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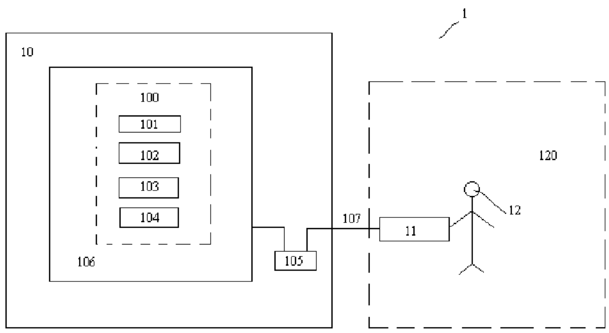

Figure 1

(57) Abstract: The present invention is concerned with apparatus, method, and recording medium for robot offline teaching. The apparatus for robot offline teaching comprises a computer that is adapted to run a virtual environment where a virtual tool and a virtual object are defined, and an interface that is adapted to send a motion information to the computer based on its movement caused by a user in a user environment and generate sense data based on a sense data information from the computer; wherein: the computer calculates the sense data information based on a virtual space relationship between the virtual tool and the virtual object and the motion information, and sends the sense data information to the interface; and the interface generates the sense data to the user based on the sense data information. By having an interface function as a motion tracking means and a haptic means, the user can manually guide the translation and/or rotation of the virtual tool in an easy and intuitive way.

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APPARATUS, METHOD, PROGRAM AND RECORDING MEDIUM FOR ROBOT OFFLINE TEACHING

Technical Field

The invention relates to apparatus, method, program and recording medium for robot teaching, and more particularly to apparatus, method, program and recording medium for robot off-line teaching.

Background Art

Robot teaching can be categorized into online teaching and offline teaching according to whether the real robot work cell is involved. On-line teaching involves real workcell setups; however it is often associated with considerable workcell downtime. Also, teaching accurate targets on sophisticated geometry in large number has been a troublesome task for programmers. On the contrary, CAD based offline teaching has its advantage in auto-generating robot targets in great number on 3D geometry in a virtual environment. With offline simulation, users can reduce the risk of damaging robots, tools and peripherals in real workcells, and improve the teaching speed.

However, the conventional offline teaching technologies are complex, requiring high technical skills for the programmers, and especially time consuming. In most cases, in the virtual environment, the robot path is composed by a group of virtual targets which are taught or generated according to the geometrical features of the workpieces. The virtual targets can not give the user an intuitive impression on how it will look like when the robot executes the path and whether collisions will happen, because the virtual targets and the virtual path are in the virtual world. Intuitive impression may be any sense data that are immediately known in sensation of any virtual tooling process or any virtual potential collision, such as sense of vision, sense of touch, sense of resistance, sense of texture, sense of shape, and so on. Such intuitive impression will help user in intuitively teaching the robot to execute the virtual path determined by the shape of the virtual workpiece and avoid moving in the way of a virtual obstacle, such as virtual table, virtual conveyor and so on.

In addition, if a user is looking at the virtual objects in the virtual environment with different point of view, he will not see exactly the same arrangement of the virtual objects. The change of the view angle brings about difficulty in the process of teaching a robot when the user shifts his point of view.

Brief Summary of the Invention

It is therefore an objective of the invention to link the execution of the virtual path in the virtual world and the sense data generated accordingly in the view point of the user in the user world.

According to an aspect of present invention, an apparatus for robot offline teaching comprises a computer that is adapted to run a virtual environment where a virtual tool and a virtual object are defined, and an interface that is adapted to send a motion information to the computer based on its movement caused by a user in a user environment and generate sense data based on a sense data information from the computer; wherein: the computer calculates the sense data information based on a virtual space relationship between the virtual tool and the virtual object and the motion information, and sends the sense data information to the interface; and the interface generates the sense data to the user based on the sense data information. By having an interface function as a motion tracking means and a haptic means, the user can manually guide the translation and/or rotation of the virtual tool in an easy and intuitive way, so as to avoid a collision.

According to another aspect of present invention, a method for robot offline teaching comprises the steps of defining a virtual tool and a virtual object in a virtual environment, sending a motion information to the virtual environment based on a movement of an interface caused by a user in a user environment, calculating a sense data information based on a virtual space relationship between the virtual tool and the virtual object and the motion information, sending the sense data information to the interface, and the interface generating a sense data to the user based on the sense data information. Therefore, the user can teach the virtual robot in an easy and intuitive way when having a sense of resistance with each of the virtual objects, which indicates any potential collision between the virtual tool and the virtual object, so as to avoid a collision.

According to another aspect of present invention, it is provided a program for robot offline teaching, said program makes a computer carry out the steps according to the above method and a computer readable recording medium recording the program for robot offline teaching.

Brief Description of the Drawings

The subject matter of the invention will be explained in more detail in the following text with reference to preferred exemplary embodiments which are illustrated in the drawings, in which:

Figure 1 is a block diagram illustrating an apparatus for robot offline teaching according to an embodiment of the invention;

Figures 2A is a schematic diagram illustrating an apparatus for robot offline teaching according to an embodiment of the invention;

Figure 2B is a schematic diagram illustrating an apparatus during a process of robot offline teaching according to an embodiment of the invention;

Figure 2C is a schematic diagram illustrating virtual robot repeating taught path holing the virtual tool according to an embodiment of the invention;

Figure 3 is a schematic diagram illustrating a coordinate transformation between a world coordinate frame used in the virtual environment and a user coordinate frame used in the user environment according to an embodiment of the invention; and

Figure 4 is a follow chart explaining the calculation of the sense data information according to an embodiment of the invention.

Preferred Embodiments of the Invention

Figure 1 is a block diagram illustrating an apparatus for robot offline teaching according to an embodiment of the invention. As shown in figure 1, the apparatus 1 for robot offline teaching comprises a computer 10 that is adapted to run a virtual environment 100 where a virtual tool 101 and a virtual object 102, 103, 104 are defined and an interface 11 that is adapted to send a motion information to the computer 10 based on its movement caused by a user 12 in a user environment 120 and generate sense data based on a sense data information from the computer 10. Thus a mapping is created between the virtual environment 100 and the user environment 120.

The virtual environment 100 may be based on computer-aided design (CAD) system, which is the use of computer technology for the design of objects, real or virtual. CAD may be used to design curves, surfaces, and solids in three-dimensional ("3D") objects. For example, virtual objects, such as virtual tool 101 and virtual object 102-104, are defined in the CAD system. Virtual object may be a virtual obstacle, such as virtual table 102 and virtual conveyor 103, which stay in the virtual path of the virtual tool 101. Virtual object may also be a virtual work piece 104, which is supposed to be processed by the virtual tool 101.

The interface 11 is manually guided by the user 12 to teach a robot each of the target points in the path of execution of a task, such as tooling and welding. The user environment 120 means the real world where the user 12 is located as an operator to the interface 11 with a user point of view. When the user's hand operates the interface 11 in translation and/or rotation, the interface 11 sends 3D translation and/or rotation information to the computer 10 running CAD system. The interface 11 is led by user's hand, the motion information of the human hand, i.e. move left with a speed of 2 cm/second, is sensed by the interface 11, and then converted to motion information to the virtual tool 101, i.e. 10 cm/second in the virtual environment 100.

The computer 10 calculates the sense data information based on a virtual space relationship between the virtual tool 101 and each of the virtual objects 102, 103, 104 and the motion information of the interface 11, such as 3D translation and/or rotation information of the interface, and sends a sense data information to the interface 11 which functions as a haptic device and generates sense data to the user 12 based on the sense data information. A haptic device adopts a tactile feedback technology that takes advantage of a user's sense of touch by applying forces, vibrations, and/or motions to the user. The journal article of "A 3-2-1 kinematic configuration of a Stewart platform and its application to six degree of freedom pose measurements," (Z. Geng and L.S. Haynes, Robotics and Computer-Integrated Manufacturing, Vol. 11, No. 1, pp.23-34, 1994) provides such a kinematic structure and configuration that is suitable for abovementioned requirements. The Stewart platform, multiple DOF parallel structure, has been widely studied and implemented both in academic and application fields for many decades. When compared to serial-linked structure, the parallel-linked structure has its advantages in accuracy, stiffness and compactness. When using string displacement sensors as the links or limb(s), the parallel structure becomes an instrument capable for multiple DOF spatial measurement and can be used as a flexible-linked apparatus for robot teaching. The sense data to the user 12 may be sense of touch to the user's hand, such as resistance to user's hand. The computer 10 may be configured by a CPU 105, memory 106 and I/O 107, such as a personal computer. CPU 105 is adapted for the calculation of the virtual space relationship, calculating the motion mapping and force mapping, memory 106 is adapted for storing the virtual environment 100, the virtual tool 101 and the virtual objects 102, 103, 104, and I/O 107 is adapted for communication between the computer 10 and the interface 11.

The sense data, which are generated according to the virtual space relationship between the virtual tool 101 and the virtual object 102, 103, 104 and the motion information of the interface 11, indicate the possibility of the collision between the virtual tool 101 and each of the virtual objects 102, 103, 104.

By having an interface function as a motion tracking means and a haptic means, the user can manually guide the translation and/or rotation of the virtual tool in an easy and intuitive way.

Figures 2A is a schematic diagram illustrating an apparatus for robot offline teaching according to an embodiment of the invention. As shown in figure 2A, the apparatus 2 for robot offline teaching comprises a computer 20 that is adapted to run a virtual environment 200 where a virtual tool 201 and a virtual object 202, 203, 204 are defined and an interface 21 that is adapted to send a motion information to the computer 20 based on its movement caused by a user 22 in a user environment 220 and generate sense data based on a sense data information from the computer 20. The computer 20 and the interface 21 are linked by a cable 22. The virtual object can be a virtual table 202, a virtual workpiece 204, a virtual conveyor (not shown) etc. For example, a virtual robot 203 is put at the centre of the virtual environment 200, the virtual table 202 is put in front of the virtual robot 203, and the virtual workpiece 204 is put on the virtual table 202.

Figure 2B is a schematic diagram illustrating an apparatus during a process of robot offline teaching according to an embodiment of the invention. The same reference number indicates the same part as shown in figure 2A. As shown in figure 2B, a virtual dangerous region 205 around the virtual tool 201 is defined in the virtual environment 200 and the taught virtual targets 2a, 2b, 2c, 2d constitute the virtual path 208. The interface 21 combines functions of motion tracking and haptic feedback. The interface 21 may be operated by user's hand 22 to send 3D translation and/or rotation information to the virtual tool 201 in the virtual environment 200. The interface 21 can be with serial linked, parallel linked structure or the mixed structure of serial linked and parallel linked. For example, the interface 21 with parallel linked structure is led by user's hand 22, the movement of the user's hand 22, i.e. move to the right with a speed Su of 2 cm/second, is sensed by the interface 21 through its motion tracking function, and then converted to virtual motion information Sv, i.e. 10 cm/second to the right from virtual target 2a towards virtual target point 2b in the virtual environment 200. Namely, the movement information of the user's hand 22 is mapped to the 3D translation and/or 3D rotation of the virtual tool 201 in the virtual environment 200.

The collision possibility between the virtual tool 201 and other virtual objects is indicated by virtual repulsive forces/torques 206 which are calculated according to the relative position and/or orientation between the virtual tool 201 and the virtual object and the motion information of the virtual tool 201 relative to the virtual object.

Let F1 denote the repulsive force, F2 denote the resistance acting on the human hand, $\vec{S}$ denote the movement direction of the virtual tool, D denote the virtual distance between the virtual tool and the surface of the virtual object, θ denote the direction of the movement of the virtual tool relative to the virtual object, d0, c0, c1, c2 the parameters to control the magnitude of the repulsive force F1. When the virtual tool enters the dangerous region, F1 is calculated by:

$$\mathrm{F1} = -\frac{c1}{c0 * \mathrm{D}^n + d0}.(1 + c2 * \cos\theta) \bullet \vec{S}$$

, wherein n can be any non-negative number. The resistance acting on the human hand is calculated by: $\mathrm{F2} = -(c4 * |F1|^n + f0) \bullet \vec{S}$, wherein c4 and f0 are the parameters to control the magnitude of the resistance force F2.

Preferably, the virtual object may be the virtual workpiece 204 and the virtual table 202.

By having the parameters as above considered, the collision possibility between the virtual tool 201 and the virtual workpiece 204 is indicated, namely, the repulsive force and/torque due the potential collision between the virtual tool 201 and the virtual workpiece 204 are mapped to the sense of the resistance to the user's hand. Therefore, the user can teach the virtual robot in an easy and intuitive way when having a sense of resistance with each of the virtual objects, such as the virtual tool 201 and the virtual object, which indicates any potential collision between the virtual tool 201 and the virtual object.

Figure 2C is a schematic diagram illustrating virtual robot 203 executing the task by holding the virtual tool 201 after the virtual path 208 has been taught according to an embodiment of the invention. The taught targets 2a, 2b, 2c, 2d are recorded automatically and composes the virtual path 208. The virtual robot 203 defined in the virtual environment 200 is adapted to hold the virtual tool 201 and repeat the virtual path 208.

The virtual tool 201 is guided by the interface 21 in an intuitive way to teach the target points 2a, 2b, 2c, 2d for executing the task. The via trajectory of the virtual tool to the target points 2a, 2b, 2c, 2d of the task is discarded by the virtual robot 203 and the virtual robot 203 moves to the taught target points directly to check reachability and collision.

Conventionally, the movement of the virtual tool that the user sees when he moves the interface depends on the relative translation and/or rotation between the world coordinate frame and the user coordinate frame. Figure 3 is a schematic diagram illustrating a coordinate transformation between a world coordinate frame used in the virtual environment and a user coordinate frame used in the user environment according to an embodiment of the invention. As mentioned in the description of figure 1, the mapping relationship is created between a world coordinate frame used in the virtual environment and a user coordinate frame used in the user environment. As shown in figure 3, the user 300 operates the interface 301 under the user coordinate frame 302 in the user environment, and the virtual tool 310 is moved under the world coordinate frame 311 in the world coordinate environment accordingly. For example, when the user 300 is looking at the world coordinate frame from a point of view V1 and moves the interface 301 to the right, he may see the virtual tool 310 move to the right also. Namely, the interface 301 in the user coordinate frame 302 and the virtual tool 310 in the world coordinate frame 311 move in substantially same way. For example, if the view angle is changed from V1 to V2, there is a change in the relative position between the world coordinate frame 302 and the user coordinate frame 311, under the current coordinate transformation, when the user moves the interface 301 to the right, he will see the virtual tool 310 move to the right. Preferably, it is desirable if the user sees the virtual tool 310 move under the world coordinate frame 311 in substantially the same way as he operates the interface 301 in the user coordinate frame 302, regardless of the change of his point of view. For example, when the user moves the interface downward 306 in the user coordinate frame, the virtual tool 310 always moves downwards 304 visually in the world coordinate frame 311 regardless of the user's point of view on the world coordinate frame 311 of the virtual environment. Therefore, there needs a change of the current coordinate transformation, which renders that the movement of the virtual tool that the user sees when he moves the interface is independent on the relative translation and/or rotation between the world coordinate frame and the user coordinate frame.. The mapping relationship is changed as follows.

Let Vf denote the point in the virtual environment from which the environment is looked, and Va the point to which the environment is looked. Vf and Va are both 3-dimentional vectors in the world frame. The view frame can be described by a 4x4 dimensional matrix *Mat_view* which is calculated by:

$$ViewZ = Vf - Va;$$
$$ViewX = [0, 0, 1] \; X \; ViewZ;$$
$$ViewY = ViewZ \; X \; ViewX;$$
$$ViewX = ViewX / |ViewX|;$$
$$ViewY = ViewY / |ViewY|;$$
$$ViewZ = ViewZ / |ViewZ|;$$
$$Mat\_view = [ViewX, ViewY, ViewZ, Vf];$$

Let a 4x4 dimensional matrix *Mat_tool* denote the position and orientation of the virtual tool in the world frame. The position and orientation of the virtual tool in the view frame can be described by a 4x4 dimensional matrix *Mat_tool_In_View* which is calculated by:

$$Mat\_tool\_In\_View = Mat\_view^{-1} \bullet Mat\_tool;$$

Let a 4x4 dimensional matrix *Mat_offset* denote the offset of the input device in the user frame**.** After mapping to the view frame, the new position and orientation of the virtual tool in the view frame is calculated by:

$$Mat\_tool\_In\_View = Mat\_offset \bullet Mat\_tool\_In\_View;$$

The new position and orientation of the virtual in the world frame is calculated by:

$$Mat\_tool = Mat\_view \bullet Mat\_tool\_In\_View.$$

Via above mapping, the virtual tool is moved in the user coordinate frame visually regardless of his point of view on the virtual environment, because the coordinate transformation is changed in consideration of a relative translation and/or rotation between the user coordinate frame and the world coordinate frame.

Figure 4 is a flow chart explaining the calculation of the sense data information according to an embodiment of the invention. The same reference number indicates the same part as shown in figures 2A, 2B and 2C.When the virtual tool 201 moves along a curve path 207 consisting of target points 2a, 2b, 2c and 2d inside of the dangerous region 205 above the virtual workpiece 204, a sense data information is generated as follows.

As shown in the flowchart, in step S200, calculating the virtual distance between the virtual tool and the virtual object. The surface of the virtual object may be shaped like a plane or curve. The virtual distance may be the length of the path starting from a virtual point of the virtual tool to a virtual point of the virtual object. For example, the virtual point of the virtual tool may be its virtual TCP (tool centre point), the virtual tip of the virtual tool or other virtual point on/in the virtual tool, and the virtual point of the virtual object may be a virtual point on the surface of the virtual object or inside the virtual object. Under different conditions, the virtual path may be linear or curved. Next in step S201, determining the direction of the movement of the virtual tool relative to the virtual object. Next in step S202, determining the sense data information based on the magnitude of the virtual distance and the direction of the movement of the virtual tool. For example, the magnitude of the resistance represented in the sense data information is determined in inverse proportion to the distance between the virtual tool and the virtual objects. In addition, when the virtual tool is moving very close to the virtual workpiece from above, a resistance in an upward direction will be represented in the sense data information. When the user moves the interface downward 306 in the user coordinate frame, the virtual tool 310 always moves downwards 304 visually in the world coordinate frame 311, and the virtual repulsive force 305 is calculated as a function of the virtual distance in inverse proportion. The direction of the virtual repulsive force 305 is determined to be opposite to the direction of the movement of the virtual tool relative to the virtual object. Anyway, the angle between the direction of the virtual repulsive force and the direction of the movement of the virtual tool may be obtuse, so as to reflect the concept of “repulsive”.

This step is being there for the purpose of preventing the user to continue moving the virtual tool, otherwise the virtual tool will collide with the virtual workpiece. Next in step S203, sending the sense data to the interface. Then, in step S204, sending the sense data information to the interface. Finally, in step S205, the interface generating sense data to user’s hand based on the sense data information. The direction of the resistance sensed by human hand is intuitive by using the frame mapping algorithm, hereby the dangerous situation is indicated effectively. For example, a upward resistance 307 is generated to the user’s hand.

A method for robot offline teaching may be utilized not only in the offline teaching with the apparatus described with reference to figures 1, 2A, 2B, 2C and 3, but also in other various applications. Thus, the method enables the user to teach the virtual robot in an easy and intuitive way when having a sense of resistance with each of the virtual objects, which indicates any potential collision between the virtual tool and the virtual object. The method includes the steps of defining a virtual tool 101, 201, 310 and a virtual object 102, 103, 104, 202, 203, 204 in a virtual environment 100, 200, sending a motion information to the virtual environment 100, 200 based on a movement su of an interface 11, 21, 301 caused by a user 12, 22, 300 in a user environment 120, 220, calculating a sense data information based on a virtual space relationship between the virtual tool 101, 201, 310 and the virtual object 102, 103, 104, 202, 203, 204 and the motion information, sending the sense data information to the interface 11, 21, 301, and the interface 11, 21, 301 generating a sense data to the user 12, 22, 300 based on the sense data information.

Preferably, a world coordinate frame 311 is used in the virtual environment 100, 200 from a visual point of view, a user coordinate frame 302 is used in the user environment 120, 220 from a user point of view, and the coordinate of each point in the world coordinate frame 311 and the coordinate of the point in the user coordinate frame 302 are associated with a coordinate transformation, and the coordinate transformation is changed in consideration of a relative translation and/or rotation between the user coordinate frame 302 and the world coordinate frame 311.

Preferably, the motion information in the user environment 120, 220 and virtual movement of the virtual tool 101, 201, 310 in the virtual environment 100, 200 are associated with the coordinate transformation and a virtual path 2a, 2b, 2c, 2d is taught in consideration of the sense data to the user 12, 22, 300 and recorded.

A program for robot offline teaching makes a computer carry out the method as described above and a computer readable recording medium recording the program for robot offline teaching are provided according to the description as above. For avoidance of redundancy, details are omitted here.

Though the present invention has been described on the basis of some preferred embodiments, those skilled in the art should appreciate that those embodiments should by no way limit the scope of the present invention. Without departing from the spirit and concept of the present invention, any variations and modifications to the embodiments should be within the apprehension of those with ordinary knowledge and skills in the art, and therefore fall in the scope of the present invention which is defined by the accompanied claims.

CLAIMS

1. An apparatus (1) for robot offline teaching, comprising:

a computer (10), being adapted to run a virtual environment (100, 200) where a virtual tool (101, 201, 310) and a virtual object (102, 103, 104) are defined; and

an interface (11, 21, 301), being adapted to send a motion information to the computer (10) based on its movement (Su) caused by a user (12, 22, 300) in a user environment (120, 220) and generate sense data based on a sense data information from the computer (10);

wherein:

the computer (10) calculates the sense data information based on a virtual space relationship between the virtual tool (101, 201, 310) and the virtual object (102, 103, 104) and the motion information, and sends the sense data information to the interface (11, 21, 301); and

the interface (11, 21, 301) generates the sense data to the user (12, 22, 300) based on the sense data information.

2. The apparatus for robot offline teaching according to claim 1, wherein a world coordinate frame (311) is used in the virtual environment from a visual point of view, a user coordinate frame (302) is used in the user environment from a user point of view, and the coordinate of each point in the world coordinate frame (311) and the coordinate of the point in the user coordinate frame (302) are associated with a coordinate transformation.

3. The apparatus for robot offline teaching according to claim 2, wherein the coordinate transformation is changed in consideration of a relative translation and/or rotation between the user coordinate frame (302) and the world coordinate frame (311).

4. The apparatus for robot offline teaching according to claim 1, wherein the virtual object is a virtual obstacle or a virtual work piece.

5. The apparatus for robot offline teaching according to claim 1, wherein the movement (Su) of the interface is of translation and/or rotation, and correspondingly the virtual tool translates and/or rotates in the virtual environment.

6. The apparatus for robot offline teaching according to claim 5, wherein the interface is a haptic device and the sense data is a sense of resistance to the user's hand (12, 22, 300).

7. The apparatus for robot offline teaching according to claim 5, wherein the motion information in the user environment and virtual movement of the virtual tool in the virtual environment are associated with the coordinate transformation.

8. The apparatus for robot offline teaching according to claim 1, wherein a virtual path (208, 2a, 2b, 2c, 2d) is taught in consideration of the sense data to the user (12, 22, 300) and recorded by the computer.

9. The apparatus for robot offline teaching according to claim 1, wherein a virtual robot (203) is defined in the virtual environment, being adapted to hold the virtual tool and repeat the virtual path (208, 2a, 2b, 2c, 2d) after check of its reachability and collision to target points of the virtual path (208, 2a, 2b, 2c, 2d).

10. A method for robot offline teaching, comprising:

defining a virtual tool (101, 201, 310) and a virtual object (102, 103, 104, 202, 203, 204) in a virtual environment (100, 200);

sending a motion information to the virtual environment (100, 200) based on a movement (Su) of an interface (11, 21, 301) caused by a user (12, 22, 300) in a user environment (120, 220);

calculating a sense data information based on a virtual space relationship between the virtual tool (101, 201, 310) and the virtual object (102, 103, 104, 202, 203, 204) and the motion information;

sending the sense data information to the interface (11, 21, 301); and

the interface (11, 21, 301) generating a sense data to the user (12, 22, 300) based on the sense data information.

11. The method for robot offline teaching according to claim 10, wherein a world coordinate frame (311) is used in the virtual environment (100, 200) from a visual point of view, a user coordinate frame (302) is used in the user environment (120, 220) from a user point of view, and the coordinate of each point in the world coordinate frame (311) and the coordinate of the point in the user coordinate frame (302) are associated with a coordinate transformation.

12. The method for robot offline teaching according to claim 11, wherein the coordinate transformation is changed in consideration of a relative translation and/or rotation between the user coordinate frame (302) and the world coordinate frame (311).

13. The method for robot offline teaching according to claim 10, wherein the virtual object (102, 103, 104, 202, 203, 204) is a virtual obstacle or a virtual work piece.

14. The method for robot offline teaching according to claim 10, wherein the movement (Su) of the interface is of translation and/or rotation, and correspondingly the virtual tool translates and/or rotates in the virtual environment (100, 200).

15. The method for robot offline teaching according to claim 14, wherein the interface (11, 21, 301) is a haptic device and the sense data is a sense of resistance to the user's hand (12, 22, 300).

16. The method for robot offline teaching according to claim 14, wherein the motion information in the user environment (120, 220) and virtual movement of the virtual tool (101, 201, 310) in the virtual environment (100, 200) are associated with the coordinate transformation.

17. The method for robot offline teaching according to claim 10, wherein a virtual path (208, 2a, 2b, 2c, 2d) is taught in consideration of the sense data to the user (12, 22, 300) and recorded.

18. The apparatus for robot offline teaching according to claim 1, wherein a virtual robot (203) is defined in the virtual environment (100, 200), being adapted to hold the virtual tool (101, 201, 310) and repeat the virtual path (208, 2a, 2b, 2c, 2d) after check of its reachability and collision to target points of the virtual path (208, 2a, 2b, 2c, 2d).

19. A program for robot offline teaching, said program makes a computer carry out the steps according to each of claims 10 to 18.

20. A computer readable recording medium recording the program for robot offline teaching according to claim 19.

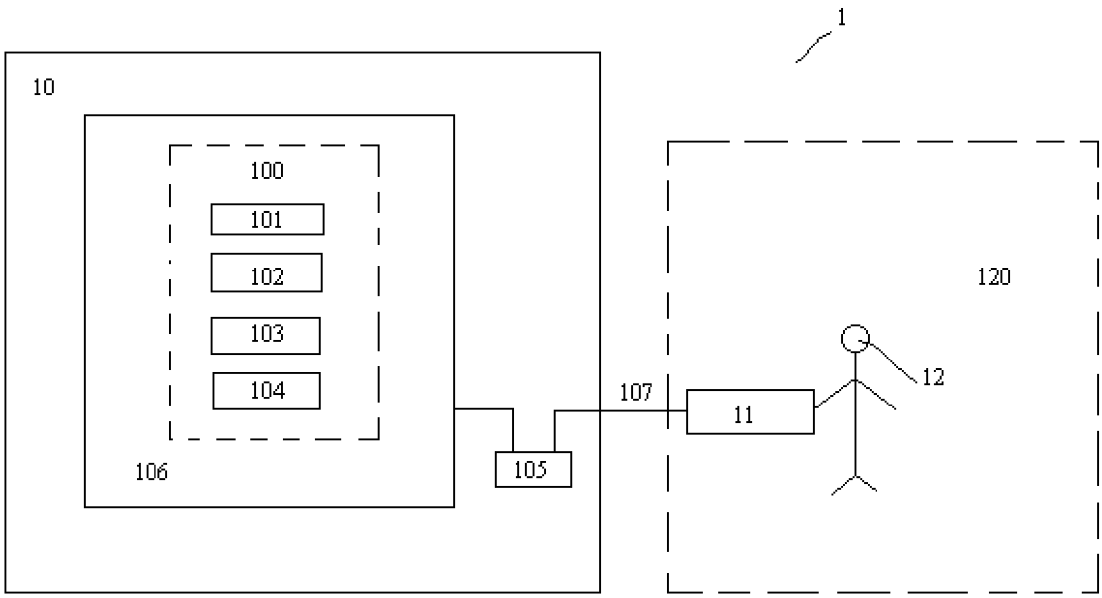

Figure 1

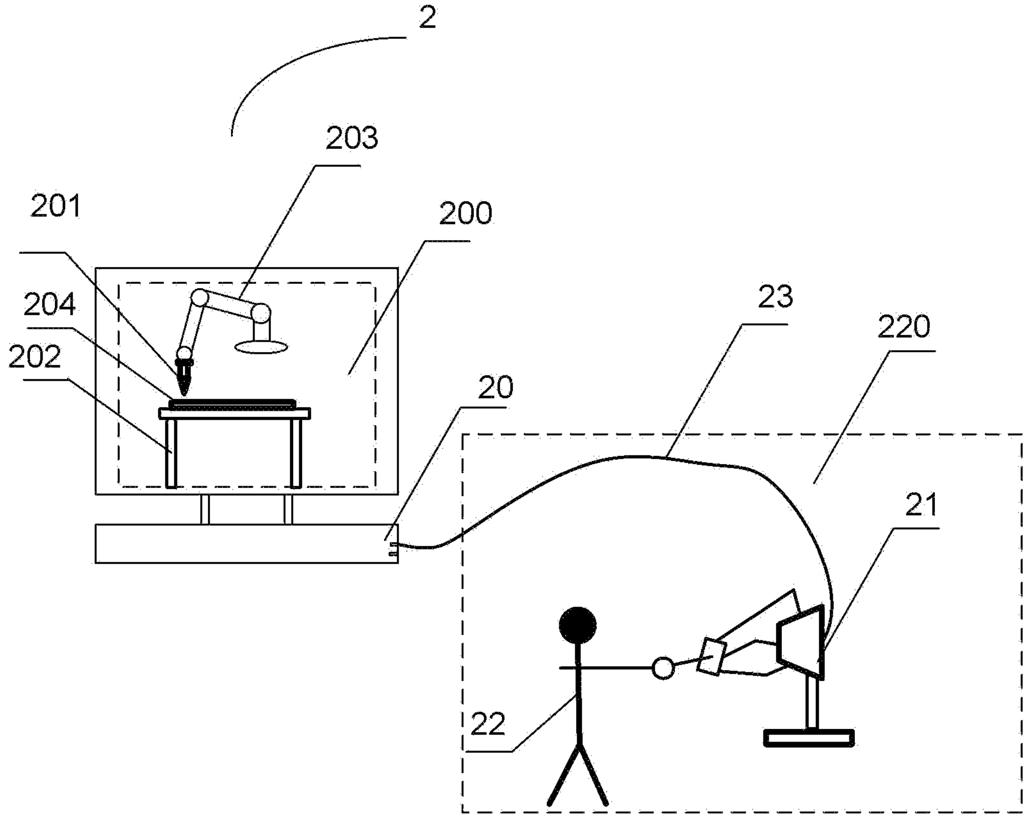

Figure 2A

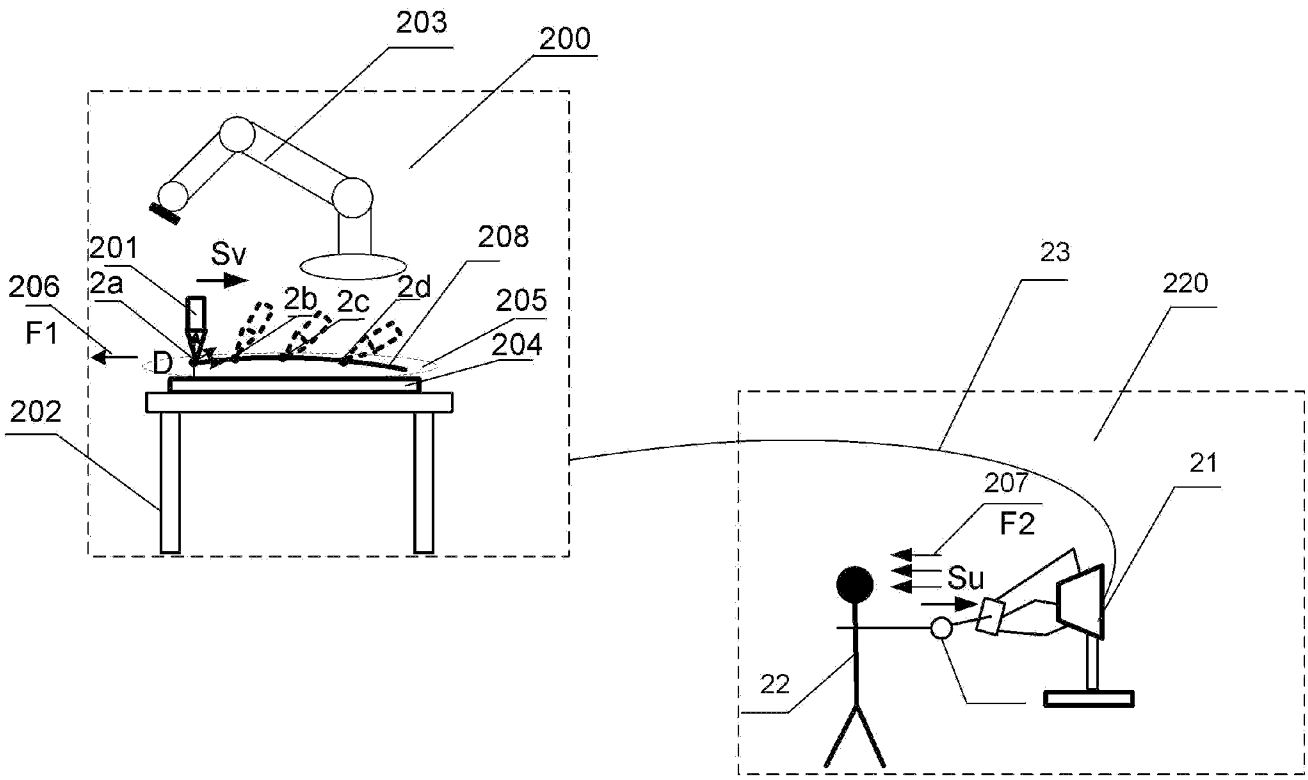

Figure 2B

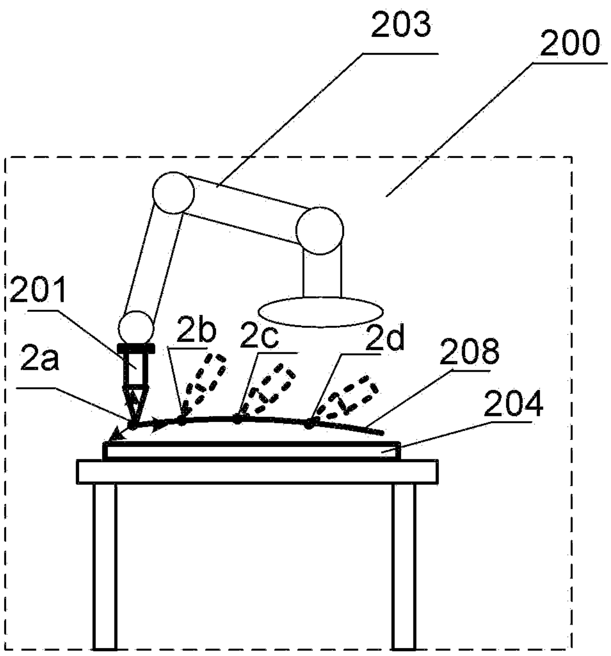

Figure 2C

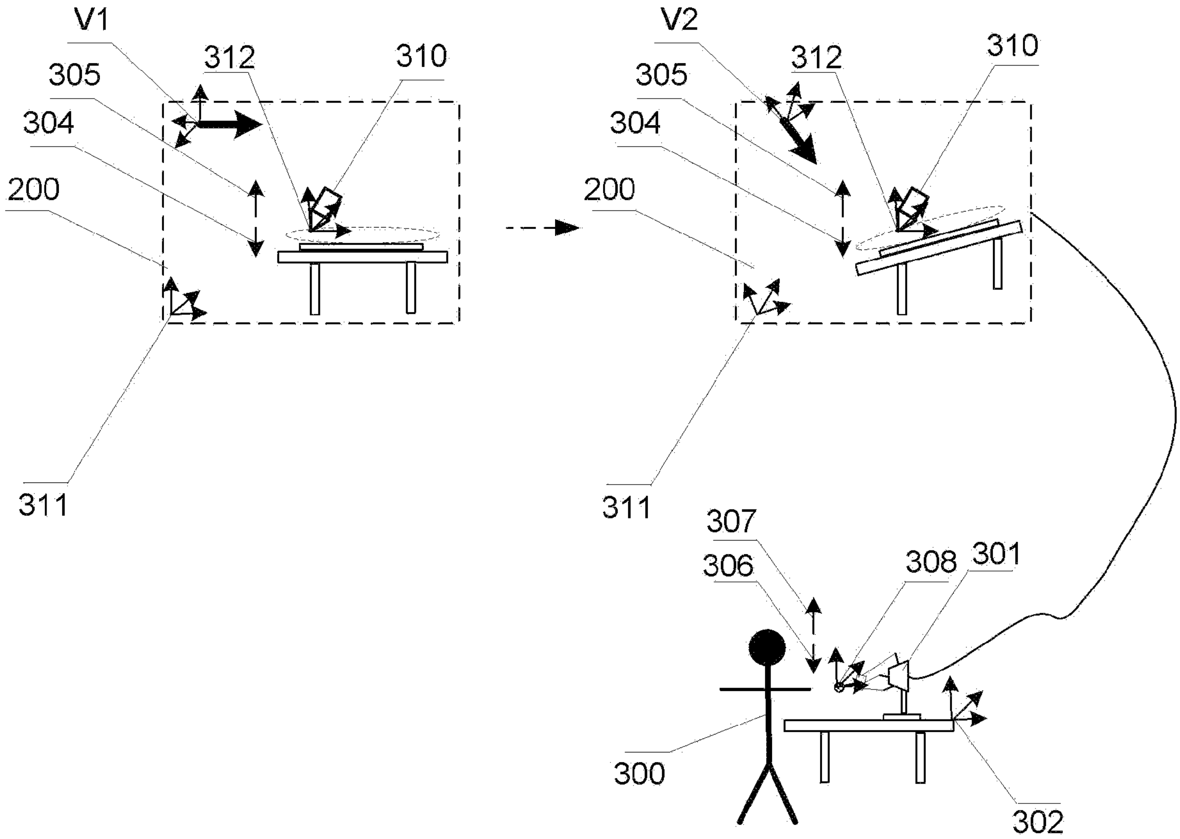

Figure 3

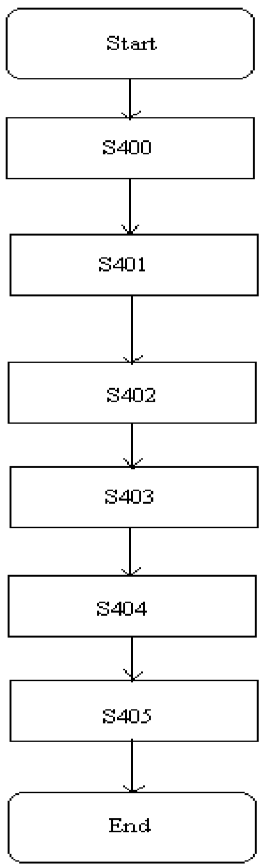

Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2010/072629

A. CLASSIFICATION OF SUBJECT MATTER

G06F 19/00 (2011.01) i

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)

IPC: G06F 19/-

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)

CNPAT,CNKI,WPI,EPODOC

robot, machine, arm, hand, hold+, virtual, user, position, coordinate, touch+, sense, data, information, teach+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN1440260A (DEPUY INT LTD) 03 Sep. 2003(03.09.2003) see the description page 3 lines 20-25, page 4 line 30 to page 5 line 15, page 6 line 25 to page 7 line 7	1-20
Y	US20090099690A1 (KUKA ROBOTER GMBH) 16 Apr. 2009(16.04.2009) see the description paragraphs 0034-0041	1-20

☐ 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

"E" earlier application or patent but published on or after the international filing date

"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
25 Jan. 2011 (25.01.2011)	**17 Feb. 2011 (17.02.2011)**

Name and mailing address of the ISA/CN
The State Intellectual Property Office, the P.R.China
6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China
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Facsimile No. 86-10-62019451

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FU, Yao
Telephone No. (86-10)62411887

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2010/072629

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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