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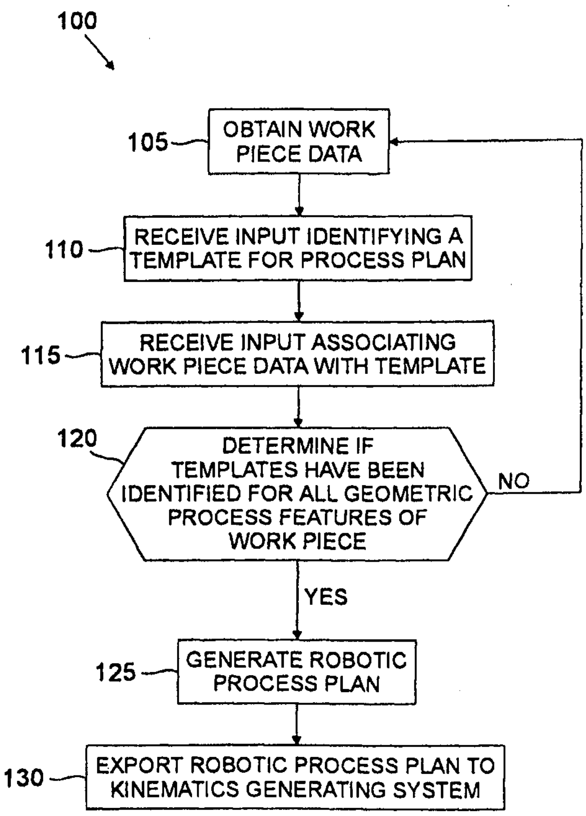
(54) Title: ROBOTIC PROCESS PLANNING USING TEMPLATES

(57) Abstract

A method of generating a robotic process plan (125) for performing a process on a work piece (105) includes a step of receiving input identifying a template (110) corresponding to a plurality of geometric features (120) of the work piece (105), each geometric feature (120) associated with one or more robotic process elements. The method further includes a step of receiving input associating work piece data (105) with the identified template (110), plan based on the associated work piece data (105) and the robotic process elements associate with the template (110).



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ROBOTIC PROCESS PLANNING USING TEMPLATES

Field of the Invention

The present invention relates generally to the field of robotic processes, and more particularly, to process planning for robotic processes.

Background of the Invention

Robotic devices have attained widespread use in the manufacturing environment in both assembly processes and work processes. Common types of robotic assembly processes include the population of printed circuit boards and other pick and place operations. Common types of work processes include robotic welding, cutting, grinding, glueing and the like.

Robotic devices require programming to perform the movements to carry out such processes. One method of programming includes manipulation of a robotic device with a numerical controller to step through an operation. In particular, an operator uses a numerical controller to slowly step the robotic device through the operations that the robotic device will perform on a repetitive basis. The operator then stores the appropriate set of steps for later execution.

To carry out the numerical controller programming, the operator typically sets up a work cell that includes the robot to be used, a sample work piece, and appropriate fixturing. The above-described programming technique is adequate for highly repetitive operations, such as small electronic component manufacturing, automotive manufacturing and the like.

However, the numerical programming technique has significant drawbacks in less repetitive operations, for example, large structural operations.

In particular, many large structural operations, such as ship, bridge, building and aircraft construction do not have assembly and work processes that are highly repetitive. As a result, the cost associated with developing a work cell numerical programming environment for robotic processes in such large structural operations cannot be easily recovered. Because robotic process programming is not cost effective, potentially dangerous and costly manual labor is often selected for work processes in large structural operations.

One potential solution to the problems presented by maintaining a work cell to develop numerical programming for a robotic process is the use of offline robotic programming systems. Offline robotic programming systems allow the movement of the robot, or *robotic path plan*, to be developed without actual movement of the robot. One method of carrying out offline robotic programming is to use computer simulation to simulate the work cell programming environment. In particular, such a method allows the operator to step through a robotic program using a computer-simulated robot and a computer-simulated work piece. The offline robotic programming system therefore does not require the manipulation of an actual workpiece in its associated fixturing devices.

Another offline robotic programming system is shown in U.S. Patent No. 5,511,147 to Abdel-Malek. U.S. Patent No. 5,511,147 shows a system in which an operator defines points in Cartesian space that represent travel points of the robot in a process. In other words, the operator defines the robotic path plan on a computer file by pointing to various start and stop points. The computer system then automatically generates the *robotic kinematics*, or in other words, converts the robotic path plan from Cartesian space to robotic space.

The above systems, while somewhat automating the process of robotic path planning, still fail to solve adequately the problems posed by large structural operations having low process repetition rates. Accordingly, there exists a need for an offline planning system and method that increases the automation of the generation of robotic process programs.

Summary of the Invention

The present invention fulfills the above need, as well as others, by providing a robotic process planning system that allows for the selection of a predefined template comprising a plurality of geometric process elements. Data pertaining to the work piece (for example, structural data) is then associated with the template to define at least a portion of a robotic process plan. In this manner, multiple process elements of a robotic process plan may be automatically generated using a predefined template, thereby increasing the automation of the robotic process planning generation system.

A first embodiment of the present invention is a method of generating a robotic process plan for performing a process on a work structure. The method includes a step of receiving input identifying a template corresponding to a plurality of geometric features of the work structure, each geometric feature associated with one or more robotic process elements. The method further includes a step of receiving input associating work structure data with the identified template. The method also includes a step of generating the robotic process plan based on the associated work structure data and the robotic process elements associate with the template.

The above-described features and advantages of the present invention, as well as others, will become more readily apparent to those of ordinary skill in the art by reference to the following detailed description and accompanying drawings.

Brief Description of the Drawings

Fig. 1 shows a flow diagram of an exemplary robotic process planning method according to the present invention;

Fig. 2 shows an exemplary robotic process planning system according to the present invention;

Fig. 3 shows a flow diagram of an exemplary template generation method according to the present invention;

Fig. 4 shows a perspective view of an exemplary work piece and geometric process elements associated therewith; and

Fig. 5 shows a functional block diagram of an exemplary template library for use by a robotic process planning system according to the present invention.

Detailed Description

Fig. 1 shows a flow diagram of an exemplary robotic process planning method 100 according to the present invention. The method is preferably carried out at least in part by a processor-based system. By way of example, Fig. 2, discussed below, shows a processor-based based system configured to be a robotic process planning system 200 according to the present invention.

Referring to Fig. 1, the flow diagram 100 includes steps that allow for an operator to generate a robotic process plan for a work piece. A work piece is a device or set of devices on which a robotic operation will be performed. The robotic operation may be cutting, grinding, gluing, painting, deburring or welding. In the exemplary embodiment described herein, the robotic operation is welding. The robotic process plan typically includes a robotic path plan and preferably includes work process information. The robotic path plan describes the movement of a work tool attached to the robot arm and the work process information describes operational parameters of the attached work tool.

Referring briefly to Fig. 4, a work piece 410 is shown as a four piece structure comprising a base plate 412, a back plate 414, and first and second upright plates 416 and 418, respectively. The robotic operation to be performed on the work piece 410 is a welding operation in which the base plate 412 and back plate 414 are welded together along their intersecting seam 420, and in which the first and second upright plates 416 and 418, respectively, are each welded to both the base plate 412 and the back plate 414.

Referring again to Fig. 1, in step 105, data regarding the work piece is obtained. To this end, the operator may retrieve and view work piece data from a computer-aided design ("CAD") file. In the alternative, the operator may view paper blueprints. In a fully automated system, a CAD file or the like may simply be retrieved from a memory storage device. In any event, the work piece data preferably includes sufficient dimensional and orientation information to describe the work piece and its geometric structural features.

Thereafter, in step 110, the processor used in connection with the method of the present invention receives input identifying a template that corresponds to a plurality of *geometric process features* of the work piece for which a robotic path plan segment has not been defined. A geometric process feature is a portion of the work operation specifically applicable to the work piece. In particular, the geometric process feature relates to the work operation as it relates to a particular geometric element or structure on the work piece, such as a two surface corner, a through-hole, or a three surface corner. The template includes a predefined template or model that describes a plurality of linked *model* geometric process features (referred to herein as *robotic process elements*). One example of a plurality of robotic process templates may be the sets that generically describe a weld that starts at one three surface corner. traverses a two surface corner. and ends at another three surface corner. As will be discussed below, a plurality of templates of differing levels of complexity may be stored in a memory storage device from which the operator may select via the processor and a suitable user interface.

As will also be discussed in more detail further below, the template includes generic path planning information and preferably includes generic work process information for the specific geometric work process represented by the template.

Examples of geometric process features may be illustrated using Fig. 4. Referring again to Fig. 4, a geometric process feature for the work piece 410 may suitably be the series of seam welds that weld the first upright plate 416 to the base plate 412 and back plate 414. In such a case, other geometric process features for the work piece 410 could include the series of seam welds that weld the second upright plate 418 to the base plate 412 and the back plate 414, and the series of seam welds that weld the base plate 412 to the back plate 414. Alternatively, a single straight line seam weld, such as the one that welds the base plate 412 to the back plate 414 between the first upright plate 416 and the second upright plate 418 may be a geometric process feature, as could a combination of *all* seam welds in the immediate vicinity of the first upright plate 416.

The definition of how many weld segments can be covered by a single template depends upon the number and type of available templates. If no template exists that corresponds to *all* of the seam welds involved in welding the first upright plate 416 to the base plate 412 and back plate 414, then several templates may be necessary to define the robotic process plan for all of the required seam welds. As will be discussed further below, however, in a preferred embodiment of the present invention, new templates may be defined which constitute combinations of existing templates. Thus, if no single template defines a process plan segment corresponding to all of the seam welds involved in welding the first upright plate 416, then the operator may, as discussed further below define a new template that may include one or more existing templates.

Referring again to Fig. 1, assuming that input has been received identifying the template that corresponds to a plurality of geometric process features, the processor receives associated work piece data in step 115. To this end, work piece data must be associated with the identified template by an operator (or automatically by the processor) and then provided to the processor as input. In particular, specifics regarding the geometric process features, including dimension and orientation information regarding a particular operation, are associated or combined with the template to define a particular robotic process plan segment.

The associated work piece data typically includes both orientation alignment data and position alignment data. This data is used to transform the *generic* template "space" into *specific* work piece "space", which may later be used to generate the robotic process plan. In addition, the associated work piece data may further include custom-defined work process parameters, such as, in the case of welding, the separation (*i.e.* gap) of the parts at the weld seam and the height of the weld. Moreover, the associated work piece data may include dynamically linked control variables that are common to an entire process that includes several process plan segments. An example of a dynamically linked control variable is weave pattern variable that is defined for an entire process, but is adjusted dynamically based on certain user-input provided in the associated work piece data.

In any event, once processor receives the associated work piece data in step 115, then the processor determines in step 120 whether a template has been identified for *all* of the geometric process features for the work piece. In other words, it is determined if the entire process for the work piece has been defined through steps 110 and 115. If not, then the process returns to step 110 and identifies a template corresponding to one or more of the remaining geometric process features and proceeds accordingly.

If, however, one or more templates have been identified (and appropriate work piece data associated therewith) that cover all of the geometric process features of the work piece, then the processor proceeds to step 125.

It is noted that the processor may determine whether a template has been identified for all of the geometric process features based on user input directed to that very determination. Alternatively, the processor may automatically make such a determination based on a CAD file of the work piece and the identified templates.

In any event, in step 125, the processor generates the robot process plan. The robot process plan includes a plan identifying the path and preferably pose of the robot and robot work tool in robot space. The robot process plan preferably also includes work tool operational instructions. To this end, the processor uses predefined process knowledge embedded within the templates to define robot movement and work tool operation. The processor combines the predefined process knowledge with the associated work piece data to generate the robot process plan.

For example, consider a template that describes a straight line weld ending at an outer corner on one end and an inner corner at another end. The template would be preprogrammed to define the robot movement for such a weld. Such a weld may include wrapping the weld around the outer corner, moving in a straight line, and then ending at the inner corner. Such process knowledge is readily obtained from sources knowledgeable about the relevant processes. For example, the processes of performing a corner weld with a wrap, or a straight line terminating in an interior corner, or even a curved arc, are well-known to those of ordinary skill in the welding art. The process knowledge may readily be represented by the template that describes the process in generalized terms.

For example, a template may include a set of rules that define a process plan when the proper associated data is provided. One such template may be that associated with the above described line weld between an outer corner and an inner corner. Those rules are provided below in Table 1.

Table 1

Input attribute data: approach_point, first_corner, wrap_point, second_corner; {work piece data input by user}

Input parameter data: gap, weld_height; {work piece data or configuration data from user, may be used for several templates}

Set P1 = wrap_point; {P1 is the wrap around end point, defined by the user in this example; in other examples, it may be derived from parameter data or simply defaulted as *n* millimeters from the first_corner)

Set P2 = first_corner; {P2 is the position of the outer corner as defined by the user}

Set P3 = second_corner; {P3 is the position of the interior corner as defined by the user}

Set D1 = direction(P1, P2); {this is a mathematical function that defines a direction of travel between the wrap around end point and the first or outer corner; such a function would be well known to those of ordinary skill in the art}

Set D2 = direction(P2, P3); {The same mathematical function is used to define the direction of travel between the two corners}

Set D3 = direction(approach_point, P1); {The same mathematical function is used to define the direction of travel from the robot approach point to the wrap around end point}

Set X1 = distance(P2-P1); {determines the distance between P2 and P1 using a common mathematical formula that provides the distance between two points in three dimensional space, which is the square root of the sum of the squares of the differences between the x, y, and z coordinates of each point}

Set X2 = distance(P3-P2); {same formula used to determine the distance between P3 and P2}

Set X3 = distance(P1-approach_point); {same formula used to determine the distance between the approach point and the wrap around point}

Move_robot (X3, D3); {start of path assumes robot is at the approach point, this command moves the end effector or weld tool from the approach point to P1}

Begin_weld (gap, weld_height); {starts a weld operation and uses the parameters to determine welding parameters such as wire feed rate and arc current}

Move_robot_weld (X1, D1); {moves the weld tool from P1 to P2 using predefined movement information associated with welding, which includes a weld velocity that is determined based on the user-defined weld height, the wire feed rate, and the arc current}

Pause_movement_weld (outer_corner); {causes robot to pause at P1 for a length of time associated with a predefined structure called "outer_corner"; which effectuates a predefined technique used to provide a slightly larger weld at the corner}

Move_robot_weld (X2, D2); {moves the weld tool from P2 to P3 using the predefined movement information}

End_weld; {causes the welding operation to stop}

The set of rules of Table 1, provided in pseudocode, illustrate the concept of how a standard set of rules can be used to generate a robotic process plan for a specific implementation of a generic template. For example, virtually any weld that starts at an outside corner with a wrap-around, and ends an inside corner via a straight line path, may be defined by simply providing the appropriate work piece data to the above template rule set.

It will be appreciated that the set of rules defined above in connection with Table 1 represent a simplified version of a set of rules that would be associated with a template. The example is provided for illustration purposes only. Those of ordinary skill in the art could readily devise their own rules by which data associated with a work piece, such as position, orientation, and control data, is applied to a generic template to define a robotic process plan segment. In any event, such sets of rules are employed in step 125 to generate the robotic path plan information on the associated work piece data and the identified template or templates.

In addition, the robot process plan may include a separate path plan for use in connection with an optical or other sensor attached to the robot. In particular, robots often use sensors to identify work piece points in real space which slightly vary from programmed points. Such sensors allow the robot to adapt its process program to account for fixturing tolerances and the like. Thus, a particular robot operation may include first moving a sensor to the work area and collecting data. The template would preferably include the information necessary to carry out such sensor operations.

In any event, once the robotic path plan is generated in step 125, it is subsequently exported to a system that generates the robotic kinematic solutions in step 130. In particular, the robotic process plan generated in step 125 preferably does not define the actual movements of the constituent components of a robot arm, but instead provides overall movement (and sometimes robot configuration) information. The robot kinematic solutions derives the movements of the robotic arm actuators to generate the robotic path plan movements. Such systems are well-known. Because the robotic process plan may be exported to a system that generates kinematics, the robotic process plan may be employed in a variety of robotic arm designs.

It will be noted that the robotic process plan may be exported by transporting the file to another system running on another processor. Alternatively, the robotic process plan may simply be exported to another software module executed by the same processor that generated the robotic process plan.

Thus, the present invention allows a robotic process plan to be generated for a work piece using predefined templates with which specific work piece data is associated. In this manner, robotic process plans for robotic operations may take advantage of prior knowledge gained from similar operations. As will be discussed below, templates may be layered and combined in hierarchical formats that allow complex operations to be defined from as little as a single template.

Fig. 2 shows an exemplary system 200 for generating a robotic process plan according to the present invention. The system 200 includes a user interface 202, a processor 204, a storage device 204, and an export device 206.

The user interface 202 is a device that is operable to receive input identifying a template corresponding to a plurality of geometric features of the work structure, each geometric feature associated with one or more robotic process elements. To this end, the user interface 202 may suitably include a keyboard, a mouse or other commonly used computer input device. In addition, the user interface 202 preferably further includes a display screen for displaying information useful to a human operator in selecting an appropriate template. In a preferred embodiment, the user interface 202 also displays information regarding the work piece (including work piece data) to assist the operator in selecting an appropriate template. The user interface 202 may also receive input comprising the associated work piece data.

The processor 204 may suitably be a controller, microcontroller, microprocessor, processor or a combination of one or more of such devices that are operable generate the robotic process plan based on the associated work structure data and the robotic process elements associate with the template. To this end, the processor 204 is operably coupled to the user interface 202 to receive the input identifying the template. In a first embodiment, the processor 204 further receives the associated work piece data from the operator through the user interface 202. In another embodiment, the processor 204 obtains the associated work piece data automatically from a file stored in the storage device 206 using image processing and/or artificial intelligence techniques.

The storage device 206 comprises at least one memory storage device coupled to the processor 204. Preferably, the storage device includes a suitable combination of non-volatile memory devices and random access memory devices sufficient to support the processor functions as well as store information as identified herein. Those of ordinary skill in the art may readily select the appropriate memory devices for their particular implementation.

The storage device 206 preferably stores a plurality of templates from which the operator may select. To this end, the storage device 206 preferably includes a template database, each template comprising one or more predefined robotic process elements. In addition, the template database further includes a set of the predefined robotic process elements from which additional templates may be defined in accordance with the method of Fig. 3. Fig. 5 described below shows an exemplary template database structure that includes a hierarchy of predefined process templates, including templates, feature templates and robotic process elements.

Referring again to Fig. 2, the export device 208 is a device that exports the generated robotic process plan to a system that generates the robotic kinematics for the generated path plan within the robotic process plan. As discussed above in connection with Fig. 1, the system that generates the robotic kinematics may include a separate processor, or may alternatively include the processor 204 executing a kinematics software module. Thus, the export device 208 may include a network connection to the kinematics generation system, a removable media device such as a disk or tape drive, or simply the processor 204 configured to pass the generated robotic process plan to another software module executed by the processor 204.

One of the features of the present invention is the ability to define new templates using fundamental process building blocks that are already available, *i.e.*, stored in the storage device 206. To this end, the process knowledge associated with the standard geometric features is in large part resident in the fundamental building blocks, referred to herein as the robotic process elements.

To build the fundamental building blocks, process expertise (*e.g.*, welding expertise, grinding expertise) is accessed. That process expertise preferably provides information regarding movement of a robot within a particular geometry as well as work process information regarding how to achieve a desired weld, grind, paint layer or the like. This process expertise is combined with standard mathematical functions to link user-provided work piece data to form the set of rules for the templates of the robotic process elements.

For example, Table 1, discussed above, includes both standard mathematical functions to link user-provided work piece data (functions *distance(P1, P2)* and *direction (P1, P2)*) to standard movement procedures, and work process information (the "Begin_weld" and "Pause_movement_weld" operations). The "Begin_weld" operation includes work process expertise pertaining to the selection of a particular wire feed rate and arc current based on the desired weld height and identified gap. The "Pause_movement_weld" operation includes process expertise that dictates that a larger weld is required at an outside corner. Such expertise, as discussed above, is provided by one of ordinary skill in the welding art. A software artisan then translates the expertise into a set of rules such as those set forth in Table 1.

According to the present invention, expertise found within one or more robotic process elements may be combined into a template that corresponds to a plurality of geometric process elements. Fig. 3 shows an exemplary flow diagram 300 of the method of defining a new template in accordance with the present invention. The process of Fig. 3 may suitably be carried out by the components of robotic process planning system 200 of Fig. 2. However, it will be recognized that another system that includes a user interface, processor and storage device may be used to generate new templates as described below.

Referring to Fig. 3, in step 305, work piece data relating to a work piece for which one or more templates are to be defined is first obtained. The operator refers to the work piece data for assistance in defining the new templates. Such work piece data may suitably consist of blueprints or CAD files relating to the work piece. However, it will be recognized that a new template may be developed directly from the human memory of the operator.

In any event, in step 310, the operator selects a set of related geometric process features relating to the workpiece for which no template exists. The operator may select all of the geometric process features relating to the work piece or a subset thereof.

Then, in step 315, the operator provides to the processor input identifying a predefined robotic process element that describes or *corresponds to* at least one geometric process feature from the set of related features selected in step 310. To this end, as discussed above, the robotic process elements are templates that are associated with a set of rules or instructions for carrying out a robot process for a relatively simple geometric feature of a work piece.

Typically, a set of robotic process elements are stored in an database within a storage device such as the storage device 206 of Fig. 2. The set of robotic process elements preferably corresponds to most, if not all, of the possible geometric process features of any work piece. In other words, sufficient robotic process elements should be defined such that various combinations of defined elements may describe virtually any work piece, similar to the manner in which the twenty-six letters of the English alphabet may be combined to form virtually any word (and sentence) in the English language.

In any event, once input identifying the robotic process element is received in step 315, the processor in step 320 adds the identified robotic process element to the new template. In particular, if the identified robotic process element is the *first* robotic process element of the new template, the processor forms the new template starting with the identified robotic process element. Alternatively, if the new template already includes one or more previously-added robotic process elements, then the processor adds the robotic process element identified in step 315 and provides any linking information (e.g., relative start and stop points) relating the identified robotic process element to the previously-added robotic process elements.

Moreover, during step 320, the processor may receive input from the operator defining the position of the identified robotic process element in the *sequence* of robotic process elements represented by the new template. In other words, the operator defines the sequence of the robotic process defined by the template. Thus, the operator may provide additional knowledge to the template by specifying not only the types of robotic process elements associated with the template, but also the sequence in which the robotic process elements are executed in the robotic process plan.

Thereafter, in step 325, the processor determines whether a robotic process element has been defined for all geometric process features in the set. To this end, the processor may receive input from the operator directly addressing that determination.

In any event, the processor, with or without additional input from the operator, determines whether the new template has been entirely defined. If not, then the operator returns to step 315 and proceeds as described above. If so, however, then the operation is complete.

The flow diagram 300 thus operates to generate templates that may be used in the flow diagram 100 of Fig. 1, described above. In time, the above flow diagram 300 may be employed to build a database of a large number of complex templates for robotic processes. As a result, defining subsequent robotic processes may be substantially simplified by the availability of a wide variety of templates. It will be appreciated that each of the templates contains accumulated knowledge of the robotic process gained from prior experiences. By exploiting such accumulated prior knowledge, robotic process planning can be greatly simplified by the present invention.

To assist in exploiting different levels of knowledge gained from past experience, the present invention preferably includes multiple hierarchical levels of templates. Specifically, in accordance with a preferred embodiment, a hierarchy of templates is defined in which one or more geometric process elements may be combined to form a *feature template*, and one or more feature elements and/or geometric process elements are combined to form an *part template*. In this manner, processes may be defined with templates of differing granularity ranging from the fundamental geometric process element to a relatively comprehensive part template.

Fig. 5 shows a block diagram showing an exemplary knowledge base 500 hierarchy and the information processing arrangement of the present invention. The knowledge base 500 comprises geometric process elements 502a . . . 502e, feature templates 504a . . . 504c, and part templates 506a and 506b. As shown in the diagram, a part template includes information from one or more feature templates, and a feature template includes information from one or more geometric process elements. For example, the part template 506b includes the information from the feature templates 504b and 504c. The feature template 504b, in turn, includes information from the geometric process elements 502c and 502d. Likewise, the feature template 504c includes information from the geometric process elements 502d and 502e.

The information processing arrangement includes the process planning system and/or method 508 which may suitably be the system 200 of Fig. 2 or the process illustrated in Fig. 1. The process planning system/method 508 relies on work file data 510, the process knowledge or expertise 512 of the operator, and the knowledge base 500 to generate the robotic process plan. The interrelationship of the process planning system/method 508, work file data 510 and process knowledge 512 of the operator is described further above in connection with Figs. 1 and 2. In the exemplary diagram shown in Fig. 5, the process planning system/method 508 has defined a robotic process that employs the part templates 506a and 506b and the feature template 504c.

It will further be appreciated that new feature templates may be generated using any combination of geometric process elements 502a . . . 502e using a method based on the flow diagram 300 of Fig. 3. Moreover, new part templates may be generated using any combination of feature templates 504a . . . 504c using a similar method based on the flow diagram 300 of Fig. 3.

It will be appreciated that the above-described embodiments are merely exemplary and that those of ordinary skill in the art may devise their own implementations that incorporate the principles of the present invention and fall within the spirit and scope thereof.

We claim:

1. A method of generating a robotic process plan for performing a process on a work structure, the robotic process plan for use in a robotic system that generates robotic kinematics from the robotic process plan, the method comprising:

a) receiving input identifying a template corresponding to a plurality of geometric features of the work structure, each geometric feature associated with one or more robotic process elements;

b) receiving input associating work structure data with the identified template;

c) generating the robotic process plan based on the associated work structure data and the robotic process elements associate with the template.

2. The method of claim 1 wherein the robotic process plan includes a sequence based on sequence data corresponding to the identified template, the sequence data relating to at least two robotic process elements.

3. The method of claim 1 wherein step b) further includes receiving input comprising position and orientation information relating to the work piece.

4. The method of claim 1 wherein step a) further comprises receiving input identifying the template corresponding to the plurality of geometric features such that each geometric feature is associated with one robotic process element.

5. The method of claim 1 wherein step a) further comprises receiving input identifying the template corresponding to the plurality of geometric features such that at least one geometric feature is associated with a plurality of robotic process elements.

6. The method of claim 1 wherein step a) further comprises receiving input identifying the template by selecting the template from a plurality of templates.

7. The method of claim 1 wherein step a) further comprises receiving input identifying the template by selecting the template from a plurality of templates, and wherein the plurality of templates comprising one or more feature templates, each feature template comprising one or more robotic process elements.

8. The method of claim 7 wherein at least one of the one or more feature templates is shared by at least two templates of the plurality of templates.

9. The method of claim 7 where at least one of the one or more robotic process elements is shared by at least two feature templates of the one or more feature templates.

10. The method of claim 1 further comprising the step of d) exporting the robotic process plan to any of a plurality of kinematics generating systems.

11. A system for generating a robotic process plan for performing a process on a work structure, the robotic process plan for use in a robotic system that generates robotic kinematics from the robotic process plan, the system comprising:

a) a user interface operable to receive input identifying a template corresponding to a plurality of geometric features of the work structure, each geometric feature associated with one or more robotic process elements;

b) a processor operable to

receive associated work structure data, the associated work structure data comprising work structure data that is associated with the identified template; and

generate the robotic process plan based on the associated work structure data and the robotic process elements associate with the template.

12. The system of claim 11 wherein the robotic process plan includes a sequence based on sequence data corresponding to the identified template, the sequence data relating to at least two robotic process elements.

13. The system of claim 11 wherein the processor is further operable to receive associated work piece data comprising position and orientation information relating to the work piece.

14. The system of claim 11 further comprising a storage device operably coupled to the user interface, the storage device including a template database that comprises a plurality of templates.

15. The system of claim 14 wherein each of the plurality of templates of the template database further comprises one or more feature templates, each feature template comprising one or more robotic process elements.

16. The system of claim 15 wherein at least one of the one or more feature templates is shared by at least two templates of the plurality of templates.

17. The system of claim 15 wherein at least one of the one or more robotic process elements is shared by at least two feature templates of the one or more feature templates.

18. The system of claim 11 further comprising a means for exporting the robotic process plan to any of a plurality of kinematics generation systems.

19. The system of claim 18 wherein said means for exporting includes a network connection.

20. The system of claim 18 wherein said means for exporting includes a portable storage medium.

21. The system of claim 11 wherein the input device is further operable to receive template definition input, said template definition input including data defining a second plurality of geometric features of the work structure, each geometric feature associated with one or more robotic process elements.

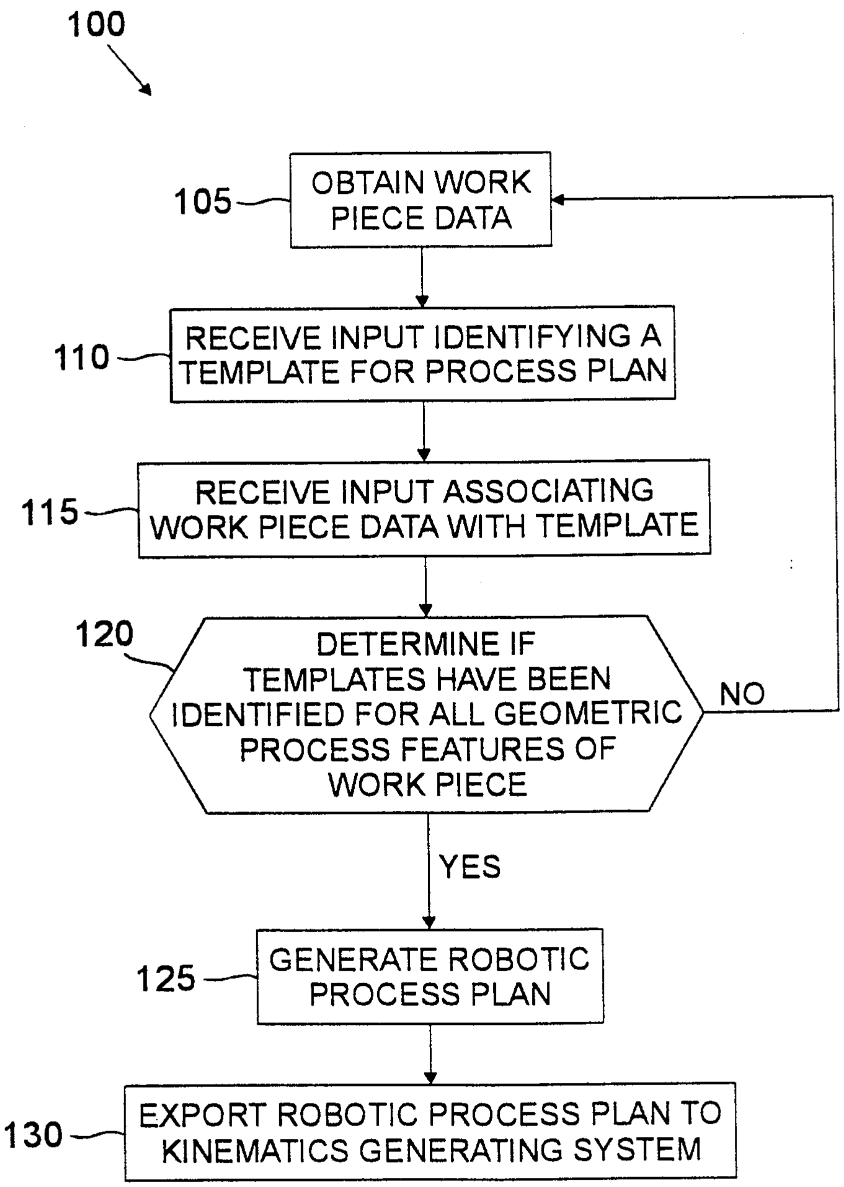
100
105
OBTAIN WORK PIECE DATA
110
RECEIVE INPUT IDENTIFYING A TEMPLATE FOR PROCESS PLAN
115
RECEIVE INPUT ASSOCIATING WORK PIECE DATA WITH TEMPLATE
120
DETERMINE IF TEMPLATES HAVE BEEN IDENTIFIED FOR ALL GEOMETRIC PROCESS FEATURES OF WORK PIECE
NO
YES
125
GENERATE ROBOTIC PROCESS PLAN
130
EXPORT ROBOTIC PROCESS PLAN TO KINEMATICS GENERATING SYSTEM

FIG. 1

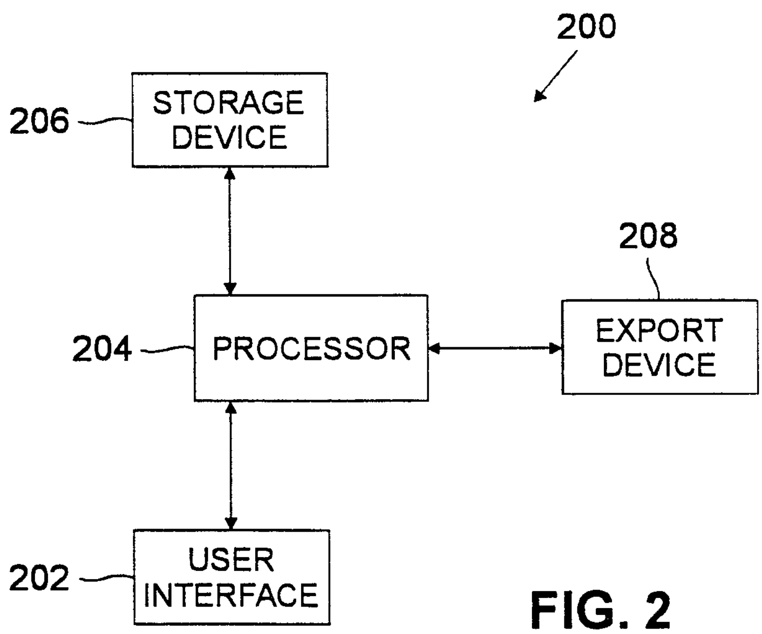
200
206
STORAGE DEVICE
208
204
PROCESSOR
EXPORT DEVICE
202
USER INTERFACE

FIG. 2

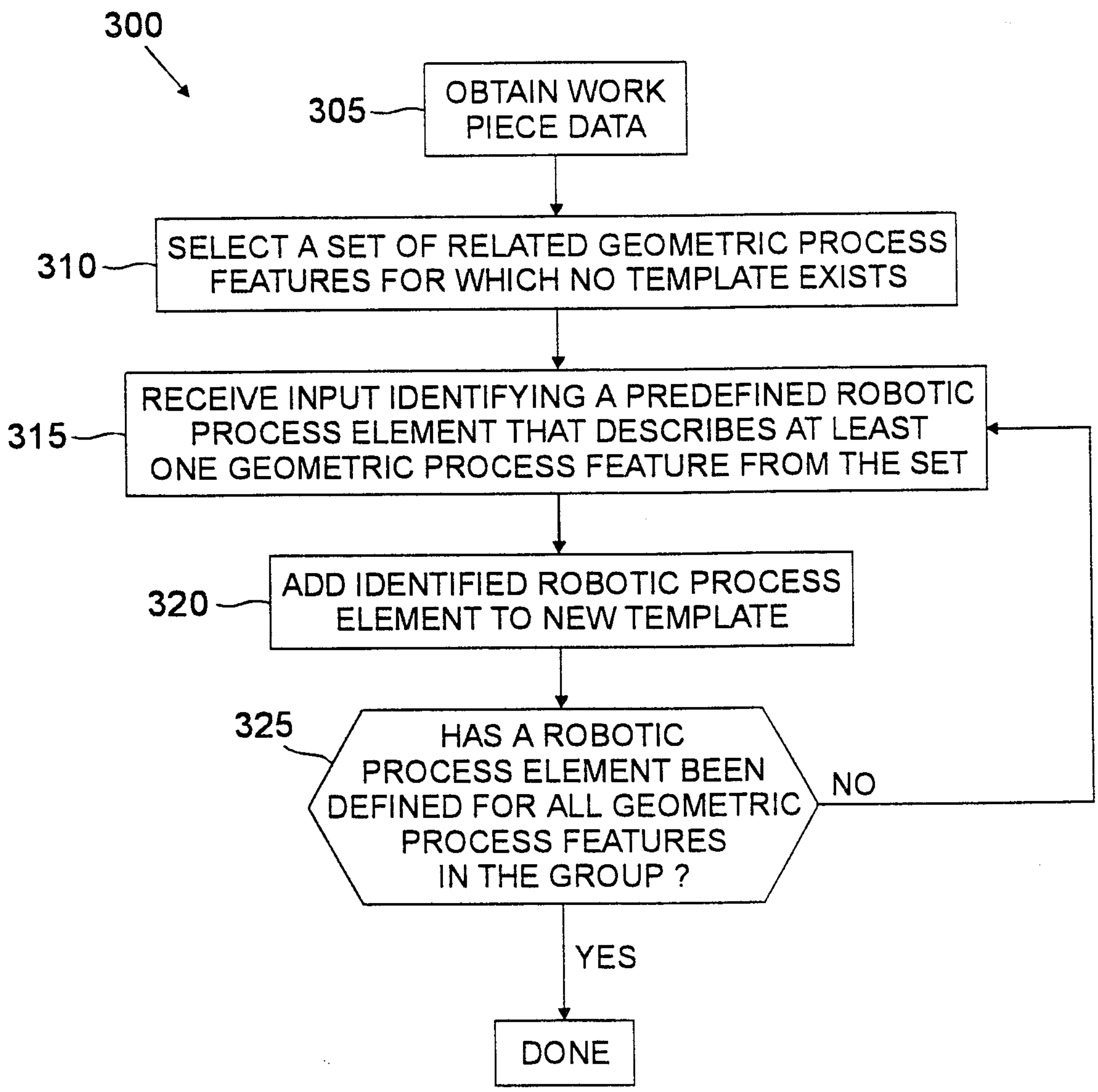
300
305
OBTAIN WORK PIECE DATA
310
SELECT A SET OF RELATED GEOMETRIC PROCESS FEATURES FOR WHICH NO TEMPLATE EXISTS
315
RECEIVE INPUT IDENTIFYING A PREDEFINED ROBOTIC PROCESS ELEMENT THAT DESCRIBES AT LEAST ONE GEOMETRIC PROCESS FEATURE FROM THE SET
320
ADD IDENTIFIED ROBOTIC PROCESS ELEMENT TO NEW TEMPLATE
325
HAS A ROBOTIC PROCESS ELEMENT BEEN DEFINED FOR ALL GEOMETRIC PROCESS FEATURES IN THE GROUP ?
NO
YES
DONE

FIG. 3

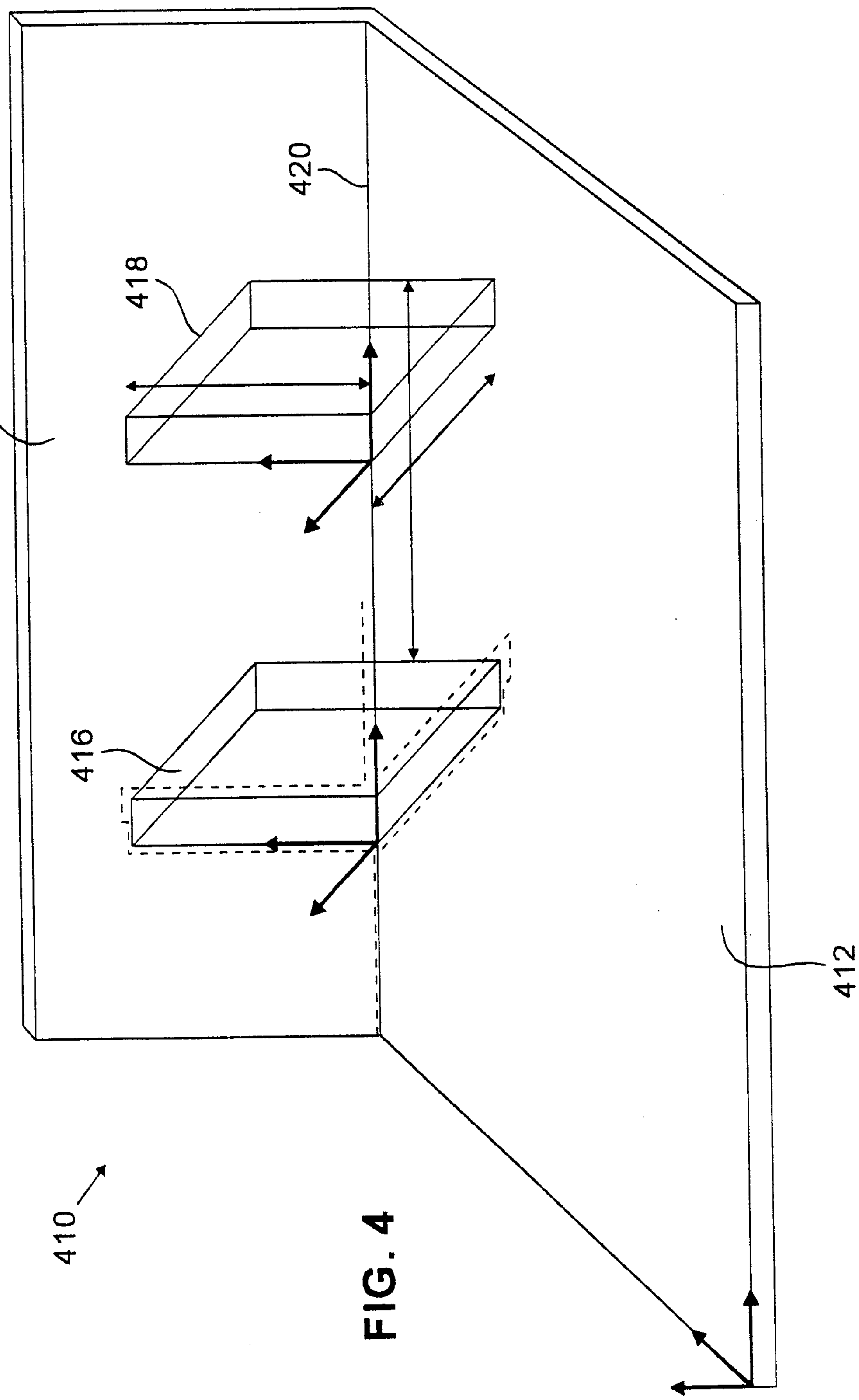

FIG. 4

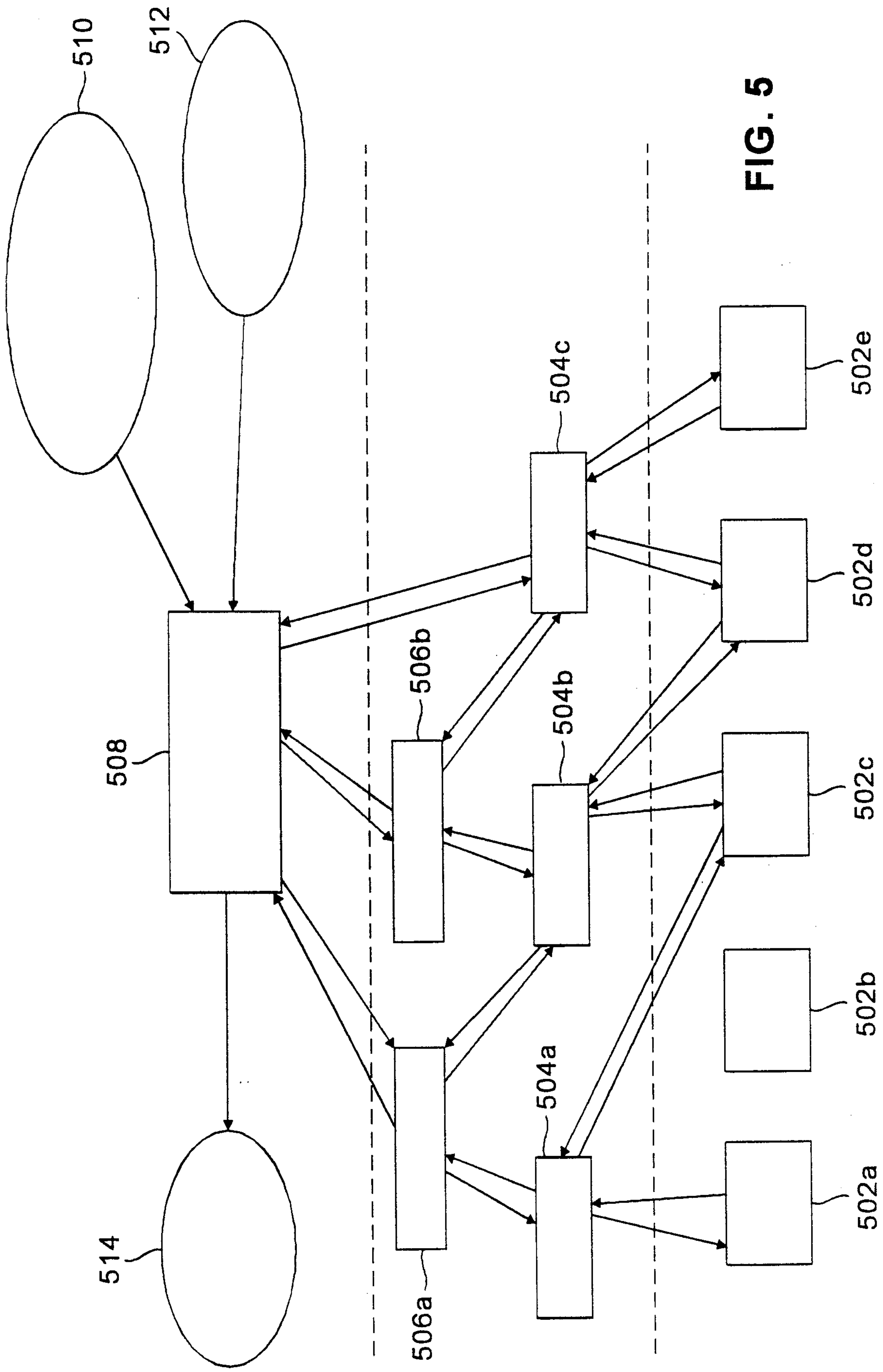
510
512
508
514
506a
506b
504a
504b
504c
502a
502b
502c
502d
502e

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/25318

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G05B 19/42
US CL : 700/264
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 700/264, 257, 253, 250; 318/568.11; 901/3 ,4, 5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,586,224 A (KUNII et al.) 17 December 1996, see entire document.	1-21
Y	US 5,511,147 A (ABDEL-MALEK) 23 April 1996, see entire document.	1-21
Y	US 5,467,003 A (KOSAKA et al.) 14 November 1995, see entire document.	1-21
Y	US 5,155,423 A (KARLEN et al.) 13 October 1992, see entire document.	1-21
Y	US 5,006,999 A (KUNO et al.) 09 April 1991, see entire document.	1-21
A	US 4,380,696 A (MASAKI) 19 April 1983, see entire document.	1-21

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 JANUARY 2000	23 FEB 2000

Name and mailing address of the ISA/US	Authorized officer
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Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/25318

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,570,458 A (UMENO et al) 29 October 1996, see entire document.	1-21