 to the third position x3, y3, z3 which is stored. According to the example, the third position is reached by rotating the secondary arm 103" and by a further projection of the extension 104. Using two corresponding actuators of the secondary arm 103" and extension 104 is also stored.

[0041] Now it is made reference to the re-performing step, if the initial position of the end-effector corresponds to the stored initial position x1, y1, z1, if the initial configuration of the crane is the same as the one the crane had during the step of storing the position x1, y1, z1 and if the desired performing speed is as the speed used in the storing step, the crane will exactly perform the same movements by actuating the same actuators used in the different segments of the trajectory of the storing step, according to what was shown in Figure 2. Checking the configuration performed at the point x1, y1, z1 will confirm that the only projection of the extension 104 enables to reach the coordinate x2, y2, z2.

[0042] Referring now to Figure 3, if it were tried to follow again a stored trajectory by simply actuating the same actuators used in the different segments of the trajectory of a storing step (in other words only the actuator of the extension 104) in a case wherein the initial position of the end-effector corresponds to the stored initial position x1, y1, z1, but the initial configuration of the crane is not the same as the one the crane had in the storing step in the position x1, y1, z1, the end-effector 105 would not be able to reach the stored position x2, y2, z2 because a rotation is also required. Therefore the control unit, once it verifies by the signals of the sensor that the only stored actuators do not enable to reach the position x2, y2, z2 based for example on the minimum flow rate logic, actuates also actuates also the actuators which moves the secondary arm 103" so that the end-effector 105 effectively reaches the position x2, y2, z2. Then, even though the effective configuration of the crane in the position x2, y2, z2 is not exactly the same as the stored one, the control unit checks that, in the configuration of the coordinate x2, y2, z2, the end-effector 105 is anyway capable to move to the position x3, y3, z3 by actuating only the stored actuators between the coordinates x2, y2, z2 and x3, y3, z3, in other words the actuators moving the secondary arm 103" and extension 104. These latter perform movements which are slightly different from the stored ones. From this example, it is observed that, even though the initial configuration of the crane is different from the one it had in the storing step, as the stored movement is gradually re-performed, the articulated arm tends to approach to the corresponding configuration it had in the storing step.

[0043] Referring now to Figure 4, if the initial position of the end-effector 105 does not correspond to the stored initial position x1, y1, z1, the control unit moves the end-effector 105, for example according to the minimum flow rate logic, so that this moves to the nearest point along the stored trajectory, a point which does not necessarily coincide with a stored point. In the example, such point, indicated by X, is in the segment between the coordinates x1, y1, z1 and x2, y2, z2. Therefore, the control unit, during the partial re-performing time, will move the end-effector 105 to such nearest point in the stored trajectory and, after that, it tries to move the end-effector to the point of coordinates x2, y2, z2 by actuating only the actuator moving the extension 104 (which was the stored actuator for moving from coordinates x1, y1, z1 to coordinates x1, y1, z1), however, since is not capable of doing it, it will actuates also a second actuator, in this case the actuator moving the secondary arm 103", according to the predetermined set logic. Then, the step of re-performing the movement continues according to what was discussed with reference to Figure 3. Obviously, if the effective sensed initial point does not coincide with a stored point, but was already present in the trajectory, the end-effector 105 would not be required to be moved to the nearest point of the trajectory since the end-effector is already present in the trajectory.

[0044] With reference now to Figure 5, it is described the case wherein the re-performing step is executed with a speed different from the speed used during the storing step. For the sake of simplicity, it is considered the case wherein the initial position of the end-effector corresponds to the stored initial position x1, y1, z1 and wherein the initial configuration of the crane is the same as the one the crane had during the step of storing the position x1, y1, z1.

[0045] For example, if it is desired to halve the performing speed, the total re-performing desired time is twice the total sampling time. Therefore, if it is considered, for example, the segment between the coordinates x1, y1, z1 and x2, y2, z2, and the time the crane requires, during the storing step, to move between these two positions (such time being equal to the sampling time), during the re-performing step, the end-effector could reach only a position x12 intermediate between x1 and x2, which represents an equivalent absolute coordinate. Therefore, the control unit will actuate the same actuator used in the storing step for moving from position x1, y1, z1 to position x2, y2, z2, in other words the one moving the extension 104 which, due to the sensed configuration of the crane, enables to reach the position x2, y2, z2 without actuating other actuators. Then, it is followed the same logic along all the trajectory.

[0046] Referring now to Figure 6, if, on the other hand, it is desired to increase the performing speed, the total desired performing time is reduced with respect to the total sampling time during the storing step. Consequently, for example, during the time required to the crane, in the storing step, to move from coordinates x1, y1, z1 to x2, y2, z2, in the re-performing step, the end-effector 105 could simultaneously reach, for example, a position x23 intermediate between x2 and x3, which is an equivalent performing coordinate. Therefore, by means of the position x1, y1, z1, the control unit will actuate the same actuators used in the storing step for moving between the positions x1, y1, z1 and x2, y2, z2, and between the positions x2, y2, z2 and x3, y3, z3, in other words the actuators which move the extension 104 and the actuator which moves the secondary arm 103". If the point x23 is not reached by means of these actuators due to the sensed configuration, the control unit would further actuate one or more other actuators according to the predetermined operative logic.

[0047] In the present description and in the attached claims, it is observed that the control unit and also the elements indicated by the expression "module", could be implemented by hardware devices (central units, for example), by software or by a combination of hardware and software.

[0048] From the above given description, a person skilled in the art could appreciate that the system, according to the invention, enables to re-perform stored movements also in the presence of complicated articulated arms, wherein the same position of the end-effector is obtainable by different configurations of the arm itself.

REFERENCES CITED IN THE DESCRIPTION

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PATENTKRAV

1. System til automatisk bevægelse af en leddelt arm (101), hvilket system omfatter:

– den leddelte arm (101), der omfatter en flerhed af korpusser, som konsekutivt er forbundet med hinanden med henblik på at danne en åben kinematisk kæde med en endeeffektor (105), der har en flerhed af translatoriske og/eller rotatoriske frihedsgrader og en flerhed af aktuatorer til bevægelse af korpusserne;

– en flerhed af sensorer, der er forbundet med korpusserne og tilpasset til at levere signaler, som er repræsentative for lineære positioner eller vinkelpositioner med henblik på at muliggøre bestemmelse af absolutte koordinater for endeeffektoren (105);

– en brugergrænsefladeindretning, der er konfigureret til at styre den leddelte arm ved hjælp af en operatør;

– en styreenhed, der omfatter et hukommelsesmodul og er operativt forbundet med aktuatorerne, sensorerne og brugergrænsefladeindretningen, idet styreenheden er konfigureret til at udføre:

et trin til lagring af en bevægelse af endeeffektoren (105), hvilket trin omfatter:

– modtagelse af bevægelsesinstruktioner for endeeffektoren (105) fra brugergrænsefladeindretningen;

– aktivering af aktuatorerne, således at endeeffektoren (105) udfører en sekvens af bevægelser svarende til bevægelsesinstruktionerne;

– detektering, under bevægelsen, på en flerhed af efterfølgende aftastningstidspunkter, som er adskilt fra hinanden med en aftastningstid, af signalerne fra sensorerne;

– bestemmelse, baseret på signalerne fra sensorerne, af de absolutte koordinater for endeeffektoren (105) på hvert aftastningstidspunkt;

– lagring, i hukommelsesmodulet, af de absolutte koordinater for endeeffektoren (105), som blev bestemt på hvert aftastningstidspunkt, og aktuatorerne, der blev anvendt til bevægelse af endeeffektoren (105) mellem hver bestemt absolut koordinat og den absolutte koordinat, som blev bestemt på det følgende aftastningstidspunkt;

et trin til genudførelse af den bevægelse af endeeffektoren (105), som blev lagret i lagringstrinnet, efter en instruktion om automatisk genudførelse af den lagrede bevægelse, hvilket trin, i en flerhed af delgenudførelsesperioder, som hver især er begrænset af to efterfølgende udførelsestidspunkter, der er adskilt med en delgenudførelsestid, omfatter:

– detektering, på genudførelsestidspunktet for begyndelsen af hver delgenudførelsesperiode, af signalerne fra sensorerne;

– bestemmelse af de effektive absolutte koordinater for endeeffektoren (105) og konfigurationen af den leddelte arm baseret på signalerne fra sensorerne;

– sammenligning af de effektive absolutte koordinater for endeeffektoren (105) med de absolutte koordinater for endeeffektoren (105), som blev lagret på hvert af aftastningstidspunkterne;

– aktivering, hvis de effektive absolutte koordinater for endeeffektoren (105) er de samme som for de absolutte koordinater for endeeffektoren, som blev lagret på ét af aftastningstidspunkterne, af de lagrede aktuatorer til udførelse af bevægelsen af endeeffektoren hen imod den absolutte koordinat, som blev lagret på det følgende aftastningstidspunkt.

2. System ifølge krav 1, hvor trinnet til genudførelse af bevægelsen af endeeffektoren (105) endvidere omfatter:

– yderligere aktivering, hvis det baseret på konfigurationen af den leddelte arm bestemmes, at endeeffektoren (105) ikke er i stand til at nå den absolutte koordinat, som blev lagret på det følgende aftastningstidspunkt, af én eller flere yderligere aktuatorer ifølge en forudbestemt operativ logik.

3. System ifølge krav 1 eller 2, hvor trinnet til lagring, i hukommelsesmodulet, af de absolutte koordinater for endeeffektoren (105) udføres uden lagring af den konfiguration af den leddelte arm, der kan opnås med signalerne fra sensorerne.

4. System ifølge et hvilket som helst af de foregående krav, hvor trinnet til lagring, i hukommelsesmodulet, af de aktuatorer, der blev anvendt til bevægelse af endeeffektoren (105), udføres uden lagring af aktuatorernes bevægelsesretninger og -omfang.

5. System ifølge et hvilket som helst af de foregående krav, hvor trinnet til sammenligning af de effektive absolutte koordinater for endeeffektoren (105) med de absolutte koordinater for endeeffektoren (105), som blev lagret på hvert af aftastningstidspunkterne, udføres med en foruddefineret tolerance.

6. System ifølge et hvilket som helst af de foregående krav, hvor trinnet til genudførelse af bevægelsen af endeeffektoren (105) endvidere, hvis de effektive absolutte koordinater for endeeffektoren (105) ikke er de samme som for de absolutte koordinater for endeeffektoren, som blev lagret på ét af aftastningstidspunkterne, omfatter:

– bestemmelse af den samlede lagrede bane for endeeffektoren (105);

– aktivering, hvis den effektive absolutte koordinat for endeeffektoren (105) ligger i et segment af banen, der er omfattet mellem en første og en anden lagret absolut koordinat mellem to følgende aftastningstidspunkter, af de lagrede aktuatorer til udførelse af bevægelsen af endeeffektoren (105) mellem de to lagrede absolutte koordinater mellem to følgende aftastningstidspunkter;

– aktivering, hvis det baseret på konfigurationen af den leddelte arm bestemmes, at endeeffektoren (105) ikke er i stand til at nå den anden lagrede absolutte koordinat, af én eller flere yderligere aktuatorer ifølge en forudbestemt operativ logik.

7. System ifølge det foregående krav, hvor trinnet til genudførelse af bevægelsen af endeeffektoren (105) endvidere, hvis den effektive absolutte koordinat for endeeffektoren (105) ligger uden for den lagrede bane, omfatter:

– beregning af punktet for den lagrede bane, nærmest ved den effektive absolutte koordinat for endeeffektoren (105);

– aktivering af aktuatorerne ifølge en forudbestemt logik for bevægelse af endeeffektoren (105) til punktet.

8. System ifølge et hvilket som helst af de foregående krav, hvor delgenudførelsestiden er lig med aftastningstiden.

9. System ifølge et hvilket som helst af de foregående krav, hvor styreenheden er konfigureret til som inputparameter at modtage en ønsket samlet genudførelsestid, hvor trinnet til genudførelse af bevægelsen af endeeffektoren (105), hvis den ønskede samlede genudførelsestid er forskellig fra den samlede tid for bevægelse af endeeffektoren under lagringstrinnet, omfatter:

– bestemmelse af den lagrede bane for endeeffektoren (105);

– beregning, på den lagrede bane, af ækvivalente absolutte koordinater for endeeffektoren, svarende til de absolutte koordinater for endeeffektoren, som ville blive detekteret i trinnet til lagring af bevægelsen, hvis endeeffektoren havde udført den bestemte bane i den ønskede samlede genudførelsestid;

– indstilling af de absolutte lagrede koordinater for endeeffektoren, som er lig med de ækvivalente absolutte koordinater.

10. System ifølge det foregående krav, hvor trinnet til genudførelse af bevægelsen af endeeffektoren (105) endvidere omfatter:

– lagring for hver ækvivalent absolut koordinat, hvis den samlede ønskede genudførelsestid er større end den samlede tid for bevægelse af endeeffektoren under lagringstrinnet, af de lagrede aktuatorer langs det segment af banen, hvorpå den ækvivalente absolutte koordinat ligger;

– lagring for hver ækvivalent absolut koordinat, hvis den samlede ønskede udførelsestid er mindre end den samlede tid for bevægelse af endeeffektoren under lagringstrinnet, af de aktuatorer, som blev anvendt i det segment af banen, hvorpå den ækvivalente absolutte koordinat ligger, og i alle de tidligere segmenter.

11. System ifølge et hvilket som helst af de foregående krav, hvor styreenheden er konfigureret til at udføre en styring i lukket kredsløb af banen mellem en første absolut koordinat og en anden absolut koordinat for endeeffektoren (105).

12. System ifølge et hvilket som helst af de foregående krav, hvor de absolutte koordinater for endeeffektoren (105) er absolutte kartesiske koordinater i et 3D-rum.

13. System ifølge et hvilket som helst af de foregående krav, hvor den leddelte arm (101) omfatter en leddelt kran.

14. System ifølge det foregående krav, hvor den leddelte kran omfatter en søjle (102), der roterer omkring aksen deraf, en hovedarm (103'), der roterer omkring søjlen (102), en sekundærarm (103"), der roterer omkring hovedarmen (103'), og omfatter mindst en forlængelse, som translatorisk kan udstrækkes fra sekundærarmen selv, og flerheden af sensorer omfatter en vinkelsensor til måling af søjlens (102) rotation omkring aksen deraf, en vinkelsensor til måling af hovedarmens (103') rotation, en vinkelsensor til måling af sekundærarmens (103") rotation, en linearsensor til måling af translationen for forlængelsen (104) fra sekundærarmen (103").

DRAWINGS

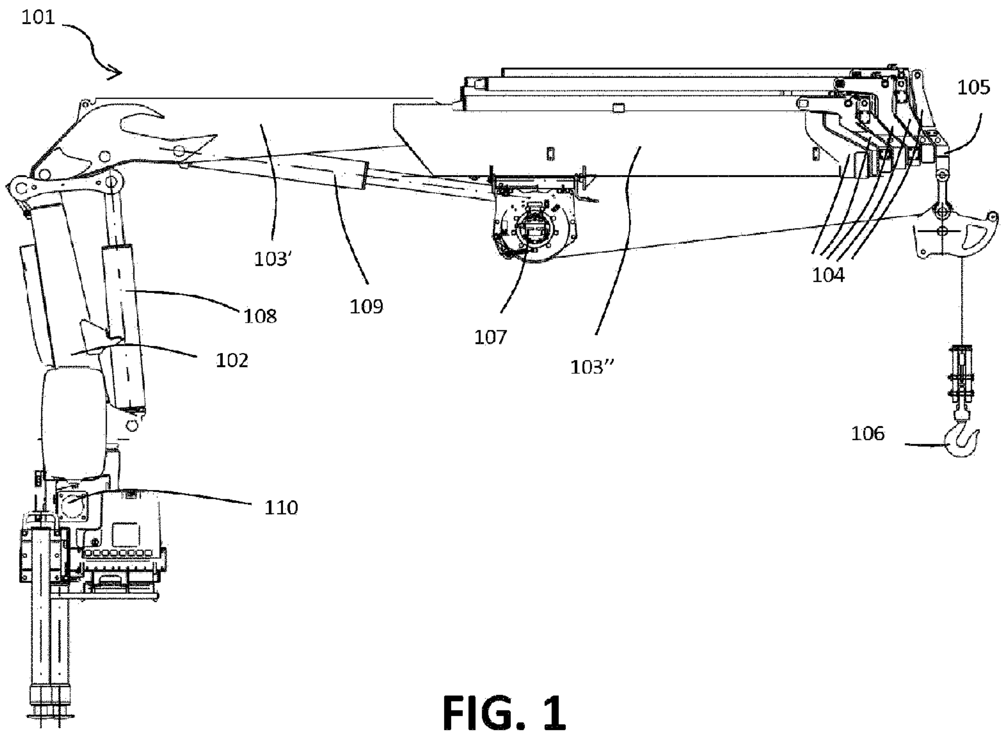


FIG. 1

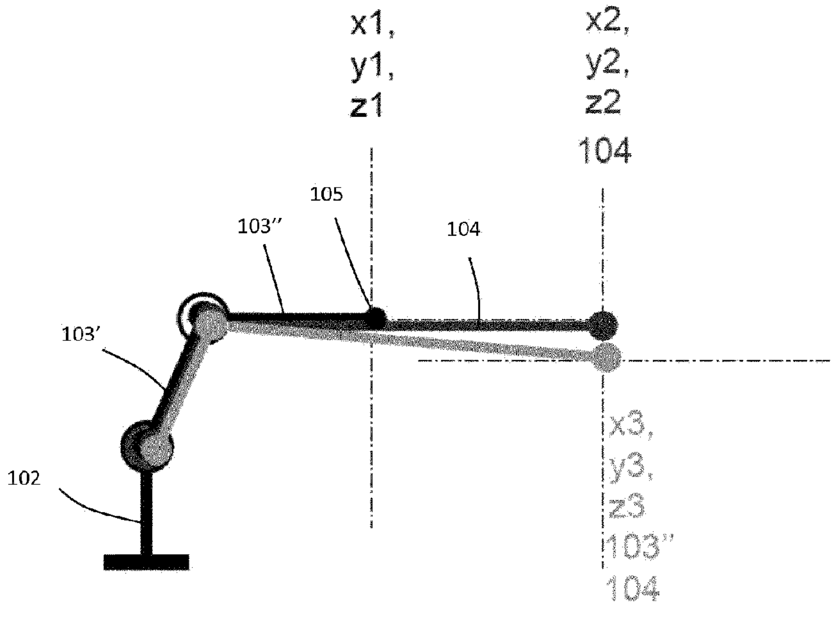
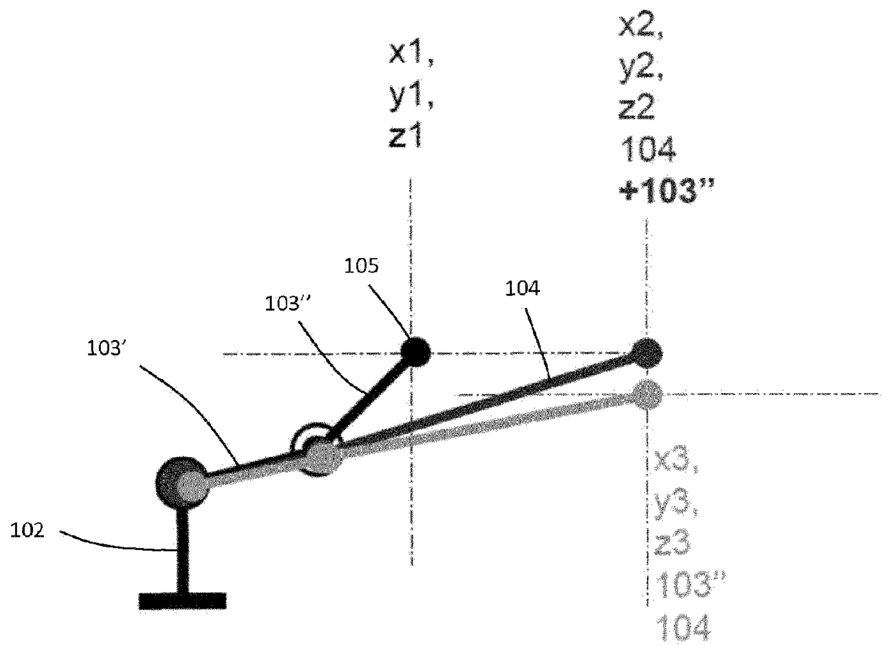


FIG. 2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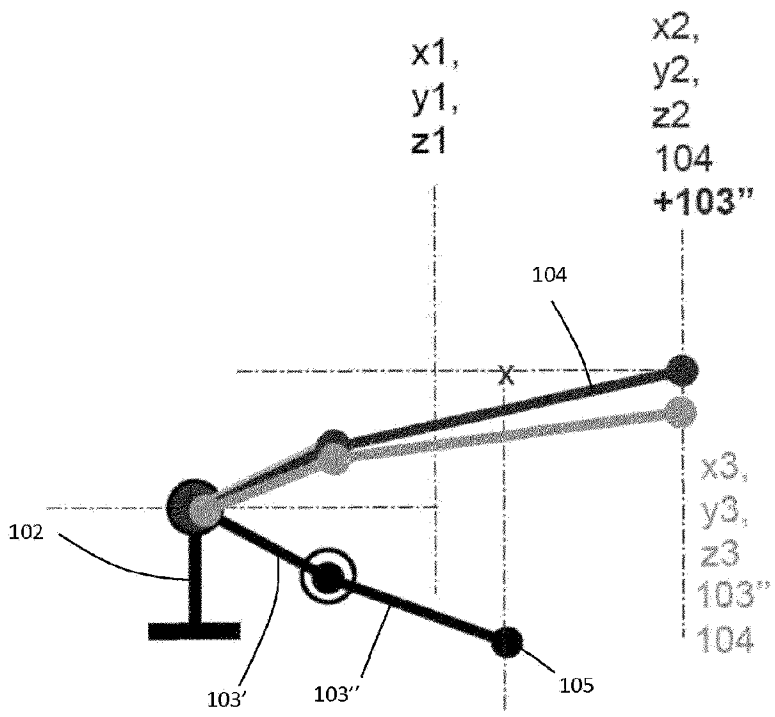
y1,
z1
x2,
y2,
z2
104
+103"
105
103"
104
103'
102
x3,
y3,
z3
103"
104

FIG. 3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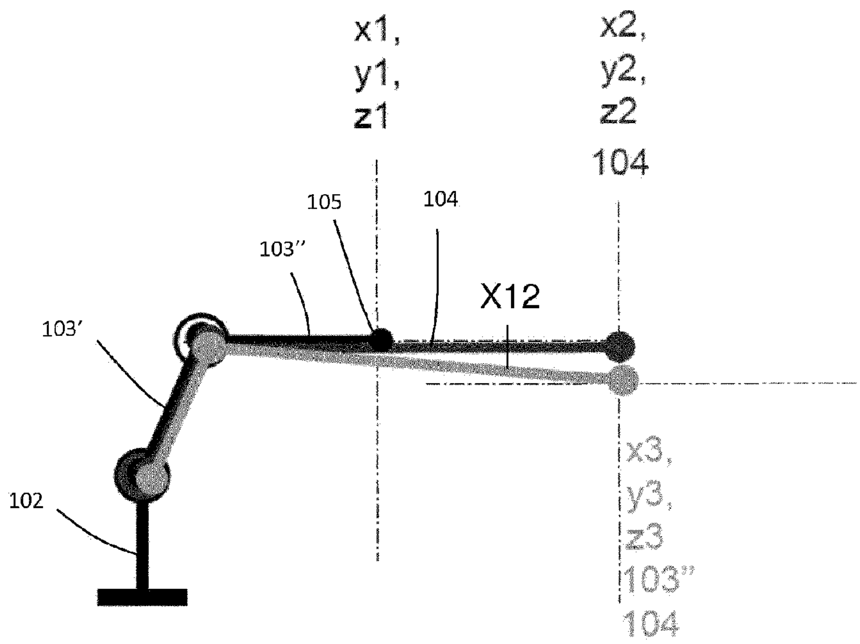
z1
x2,
y2,
z2
104
+103"
104
x
102
x3,
y3,
z3
103"
104
103'
103"
105

FIG. 4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y1,
z1
x2,
y2,
z2
104
105
104
103''
X12
103'
102
x3,
y3,
z3
103''
104

FIG. 5

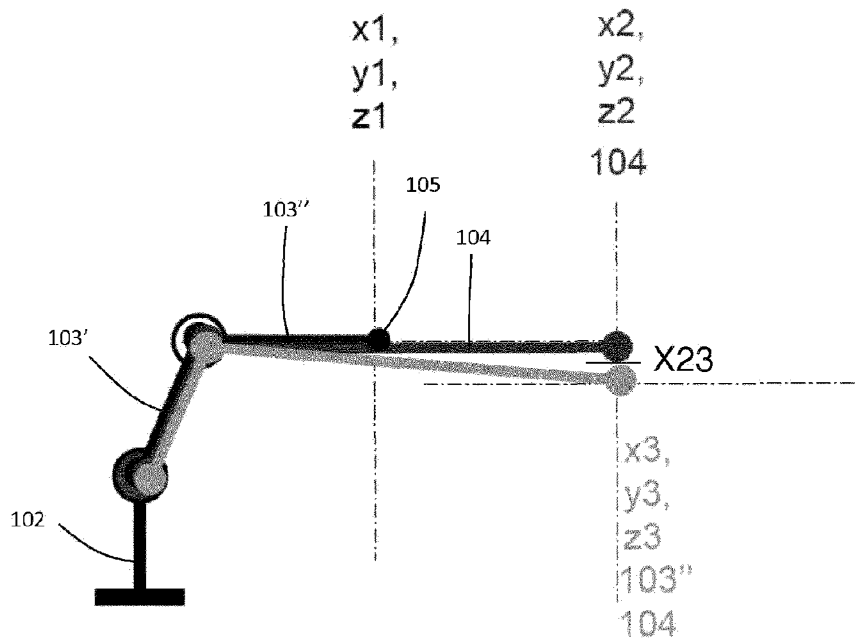
x1,
y1,
z1
x2,
y2,
z2
104
105
103''
104
103'
X23
102
x3,
y3,
z3
103''
104

FIG. 6