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D E C I S I O N
of 4 December 2000

Case Number: T 0135/97 - 3.2.6

Application Number: 91102041.0

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Title of invention:
Industrial robot control method and apparatus

Applicants:
KAWASAKI JUKOGYO KABUSHIKI KAISHA, et al

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 54, 56

Keyword:
"Novelty (yes)"
"Inventive step (yes)"

Decisions cited:
-

Catchword:
-



Case Number: T 0135/97 - 3.2.6

D E C I S I O N
of the Technical Board of Appeal 3.2.6
of 4 December 2000

Appellants:

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Decision under appeal:

Decision of the Examining Division of the
European Patent Office posted 23 August 1996
refusing European patent application
No. 91 102 041.0 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: P. Alting van Geusau
Members: T. Kriner
J. C. M. De Preter

Summary of Facts and Submissions

I. The appellants (applicants) lodged an appeal on 22 October 1996, against the decision of the Examining Division, dispatched on 23 August 1996, refusing European patent application No. 91 102 041.0. The fee for the appeal was paid simultaneously with the filing of the appeal. The statement of grounds was received on 27 December 1996.

II. The Examining Division held that the application did not meet the requirements of Article 52(1) EPC in conjunction with Articles 54 and 56 EPC, in particular because the subject-matter of the main request lacked novelty and the subject-matter of the auxiliary request did not involve an inventive step with regard to the disclosure of document:

D1: US-A-4 893 254.

In addition to D1 the following documents have been cited in the search report:

D2: US-A-4 873 476

D3: US-A-4 620 436

D4: US-A-4 677 568.

III. The appellants requested that the decision under appeal be set aside and a patent granted on the basis of the following documents:

Claims: 1 and 2 filed with letter of 13 October 2000.

Description: Pages: 1, 1a and 4 filed with letter of 13 October 2000.
Pages 5 to 16 as originally filed.

Drawings: Figures 1 to 7 as originally filed.

With the amendments in claim 2 and in the description on page 12 as agreed upon on 18 October 2000 (see minutes of the telephone conversation dated 18 October 2000).

IV. Independent claims 1 and 2 read as follows:

"1. A control method for an industrial robot having a base, a plurality of arms each having a predetermined length (L1-L7), a plurality of axes, a hand adapted to mount a workpiece and a tool fixedly mounted with respect to the base, the control method comprising the steps of:

- a) determining angular values θ_i of each axis corresponding to positions/postures of each axis when each position of a plurality of i predetermined positions of the workpiece mounted to the hand is successively located at the position of the distal end of the tool;
- b) determining - in a reverse matrix representation - the positions/postures \bar{X}_i of the robot base with respect to a coordinate system of the end of the hand by means of a forward transformation operation using each of the values θ_i for each axis and the length of said arms;
- c) determining - in a matrix representation - the positions/postures T_i of the distal end of the tool with respect to the coordinate system of the end of the hand, on the basis of the

positions/postures \bar{X}_i and the relationship P of the position/posture of the distal end of the tool with respect to the coordinate system of the robot base;

- d) determining intermediate positions/postures T_j each between two positions/postures T_i , using an interpolation function;
- e) determining - in a reverse matrix representation - the positions/postures \bar{X}_j of the robot base with respect to the coordinate system of the end of the hand, on the basis of the relationship P and the intermediate positions/postures T_j ;
- f) determining each of the angular values θ_j for each axis on the basis of the positions postures \bar{X}_j , using the reverse transformation operation of the forward transformation operation; and
- g) driving the robot using the values θ_j as command values."

"2. An apparatus for controlling an industrial robot having a base, a plurality of arms each having a predetermined length (L1-L7), a plurality of axes, a hand adapted to mount a workpiece and a tool fixedly mounted with respect to the base, the apparatus comprising:

- a) detection means for detecting angular values θ_i of each axis corresponding to positions/postures of each axis when each position of a plurality of i predetermined positions of the workpiece mounted to the hand is successively located at the position of the distal end of the tool;
- b) drive means for driving the axes;
- c) control means for controlling the drive means;
- d) the control means determining
- in a reverse matrix representation - the positions/postures \bar{X}_i of the robot base with respect to a coordinate system of the end of the

hand by means of a forward transformation operation using each of the values θ_i for each axis and the length of said arms;

- in a matrix representation - the positions/postures T_i of the distal end of the tool with respect to the coordinate system of the end of the hand, on the basis of the positions/postures \bar{X}_i and the relationship P of the position/posture of the distal end of the tool with respect to the coordinate system of the robot base;

- intermediate positions/postures T_j each between two positions/postures T_i , using an interpolation function;

- in a reverse matrix representation - the positions/postures \bar{X}_j of the robot base with respect to the coordinate system of the end of the hand, on the basis of the relationship P and the intermediate positions/postures T_j ;

- each of the angular values θ_j for each axis on the basis of the positions postures X_j , using the reverse transformation operation of the forward transformation operation; and

wherein said control means control the drive means using the values θ_j as command values."

V. In support of their requests, the appellants relied essentially on the following submissions.

D1 referred to a conventional industrial robot, wherein the tool was held by a hand of the robot and the workpiece was fixedly mounted with respect to the base. All calculations for controlling this robot related to a coordinate system of the robot base.

The inventors of the invention according to the present application had found, that when the tool was held by the robot hand, the rapid movements of the robot hand could result in damage to the wires and tubes connected to the tool. Therefore, they suggested to mount the workpiece at the hand of the robot and to fix the tool with respect to the robot base.

Since the provision of the reference coordinate system for the calculations for controlling such a robot at the robot base required substantial re-programming, the present invention suggested a control method which used a reference coordinate system at the robot's hand.

The use of such a reference coordinate system was neither known, nor suggested by the prior art.

Therefore, even when assuming that the tool and the workpiece shown in D1 could be exchanged at will, or when this exchange was regarded as a simple kinematic reversal, the subject-matter of the application involved further measures not shown or suggested in the prior art.

Reasons for the Decision

1. The appeal is admissible
2. *Amendments*
 - 2.1 The present claims essentially differ from the originally filed claims by the addition of the following features:

- A) each arm of the robot has a predetermined length which is used for determining the positions/postures \bar{X}_i of the robot base;
- B) the values θ_i are angular values which correspond to positions/postures of each axis when each position of a plurality of i predetermined positions of the workpiece is successively located at the position of the distal end of the tool;
- C) the positions/postures \bar{X}_i and \bar{X}_j are determined in a reverse matrix representation;
- D) the positions/postures T_i are determined in a matrix representation.

These features are disclosed in that part of the originally filed description which explains the principles and the operation of the present invention (see Figures 6, 7 and the corresponding part of the description).

The use of the length of the arms for determining the positions/postures \bar{X}_i of the robot base according to feature A is described on page 14, line 24 to page 15, line 18.

Feature B is disclosed in Figure 3 and the corresponding description on page 6, lines 21 to 28. Although this disclosure does not explicitly refer to the present invention, rather to a comparative apparatus and method for controlling an industrial robot, it is clear from the description as a whole (see in particular page 5, line 35 to page 6, line 6; page 8, lines 5 to 31; page 15, lines 19 to 30) that feature B is also used in the method and apparatus according to the present application.

Features C and D are evident from equations 17 (see page 11, line 27), 18 (see page 12, line 1) and 20 (see page 12, line 17) in conjunction with the explanation on page 13, lines 14 to 22.

2.2 The description has been amended to adapt it to the present claims, and to cite D1.

2.3 In view of the above assessments, the amendments do not give rise to objections under Article 123(2) EPC.

3. Novelty

3.1 D1 discloses a control method and an apparatus for controlling an industrial robot having a base, a plurality of arms (18, 22) each having a predetermined length, a plurality of axes, a hand (24) and a tool.

With respect to the control method, D1 describes only the steps of:

- defining a target position for the hand;
- defining the amount of change of each joint angle for each joint of the arms to be actuated in order to reach this target position, wherein an iterative pseudo inverse Jacobian having a damping factor is used;
- changing the magnitude of the damping factor for each iteration in accordance with the calculated work space distance between the hand and the target position; and
- adjusting the angles of the joints of the arms by an iteration process

(see for example claim 1 of D1).

The apparatus according to D1 for controlling the robot comprises drive means (14, 16) and control means (12) for controlling the drive means.

However, D1 is silent about the arrangement of the tool and the workpiece, and it is silent about the reference coordinate system used for the calculating steps for controlling the axes of the robot.

Therefore, D1 does not disclose any of the steps described in features a to g of claim 1 or feature d of claim 2 which inevitably require that

- the tool is separated from the robot and the workpiece is fixed to the hand of the robot; and
- the reference coordinate system is the coordinate system of the end portion of the hand.

3.2 Documents D2 to D4 are less relevant than D1.

D2 refers to a servomotor control method based on non-linear torque calculations, said method being used in an apparatus for controlling an industrial robot.

The method according to D2 is based on the detection of weights.

D3 refers to a method and an apparatus for calibrating a transformation matrix of a force sensor.

D4 refers to a method and a system for programming of the motional actions of a robot which method is based on Fourier transformations.

3.3 Novelty of the subject-matter of claims 1 and 2 can therefore be concluded.

4. *Inventive step*

4.1 Starting from a method and apparatus for controlling a conventional robot, wherein the tool is held by the robot hand and the workpiece is separated from the robot, the object of the present application is to provide a control method and an apparatus for controlling an industrial robot that can improve the quality of work such as sealing and welding and the like, simplify the processing in relation to flexible tubes for conveying fluid and cables that are connected to the tool, and simplify the configuration for the conveying and positioning of the work (see page 1, lines 23 to 30).

4.2 To achieve this object claims 1 and 2 propose control steps and control means suitable for controlling an industrial robot comprising a hand adapted to mount a workpiece and a tool fixedly mounted with respect to the robot base.

The essential difference of the claimed method and apparatus over the prior art is the use of a reference coordinate system which is located at the robot's hand.

The use of this reference coordinate system avoids a complete re-programming of the control system, because the exchange of the reference coordinate system in combination with the exchange of the tool and the workpiece creates a situation which is comparable with the situation according to the state of the art.

Since there is neither a suggestion in the state of the art for exchanging the usual arrangement of a tool and a workpiece of a robot, nor a suggestion to provide a particular control method for such an arrangement as proposed in the present claims, the subject-matter of claims 1 and 2 cannot be regarded as obvious.

Furthermore, the Board agrees with the appellants' line of argument according to which, even if it was obvious to arrange a workpiece at a robot's hand and to fix the tool separately from the robot, it was not obvious to control such a robot on the basis of calculations using a reference coordinate system at the robot's hand, because the selection of the reference point for a reference coordinate system in connection with the underlying problem to be solved is neither known from nor suggested in the available state of the art.

5. The Board therefore comes to the conclusion that the subject-matter of claims 1 and 2 according to the appellant's request is not disclosed in the available prior art and can also not be derived in an obvious manner from the cited documents. Accordingly it is novel and involves an inventive step (Articles 54 and 56 EPC).

Claims 1 and 2, together with the amended description and the originally filed figures, therefore form a suitable basis for the grant of a patent.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.
2. The case is remitted to the first instance with the order to grant a patent on the basis of the following documents:

Claims: 1 and 2 filed with letter of 13 October 2000.

Description: Pages: 1, 1a, 4 filed with letter of 13 October 2000.
Pages 5 to 16 as originally filed.

Drawings: Figures 1 to 7 as originally filed.

With the amendments in claim 2 and in the description on page 12 as agreed upon on 18 October 2000.

The Registrar:

The Chairman:

M. Patin



P. Alting van Geusau



