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D E C I S I O N
of 4 March 1997

Case Number: T 0279/94 - 3.2.2

Application Number: 90101897.8

Publication Number: 0381185

IPC: B25J 13/08

Language of the proceedings: EN

Title of invention:

Method and apparatus for controlling tracking path of working point of industrial robot

Applicant:

HITACHI, LTD., et al

Opponent:

-

Headword:

-

Relevant legal provisions:

EPC Art. 52(1), 56, 123(2)

Keyword:

"Inventive step (yes), after amendment"

Decisions cited:

-

Catchword:

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Boards of Appeal

Chambres de recours

Case Number: T 0279/94 - 3.2.2

D E C I S I O N
of the Technical Board of Appeal 3.2.2
of 4 March 1997

Appellant: HITACHI, LTD.
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Decision under appeal: Decision of the Examining Division of the
European Patent Office posted 16 November 1993
refusing European patent application
No. 90 101 897.8 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: H. J. Seidenschwarz
Members: C. G. F. Biggio
J. C. M. De Preter

Summary of Facts and Submissions

- I. European patent application No. 90 101 897.8, claiming the priority of patent application No. 20 712/89, filed in Japan on 1 February 1989, was filed on 31 January 1990. It concerns a method and an apparatus for controlling the tracking path of a working element of an industrial robot.
- II. The application was refused by a decision of the Examining Division dated 16 November 1993.

The Examining Division held that the subject-matter of independent "method" Claim 1 and "apparatus" Claim 8, as filed on 12 August 1993, lacked an inventive step over the teaching of the prior art document: D2 = R. P. Paul: "Robot Manipulators, The Computer Control of Robot Manipulators", 1981, MIT PRESS, Cambridge, Massachusetts and London, England, pages 118 to 155.

- III. On 14 January 1994, an appeal was lodged against that decision. The appeal fee was paid the same day and the statement of grounds was filed on 15 March 1994.
- IV. In a communication annexed to the summons to oral proceedings, the Board
- drew the appellant's attention to prior art document EP-A1-0 271 691, referred to as document D1, and
 - expressed the provisional opinion that the disclosure of that document could be relevant for the evaluation of any inventive step in the subject-matter of the pending application.

V. During the oral proceedings, which were held on 4 March 1997, the appellant requested that the decision under appeal be set aside and a patent be granted on the basis of newly drafted Claims 1 and 2 and new description pages 1 to 9, 9a and 10, filed during the oral proceedings, and description pages 11 to 54 and the drawings of the application as originally filed.

VI. The newly drafted Claims 1 and 2 read as follows.

Claim 1

"A method for controlling a tracking path of a working element (3) so that the working element (3) moves along a path having a predetermined positional relationship with a work piece (5) by adjusting the relative positional relationship between the working element and the work piece through the movement of individually movable at least one moving element (1, 2, 4) each being operatively coupled with either the working element or the work piece in a prescribed coupling condition, comprising the steps of:

allotting individual orthogonal coordinate systems (1a, 2a, 3a, 4a, 5a) to said working element (3), said work piece (5) and said moving elements (1, 2, 4), each coordinate system having an individual discriminator represented by a numerical value;

setting a first coordinate system (5a) with discriminator β of said coordinate systems as a coordinate system expressing the data for controlling the movement of said working element and storing said controlling data together with their discriminator β ;

describing, using a second coordinate system (1a) with discriminator α of the coordinate systems, during learning, the data representing the positions of the working element corresponding to specific points (51,

52) on the tracking path along which said working element is to move, on the basis of a prescribed working schedule to store the data together with the discriminator representative of the corresponding coordinate system and storing said position data together with their discriminator α ;

deciding, when executing a real job, with reference to said discriminators α , β if or if not said first coordinate system and said second coordinate system are the same;

and

if both coordinate systems are different coordinate systems, converting, with reference to the stored discriminators, the position data of the working element corresponding to the specific points into data expressed in the first coordinate system and controlling the movement of said working element on the basis of the converted data, wherein

the position data and the controlling data are given, stored and processed in matrix format".

Claim 2

"An apparatus for controlling a tracking path of a working element (3) of an industrial robot so that the working element (3) moves along a path having a predetermined positional relationship with a prescribed work piece (5), wherein the relative positional relationship between the working element and the work piece varies in accordance with the movement of at least one individually movable moving element (1, 2, 4), each being operatively coupled with either the working element or the work piece in a prescribed coupling condition, said apparatus comprising:

discriminators for discriminating individual coordinate systems (1a, 2a, 3a, 4a, 5a) allotted to said working element (3), said work piece (5) and said moving elements (1, 2, 4);

means (6) for controlling the movement of said working point on the basis of data expressed by a first coordinate system (5a) with discriminator β of said coordinate system;

means (63) for storing the discriminator of the selected first coordinate system;

means for describing, using a second coordinate system (1a) with discriminator α of the coordinate systems, during learning, the data representing the positions of the working element corresponding to specific points (51, 52) on the tracking path along which said working element is to move on the basis of a prescribed working schedule to store the data together with the discriminator representative of the corresponding coordinate system;

means (1001) for deciding, prior to executing actual work, if or if not said first coordinate system and said second coordinate system are the same from their discriminators (512, 591);

means (1001) for converting, with reference to the stored discriminators, if both coordinate systems are different coordinate systems, the position data of the working element corresponding to the specific points into data expressed in the first coordinate system and

means for supplying to said means (6) for controlling the movement of said working point said converted position data of the working point corresponding to said at least two specific points, wherein the position data and the controlling data are given, stored and processed in matrix format".

VII. In the written procedure and during the oral proceedings, the appellant made substantially the following submissions in support of its request.

The invention was concerned with operating systems comprising a robot cooperating, under the control of a single supervising computer, with a plurality of "peripherals", e.g. a positioner setting the position of work pieces, a conveyor conveying said work pieces, a travelling truck expanding the motion range of the robot, a sensor attached to the robot working tool and a further sensor located in the neighbourhood of the robot and sensing the working environment; the robot and each one of said peripherals having its own coordinate system, whereby the commands controlling the movements of the robot and of each one of said peripherals are, according to the common practice in the field, expressed and defined ("described" in the language of the application) with reference to the specific coordinate system pertaining to the robot and to each one of said peripherals, respectively.

In such operating systems, the synchronous and harmonic cooperation of the robot and its peripherals requires that all the commands controlling the movements of each element of the system are expressed in a single homogeneous coordinate system. According to the common practice in the field, such a single homogeneous coordinate system is fixed at the base of the robot

itself. It is, accordingly, necessary to convert all those controlling commands, which are not expressed with reference to said coordinate system, into controlling commands expressed with reference to that single coordinate system fixed at the base of the robot itself.

The prior art operating systems illustrated by documents D1 and D2 worked according to the so called "procedural driven approach"; this implying that all the algorithms, necessary to convert controlling commands and positions, not expressed with reference to the coordinate system fixed at the base of the robot itself, into controlling commands and positions effectively expressed with reference to said coordinate system, had to be written by a programmer beforehand and stored together with the global controlling software as an essential element thereof.

According to the prior art, the programmer, having already written the global controlling software, was, thus, compelled to extensively rewrite it; at least all the algorithms required for the unavoidable conversion work, by a new, or even slightly modified, configuration of the operating system.

This extensive rewriting of the global controlling software by a new, or slightly modified, configuration of the operating system was the drawback of the prior art, which the invention aimed to remedy.

The technical problem to be solved by the invention was, accordingly, that of providing a method and an apparatus for controlling the tracking path of a robot incorporated in such a complex operating system; the method and apparatus being such that an extensive rewriting of the global controlling software by new, or even slightly modified, configurations of the operating system was no more required.

The solution of that technical problem relied on the basic idea that all the algorithms required for the unavoidable conversion work did not need to be written beforehand, and thereafter modified by the human programmer; this basic idea being particularly useful for all the complex operating systems working according to the well known "teach and repeat" method.

In order to implement this basic idea, it was the essential feature of the invention to allot a discriminator represented by a numerical value to each of the various coordinate systems and to store any controlling "data", i.e. any controlling command and position together with the discriminator corresponding to the coordinate system in which said controlling data had been taught, during the "teaching" phase, or "learning" in the language of the claims, before starting any "repeat" action.

Summing up, the claimed method and apparatus operated in such a way that they allowed the central processor itself to interpret the coordinate relationships of given data using, for this purpose, software means utilizing the discriminators and realising, accordingly, a control approach of the "data driven" type.

Neither prior art document D1, which represented the closest prior art on file, nor document D2 disclosed or even hinted at a method or at an apparatus according to the invention and as defined in Claims 1 and 2.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments*

2.1 In order to decide whether or not the newly drafted Claim 1 and 2 meet the requirements of Article 123(2) EPC, the Board considers it expedient to refer to the published version of the application as originally filed.

2.2 The subject-matter of the newly drafted "method" Claim 1 substantially reproduces the subject-matter of independent "method" Claim 3, as originally filed.

In respect of the features added to the subject-matter of said independent "method" Claim 3, suitable support is to be found: - on page 8 (lines 13 to 28) for the feature added to

- the method step of: "setting a first coordinate system...", respectively,
- to the method step of: "describing, using a second coordinate system...",

i.e. for the features:

- "... and storing said controlling data together with their discriminator β ",

respectively,

- "... and storing said position data together with their discriminator α "; and
- on pages: 11 (lines 24 to 28), 12 (lines 15 to 20) and 16 (lines 41 to 47) for the last feature: "... wherein the position data and the controlling data are given, stored and processed in matrix format", added to the very end of Claim 1.

2.3 The wording of "apparatus" Claim 2 is substantially identical to that of "apparatus" Claim 9, as originally filed.

The features added thereto merely reproduce, in "apparatus" terms, the above considered method features, added to the subject-matter of "method" Claim 1.

Suitable support for these added features is, consequently, also to be found in the above indicated passages of the published version of the application as originally filed.

2.4 New description pages 1 to 9, 9a and 10 substantially correspond to the originally filed description pages 1 to 10, the major amendment being the acknowledgement of prior art document D1, on added page 9a.

2.5 The Board is, accordingly, of the opinion that none of the amendments proposed for the pending application offend against Article 123(2) EPC.

3. *Novelty*

3.1 Document D1

This document discloses a method and an apparatus for controlling the three dimensional movements of a robot relative to a work piece. Control is effected using a chain of coordinate transformations, i.e. algorithms comprising products of matrices; the algorithms being freely programmable by the user, according to each configuration of the operative system comprising the robot and the work piece carrier. The robot is controlled with reference to significant points in space and equidistant interpolation points between the significant points. Approach of robot and work piece is effected by movements between the robot pedestal and the work piece carrier. The significant points and the interpolation points are given in a coordinate system fixed to the work piece carrier. All these points are transformed into the coordinate system fixed to the robot pedestal by using the freely programmable algorithms comprising products of matrices.

This document, thus, deals with the coordinate conversion problem for the control of an operative system comprising a robot and a work piece carrier; the operative system being susceptible of various different configurations. The disclosed solution of the coordinate conversion problem is represented by the use of the freely programmable algorithms comprising products of matrices, which, though freely programmable, have, nevertheless, to be "programmed", i.e. written beforehand by a human programmer and, consequently, rewritten for each new or modified configuration of the operative system.

Therefore, the method and apparatus according to Claims 1 and 2 of the pending application differ from the disclosure of document D1 by the features concerning the discriminators α and β , associated with different coordinate systems, and by the claimed use of said discriminators for calculating the various coordinate relationships.

3.2 Document D2

This document also deals with the coordinate conversions required by the control of an operative system comprising at least a robot and a work piece carrier, the operative system being susceptible of various different configurations. Its disclosure is essentially dedicated to the theoretical analysis of the method for carrying out the coordinate conversion, rather than to the practical implementation thereof. The coordinate conversions may be carried out by using chains of coordinate transformations (see e.g. pages 126 and 127), i.e. by using algorithms comprising products of matrices which, however, have to be "programmed", i.e. written beforehand by a human programmer and, consequently, rewritten for each new or modified configuration of the operative system.

The symbols "P" and "H", comprised in the robot control programs shown on pages 130 and 132 of document D2, might, at least prima facie, be construed as being somewhat analogous to the discriminators α and β mentioned in Claims 1 and 2 of the pending application; this because they identify two different coordinate systems.

The Board is, however, of the view that a disclosure of the discriminators α and β , within the meaning of Claims 1 and 2 of the pending application, is not to be found in document D2.

The essential reasons leading the Board to this view are:

- the fact, already mentioned, that according to this document, the algorithms comprising products of matrices, must be "programmed", i.e. written beforehand or rewritten for each new or modified configuration of the operative system, in spite of the fact that "P" and "H" are comprised in the robot control programs shown on pages 130 and 132 of said document; and
- the fact that the use of the symbols "P" and "H", in the same manner as the discriminators α and β are used according to Claims 1 and 2 of the pending application, is not disclosed by said document.

3.3 It follows from the above, that neither document D1 or D2 discloses a method and an apparatus having all the features claimed by Claims 1 and 2 of the pending application. Therefore said subject-matter can be regarded as new within the meaning of Article 54 EPC.

4. *Inventive Step*

4.1 Problem

According to documents D1 and D2, the programmer, having written beforehand the global controlling software, was compelled to extensively rewrite it, or at least all the algorithms required for the unavoidable conversion work, by new, or even slightly modified, configurations of the operating system.

Such an extensive rewriting of the global controlling software is, accordingly, to be considered as the drawback of the prior art which the invention had the aim to remedy.

The Board, thus, agrees that the technical problem to be solved by the invention was, indeed, that of providing a method and an apparatus for controlling the tracking path of a robot incorporated in complex operating systems which allows the avoidance of any extensive rewriting of the global controlling software by new, or even slightly modified, configurations of the operating system, i.e. which can easily cope both with any variation of the moving conditions of the moving elements and with the increasing or decreasing number of the moving elements, without having to modify the basic structure of a basic software program (see page 5, lines 17 to 27 of the published application).

4.2 Solution

Having regard to the disclosure and to Claims 1 and 2 of the pending application, the Board construes the subject-matter of said claims as requiring that:

- the solution of the technical problem relies on the basic idea that all the algorithms required for the unavoidable conversion work do not even need to be written a first time, by the human programmer, and, accordingly, do not need to be rewritten for a new, or even slightly, modified configuration of the operating system; this basic idea being particularly useful for all the operating systems working according to the well known "teach and repeat" method;

- in order to implement this basic idea, it is the essential feature of the invention to allot a discriminator represented by a numerical value to each of the various coordinate systems and to store any controlling "data", i.e. any controlling command and position together with the discriminator corresponding to the coordinate system in which the controlling data has been taught, during the "teaching" phase, before starting any "repeat" action;

- the discriminator contains in itself the indication in which coordinate system any controlling "data" has been taught and is intended for supplying the processor of the controlling computer with the information necessary to allow the processor to carry out a routine comprising the steps of:
 - comparing the value of the discriminator stored together with a controlling command or a controlling position under elaboration with the discriminator of the coordinate system in which the controlling command has to be carried out and the controlling position has to be reached, i.e. with the discriminator of the coordinate system fixed at the base of the robot itself;

 - deciding, on the basis of the result of that comparison, whether or not said two discriminators are identical and, thus, whether or not coordinate conversion of the controlling "data" is required;

- executing, if such a coordinate conversion is indeed required, a first coordinate conversion of the controlling "data" under elaboration from the coordinate system in which this controlling "data" has been taught into a neighbouring coordinate system, also indicated by the discriminator stored together therewith; and
- repeating the previous steps until the result of the comparison indicates that the controlling "data" under elaboration is expressed with reference to the coordinate system fixed at the base of the robot itself.

The Board is, consequently, satisfied that

- the operating system according to the invention works according to the so called "data driven approach"; this implying that all the algorithms, necessary to convert controlling commands and positions, not expressed with reference to the coordinate system fixed at the base of the robot itself, into controlling commands and positions effectively expressed with reference to said coordinate system are computed, only if required and to the required extension, by the processor of the controlling computer carrying out the previously summarized routine and, thus, do not need to be written by a programmer beforehand and stored together with the global controlling software as an essential element thereof, and
- the necessity of extensively rewriting the global controlling software by any new, or even slightly modified, configuration of the operating system representing the drawback of the prior art is thereby eliminated.

4.3 Summing up, neither document D2 nor document D3 (see point 3 above) discloses the use of discriminators associated with the different coordinate systems, identifying the latter, and intended to allow the central processor itself and alone to calculate, on the basis thereof, the various spatial relationships between "data" expressed with reference to the different coordinate systems.

The Board is, consequently, of the view that these documents do not provide the person skilled in the art with any hint leading him to replace a control method and apparatus of the known "procedural flow" type, where such "discriminators" merely identify the various coordinate systems, with a control method and apparatus of the "data driven" type, i.e. of the type in which, the discriminators are associated with the different coordinate systems, not merely for identifying the latter, but for allowing the central processor itself and alone to calculate the various spatial relationships between data expressed with reference to the different coordinate systems, thereby allowing the central processor to cope both with any variation of the moving conditions of the moving elements and with the increasing or decreasing number of moving elements, without having to modify the basic structure of a basic software program.

4.4 The Board, accordingly, concludes that the subject-matter of Claims 1 and 2 involves an inventive step as required by Article 56 EPC.

Order

For these reasons it is decided that:

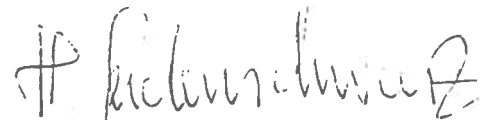
1. The appealed decision is set aside.
2. The case is remitted to the first instance with the order to grant a patent on the following basis:
 - Claims 1 and 2, and description pages 1 to 10, as filed during the oral proceedings;
 - description pages 11 to 54 and the drawings as originally filed.

The Registrar:



S. Fabiani

The Chairman:



H. Seidenschwarz



