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Datasheet for the decision of 17 December 2015

Case Number: T 0559/12 - 3.2.07

Application Number: 02252685.9

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Language of the proceedings: EN

Title of invention:
Robot controller including bending compensation means

Applicant:
FANUC CORPORATION

Headword:

Relevant legal provisions:
EPC Art. 56

Keyword:
Inventive step - main request and auxiliary request (no)

Decisions cited:

Catchword:

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Case Number: T 0559/12 - 3.2.07

D E C I S I O N
of Technical Board of Appeal 3.2.07
of 17 December 2015

Appellant: (Applicant)	FANUC CORPORATION 3580 Shibokusa Aza-Komanba Oshino-mura Minamitsuru-gun Yamanashi 401-0597 (JP)
Representative:	Haseltine Lake LLP Redcliff Quay 120 Redcliff Street Bristol BS1 6HU (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 12 October 2011 refusing European patent application No. 02252685.9 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	H. Meinders
Members:	G. Patton
	C. Brandt

Summary of Facts and Submissions

I. The applicant (appellant) lodged an appeal against the decision to refuse the European patent application No. 02 252 685.9.

II. The following documents considered in the impugned decision are referred to:

D4: JP-A-9-123075
D5: EP-A-0 519 081

III. According to the impugned decision, the claimed subject-matter of the main and the auxiliary request, both filed with letter dated 26 August 2011, was lacking inventive step on the basis of D5 combined with the common general knowledge of the skilled person (Article 56 EPC). D4 was mentioned for illustrating this common general knowledge.

IV. With the statement setting out the grounds of appeal the appellant requested to set aside the impugned decision and to grant a patent on the basis of the main or the auxiliary request, both underlying the impugned decision.

V. With a communication dated 6 October 2015 and annexed to the summons for oral proceedings the Board presented its preliminary non-binding opinion that, taking account of the appellant's arguments, it could not find fault in the reasoning and the conclusion of the impugned decision with respect to both requests.

VI. Oral proceedings took place on 17 December 2015. It was discussed whether the subject-matter of the claims 1 of the main and the auxiliary request meets the

requirements pursuant to Article 56 EPC starting from the teaching of D5 as closest prior art in combination with the common general knowledge of the person skilled in the art.

VII. The appellant requested that the decision under appeal be set aside and a patent be granted on the basis of the main request, or, alternatively, on the basis of the auxiliary request, both requests underlying the impugned decision and filed with letter dated 26 August 2011.

The Board announced its decision at the end of the oral proceedings.

VIII. Independent claim 1 of the **main request** reads as follows:

"A robot controller operable to drive respective links of a robot by respective actuators, comprising a data processor (1) adapted to determine bending produced in respective joints of the robot and to determine offset in a target position and/or attitude of a part of the robot produced by said bending, and to determine corrected positions for said actuators to drive said robot part to a position and/or attitude to which a correction having the same magnitude as that of said determined offset is applied in an inverse direction;

wherein the data processor (1) is adapted to correct said offset in operation of the robot by determining said bending in respective joints of the robot by calculating said bending at a present target position and/or attitude of a robot hand distal end as provided by a teaching program, the bending calculation comprising:

reading the present axial angles and actual rotational speeds of respective x-, y-, and z- axes (x, y, z) of the respective joints for said present target position and/or attitude;

determining the torques (Tx, Ty, Tz) about said respective x—, y-, and z- axes (x, y, z) for said present target position and/or attitude; and

dividing said torques (Tx, Ty, Tz) by the spring constants (kx, ky, kz) of said x-, y-, and z- axes (x, y, z) to obtain bendings (Δα, Δβ , Δθ) of said respective joints about their respective axes;

the data processor (1) being adapted to determine said corrected positions for said actuators by a converging calculation in which forward kinematics in consideration of the bendings and inverse kinematics ignoring the bendings are alternately repeated to drive the robot hand distal end, as said driven robot part, to the corrected position and/or attitude thereof corresponding to said present target position and/or attitude of the robot hand distal end taking said bendings (Δα, Δβ , Δθ) of the respective joints into consideration."

Independent claim 1 of the **auxiliary request** reads as follows (amendments as compared to independent claim 1 of the main request are in bold with deletions in strikethrough; emphasis added by the Board):

"A robot controller operable to drive respective links of a robot by respective actuators, comprising a data processor (1) adapted to determine bending produced in respective joints of the robot and to determine offset

in a target position and/or attitude of a part of the robot produced by said bending, and to determine corrected positions for said actuators to drive said robot part to a position and/or attitude to which a correction having the same magnitude as that of said determined offset is applied in an inverse direction;

wherein the data processor (1) is adapted to correct said offset in operation of the robot by determining said bending in respective joints of the robot by calculating said bending at a present target position and/or attitude of a robot hand distal end as provided by a teaching program, **corrected D—H parameters being used to perform coordinate transformation between the position and/or attitude of the robot hand distal end in world and tool coordinate systems respectively**, the bending calculation comprising:

reading **(S2)** the present axial angles and actual rotational speeds of respective x-, y-, and z- axes (x, y, z) of the respective joints for said present target position and/or attitude;

determining **(S3)** the torques (Tx, Ty, Tz) about said respective x—, y-, and z- axes (x, y, z) for said present target position and/or attitude; ~~**and**~~

dividing **(S4)** said torques (Tx, Ty, Tz) by the spring constants (kx, ky, kz) of said x-, y-, and z- axes (x, y, z) to obtain bendings (Δα, Δβ , Δθ) of said respective joints about their respective axes; **and**

determining (S5) corrected D-H parameters (α, β, θ0) in consideration of the bendings by adding said bendings (Δα, Δβ , Δθ) to corrected D—H parameters (αs, βs, θ0s) where no bending is produced;

the data processor (1) being adapted to determine **(S6 — S17)** said corrected positions for said actuators by a converging calculation in which forward kinematics **by using said corrected D-H parameters (α, β, θ0)** in consideration of the bendings and inverse kinematics ignoring the bendings **by using said corrected D-H parameters (αs, βs, θ0s) where no bending is produced** are alternately repeated to drive the robot hand distal end, as said driven robot part, to the corrected position and/or attitude thereof corresponding to said present target position and/or attitude of the robot hand distal end taking said bendings (Δα, Δβ, Δθ) of the respective joints into consideration."

IX. The submissions of the appellant are essentially as follows:

Main request

Claim 1 of this request differs from D5 in that:
- it is applicable to a six-axis robot;
- it relates to a robot "in operation"; and
- it comprises "a converging calculation in which forward kinematics in consideration of the bendings and inverse kinematics ignoring the bendings are alternately repeated" to drive a robot hand to a corrected position.

Since these distinguishing features are neither disclosed nor suggested by any of the cited prior art documents, inventive step should be acknowledged for the claimed subject-matter.

Auxiliary request

Additionally to the above, claim 1 of the auxiliary request differs from the robot controller of D5 in the use of corrected D-H parameters. Their use would not be obvious in the controller of D5 which concerns the correction in only one direction $\Delta\theta$, with no coordinate transformation.

In view of the technical effects, the problem to be solved can be defined as to provide a method to perform complex three-dimensional corrections of the robot endpoint position in short time.

Since the skilled person would not be directed to the claimed solution taking into consideration D5 or any of the other cited prior art documents, inventive step should be acknowledged for this claimed subject-matter.

Reasons for the Decision

1. *Main request*

1.1 Since the Board considers that the subject-matter of claim 1 of the main request lacks inventive step (see below) there is no need in this decision to deal with the question whether the amendments made therein comply with Articles 84 and 123(2) EPC.

1.2 Like claim 1 of the main request, document D5 lies in the field of robot controllers and aims at correcting the deflection of a robot endpoint (column 1, lines 3-10). D5 is therefore regarded as an appropriate closest prior art for assessing inventive step.

1.3 As put forward in the impugned decision, point 2.1, the bending calculation in D5 comprises the following steps:

(a) The configuration of the robot θd (the angle of each axis) corresponding to the robot endpoint position command value Xd0 is first determined by executing inverse transformation without taking into consideration the bendings, using equation (3), see column 4, lines 15-22; column 6, lines 25-36);

(b) From these angles θd, the joint torque τ acting on each axis is determined, using the robot motion equations, see column 4, lines 15-28; column 6, lines 37-40;

(c) Once said joint torques τ are determined, a deflection angle (bending) Δθd can be computed for each joint by using a relationship equation previously stored in the robot control unit, see column 4, lines 28-32; column 5, lines 10-20; column 6, lines 41-48 and figures 2-4;

(d) The actual position Xd1 of the endpoint of the robot is finally determined by executing forward kinematics in consideration of said bendings (column 5, lines 20-37; column 7, lines 12-17). Although initially contested in the statement setting out the grounds of appeal, the appellant agreed with the Board at the oral proceedings that D5 actually discloses forward kinematics.

The command value θd for each axis is corrected by using said deflection angle Δθd, i.e. by applying it in an inverse direction (see column 6, line 49 to column 7, line 11).

As also mentioned in the impugned decision with respect to above step c), the embodiments disclosed in the present application correspond to the particular case of the relationship in D5 wherein the inclination Ap shown in figures 2 to 4 is the same in both the positive and negative regions of the joint torque τ and no backlash is considered (see column 4, line 33 to column 5, line 10). In that case, the inclination Ap corresponds to the spring constant k of claim 1 and the bending Δθd is calculated according to page 6, lines 11-20 of the description of the present application.

1.4 According to the appellant the claimed subject-matter differs from D5 in that:

(i) D5 relates to a four-axis robot, whilst the present invention provides a correction technique applicable to a six-axis robot;

(ii) D5 relates to an offline correction process, whilst the present invention relates to an online process, i.e. a robot in operation; and

(iii) the present invention features "a converging calculation in which forward kinematics in consideration of the bendings and inverse kinematics ignoring the bendings are alternately repeated" to drive a robot hand to a corrected position.

1.5 With respect to feature (i)

1.5.1 The appellant considers that the disclosure of D5 is limited to a four-axis robot. However, as put forward in point 5.2 of the annex to the summons for oral proceedings (hereafter the "annex"), and also discussed

at the oral proceedings, the Board cannot share this view. The passage of D5 the appellant refers to for supporting its view, column 3, lines 51-55, concerns a specific example shown in figure 1, i.e. not the complete disclosure of D5. Indeed, as explicitly mentioned, column 7, lines 33-36, the invention of D5 "may be applied to a robot **with any number of axes**". Therefore, the selection of a six-axis robot is already part of the disclosure of D5. Further, as also admitted by the appellant at the oral proceedings, claim 1 is **not limited** to a correction technique of a six-axis robot (see also application as originally filed, page 4, final complete paragraph).

The fact that, as further argued by the appellant, D5 does not consider the bendings in the three directions X, Y and Z as claimed (see claim 1, page 22, lines 21-24 and figures 1 and 2 of the present application) but rather the bending in a single direction only (column 4, line 6; see Δθd1, Δθd2 in figure 1 of D5) does not change the above facts. It might well be that claim 1 covers a more complex situation than that disclosed in D5. However, claim 1 still does not limit the robot to a six-axis robot and further also encompasses the simplified single direction bending configuration of D5.

Therefore, feature (i) is not considered as a distinguishing feature over D5.

1.5.2 It is further remarked that, should performing the same bending computation in three different directions instead of only in one for each joint have been regarded as a distinguishing feature, it could still not justify inventive step. Indeed, this merely relates to the calculation capacities of the controller at the

disposal of the skilled person for performing (more frequently) the same known computations.

1.6 With respect to feature (ii)

1.6.1 The appellant considers that, in view of the passage of D5, column 1, lines 17-58, describing the background art the correction of the deflection would not be performed in operation as claimed but off-line. For the appellant, since the correction according to the background art would be performed off-line, the disclosure of D5 can only be interpreted in view of the problems derived on this basis. This interpretation would also be confirmed by the rest of the disclosure of D5, such as column 2, lines 15-29 and column 3, lines 18-24.

1.6.2 The Board, however, cannot share the appellant's view since the actual disclosure of D5, i.e. not its prior art, relates to an online process such that the correction is performed with the robot in operation. This is unambiguously derivable by the skilled reader from the passage of D5, column 2, lines 15-24, where the robot operation program is prepared off-line but "the robot is **operated according to this program**", i.e. on-line. This is further confirmed by the passages in column 3, line 56 to column 4, line 14 and column 7, lines 18-32. The additional passage of D5 referred to by the appellant, column 3, lines 18-24, merely mentions that the robot can recognize the actual position of its endpoint in the deflected state. It does not deal with the correction - whether on-line or not - of said deflection.

It is also emphasized that, like claim 1 (see page 22, lines 18-20 of claim 1), D5 discloses the program

including a teaching program for the determination of the bendings which is performed online (see discussion of the disclosure of D5 under point 1.3 above, last paragraph).

Therefore, feature (ii) is not considered as a distinguishing feature over D5.

1.6.3 It is further remarked that the skilled person iterating the method of D5, which is regarded as being obvious in view of the skilled person's common general knowledge as discussed under point 1.7 below, would directly think of performing the corrections on-line in order to avoid "stop-and-go" for the robot hand distal end to reach a target position. Therefore, even if above feature (ii) were to be regarded as a distinguishing feature over D5, it could still not justify inventive step.

1.7 With respect to feature (iii)

1.7.1 In its written submissions, the appellant argued that the disclosure of forward kinematics in D5 would be either obscure or incomplete.

As put forward in the annex, point 5.2, the Board cannot share this view, referring to column 5, lines 20-21 of D5, where forward kinematics is unambiguously disclosed (see also impugned decision, point 2.1.d).

1.7.2 At the oral proceedings the appellant agreed that D5 discloses forward kinematics. It then argued that the purpose of D5 was twofold: on the one hand to provide a deflection correction method, on the other hand to provide a deflection recognizing method (column 2, lines 15-29).

For the appellant, the actual position Xd1 would be determined only in order to fulfill the latter purpose. It would then not be related to the former purpose of correcting the deflection. This would be confirmed by the fact that Xd1 would not be used for determining the deflection angles Δθd1 or Δθd2, i.e. for calculating the corrected amounts of operation commands to be given to the respective joints.

1.7.3 The Board agrees with the appellant that **iteration** as mentioned in feature (iii) is not disclosed in D5 so that iteration is regarded as the only distinguishing feature of claim 1 over D5.

However, as put forward in the annex, point 5.2, and also discussed at the oral proceedings, the Board, contrary to the appellant's view, agrees with the findings of the examining division that iteration belongs to the common general knowledge of the skilled person in the present technical field in order to improve accuracy of the calculation. No document is deemed necessary for acknowledging such obviousness (impugned decision, point 2.4). Hence, it cannot justify inventive step.

1.7.4 As further discussed at the oral proceedings, the Board is of the opinion that when performing iteration in view of increasing accuracy, the skilled person will immediately think of making use of the actual position Xd1 and the deviation Xd1-Xd0 in order to give a new command position "Xd0" in the first step of the deflection correction method of D5. As a matter of fact, the command value (Xd0) initially required for determining the configuration of the robot in the method of D5 is expressed in a similar coordinate

system as that of the endpoint position (Xd1) (see point 1.3(a) above). As a consequence, the appellant's argument that the actual robot endpoint position would not be used for determining the corrected amounts of operation commands to be given to the respective joints is not convincing, when considering that iteration is an obvious measure for the skilled person.

1.7.5 Further, the Board agrees with the appellant that the correction is performed in D5, column 5, lines 20-37 and column 6, line 49 to column 7, line 11 using deflection angles Δθd (impugned decision, point 2.1.d). However, as also put forward at the oral proceedings this is not excluded by claim 1. As a matter of fact, it is actually not specified when and on which basis the correction takes place in the claimed method. Therefore, the appellant's argument that the correction is applied in D5 using the deflection angles Δθd is not convincing for justifying inventive step.

1.8 In view of the above the Board cannot find fault in the reasoning and the conclusion of the impugned decision with respect to the main request.

2. *Auxiliary request*

2.1 Since the Board considers that the subject-matter of claim 1 of the auxiliary request lacks inventive step (see below) there is no need in this decision to deal with the question whether the amendments made therein comply with Articles 84 and 123(2) EPC.

2.2 With respect to claim 1 of the main request, claim 1 of the auxiliary request further specifies the use of "corrected D-H parameters" (see impugned decision,

point 3; statement of grounds of appeal, page 4, penultimate and last paragraphs; point VIII above).

2.3 D5 is regarded as the closest prior art for claim 1 of the auxiliary request for the same reasons as those given under point 1.2 above for the main request.

2.4 The appellant argues that the use of corrected D-H parameters is not disclosed in D5 and would not be obvious in the context of the converging calculation which accounts for the twists $\Delta\alpha$, $\Delta\beta$ and $\Delta\theta$ determined from the torques about the x, y and z-axes of each joint. In D5 there would be mention of a correction in only one direction $\Delta\theta$, i.e. not the two other directions $\Delta\alpha$ and $\Delta\beta$. There would be in D5 no coordinate transformation as claimed (claim 1, page 22, lines 20-23 and page 23, lines 5-20) and as taught in the application as originally filed. The technical effects of the use of corrected D-H parameters would then be to provide an easy way to perform complex corrections in the three directions within tight time constraints. Since the skilled person would not be directed to the solution taking into consideration D5 or any of the other cited prior art documents when trying to solve the technical problem of providing a method to perform complex three-dimensional corrections in short time, inventive step should be acknowledged for the claimed subject-matter.

2.5 The Board agrees with the appellant that D5 does not disclose the use of the corrected D-H parameters so that it is, in addition to "iteration" (see point 1.7 above), a further distinguishing feature of claim 1 of the auxiliary request over D5.

However, as admitted by the appellant, such corrected D-H parameters are well-known in the technical field of robotics. As a result, the Board is of the opinion that the selection of the corrected D-H parameters among such well-known models is obvious and also arbitrary so that it cannot justify inventive step (see also impugned decision, point 3).

This is all the more true since, as appearing from the discussion at the oral proceedings, the technical effects alleged above by the appellant do not appear in the application as originally filed. The advantages mentioned in the paragraphs linking pages 20 and 21 and pages 10 and 11 - the robot can be operated at high speed with high accuracy - cited by the appellant concern the method in its entirety as originally claimed, not the use of the corrected D-H parameters in particular, the latter not even being mentioned in the original claims. Consequently, no specific technical effect can be attributed to the choice of corrected D-H parameters.

The above also confirms *a posteriori* that the two distinguishing features of claim 1 over D5 ("iteration" as discussed under point 1.7 above for the main request and the use of "corrected D-H parameters") can be dealt with independently from each other for assessing inventive step of the claimed subject-matter, in view of the lack of synergy in their technical effects.

2.6 It is further emphasized that the fact that the claimed method foresees more complex three-dimensional computations cannot justify inventive step, as already discussed under point 1.5.2 above. In particular, the skilled person will know how to apply the in any case usual and known corrected D-H parameters also in more

complex situations. The availability of more powerful computation facilities in fact allows for this.

Finally, contrary to the appellant's allegation, the method of D5, column 6, lines 12-17, also comprises "coordinate transformation" as in claim 1 of the auxiliary request.

2.7 Therefore, the Board cannot find fault in the reasoning and the conclusion of the impugned decision with respect to claim 1 of the auxiliary request.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

G. Nachtigall H. Meinders

Decision electronically authenticated