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(54) **ROBOT FOR ULTRASONIC EXAMINATION**

ROBOTOR FÜR ULTRASCHALLUNTERSUCHUNG

ROBOT D'EXAMEN ULTRASONORE

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Description

[0001] This invention relates to a robot for medical ultrasonic examination comprising an articulated robot arm with a plurality of arm units successively mounted one on the other to be movable thereon, and a computerised system for controlling the movements of the arm, the outermost arm unit being arranged to carry a probe.

[0002] Ultrasonic examination is a common method. Usually, the transducer probe is held by hand. It is possible to transmit ultrasonic images over internet to an expert, telemedicine. It is desirable that the expert himself controls the positioning of the probe in real time, which calls for a robot that is convenient to control. Also when the expert is at hand, it is desirable to have such a robot instead of having a hand-held probe.

[0003] There are different probes for different ultrasonic medical examinations and interchangeability is desirable.

[0004] US 4,444,197 discloses an ultrasonic diagnostic probe scanner having an articulated arm carrying the probe. The probe tip is at a distance from the intersection of the three axes about which it can be swung. The tip of the probe will therefore move away from the target when its angular direction is adjusted which calls for adjustment of the entire arm.

[0005] It is an object of the invention to facilitate replacement of the probe and to permit for adjustment of the direction of the probe without repositioning of the probe.This object is achieved by the robot exhibiting the features defined in the independent claim 1.

Figure 1 shows in a side view a robot as an example of the invention.
Figure 2 is a top view of the robot shown in figure 1.
Figure 3 shows in a longitudinal section and enlarged a detail of the robot.

Detailed description of the illustrated and preferred embodiment

[0006] As shown in figure 1, the robot has a base 11 on wheels and it has a handle 12. The base is shown cut up so that its interior is shown. The wheels can be locked to make the base stand stably. The base has a vertical mount 13 for a first unit 14 of an articulated arm comprising arm units 14-16 and a probe holder 20. The mount 13 and thereby the arm unit 14 is turnable about the vertical axis I and the arm units 15 and 16 are pivotable about the respective axes II and III which are parallel with each other and perpendicular to axis I. The arm unit 16 has an outer portion 17 that is turnable about the longitudinal axis IV of the arm. This portion 17 is bifurcated and between its two extensions 18,19, figure 2, it carries the probe holder 20 which is pivotable about a transverse axis V perpendicular to the longitudinal axis IV. The arm 14-16 is not shown in the same position in figures 1 and 2.

[0007] The probe holder 20 with its probe 40 is shown in figure 3. It comprises a housing 21 with a steel tube 22 rotatable in bearings 23,24 in the housing about the axis VI of the probe but axially fixed. Another steel tube 25 inside tube 22 is locked to rotate together with the tube 22 by means of a bearing 27 that is fixed to the tube 25 and slideable in an axial groove 38 in the tube 22 so that the inner tube 25 will be axially slideable a limited length of one or a few mm in the outer tube 22. The bearing 27 ensures that there will be no friction that hinders axial movement of the inner tube 25 if there is a tangential force between the two tubes 22,25. Inside the inner tube 25 is a longitudinally split insert 26 of plastic that is adapted to the form of the probe and holds the probe fixed in it An annular cap 28 is screwed to the outer tube 22 and engages with an annular shoulder 29 on the insert 26 to prevent the insert from falling out. The inner tube 25 has an axial groove for an axial ridge 43 on the insert 26 so that the insert cannot turn in the inner tube.

[0008] When there is an axial force on the probe 40, the shoulder 29 on the insert 26 transmits the axial force to the tube 25 which transmits the force to a pin 30 that exerts the force onto a force sensor 31 that provides an electric signal via a non-illustrated line to an electronic unit 34 in the base 11.

[0009] There are different probes for different ultrasonic medical examinations and the probes are easily interchangeable. For replacing a probe for the one mounted, one removes the cap 28, and pushes out the tube 25 forwards. Then, the insert 26 with the probe is pushed out of the tube 25 and the split insert 26 is separated from the probe and the probe is pulled backwardly in its cable 41 out of the tube 22 and out of the housing 21. The opening 42 at the back of the housing 21 and the tube 22 are dimensioned to permit for this withdrawal of the probe. The cable extends sideways out through one of the lateral openings 32 that are provided between the two extensions 18,19 of the bifurcated portion 17, and the probe can be pulled through the opening 32.

[0010] Now another probe can be moved through the outer tube 22 and mounted in the inner tube 25 with inserts adapted for this particular probe. Then, the inner tube 25 with inserts and probe are inserted in the outer tube 22 and the cap 28 is screwed on. The probe is thus moved through the point where the three axes IV, V, and VI intersect and the distance between the axis V and the point of the probe, when the probe is in place, is small. The probes are normally elliptical and, therefore, such probes need not be held against rotation in the inserts solely by friction.

[0011] The robot includes built-in motors, electric motors, for carrying out the pivoting or rotation about the axes I-VI. The motors and their transmissions are not illustrated. The two motors for pivoting about the axes V and VI are placed inside the portion 17 of arm 16 and they transmit movement via transmission belts, one belt in each extension 18,19. The transmission belt for rotating the outer tube 22 rotates a non-illustrated gear that engages with a ring gear 33 on the tube. Thus, in order

for maintaining the outer tube fixed in the housing 21, the motor for rotating the outer tube must be actuated when the housing 21 is pivoted about the axis IV by the other motor in order to counteract the rotation of the tube 22 that otherwise would occur.

[0012] The computerised system for controlling the movements of the arm and probe includes the computerised electronic unit 34 in the base 11 coupled to a control unit for example in the form of a joystick 35 and some buttons or a joystick and a keyboard. The force sensed by the force sensor will appear on a display (monitor) 36. The ultrasonic image from the probe will also appear on the same display or on a separate display. The line between the electronic unit and the operator's panel is indicated with dashed lines 37. The operator, that is, the medical expert can be in the room or he can remote control the robot via internet or other communication means (telemedicine examination).

[0013] The computerised system includes two control systems:

> The first programmed control system controls the probe in cartesian coordinates which means that the probe is moved in X, Y and Z coordinates in response to movement of the joystick, that is the joystick controls the movements about all the axes and the direction of the probe is maintained constant during its movement

[0014] The second programmed control system controls the probe in an Euler angle system, which means that the direction of the probe is controlled by the joystick but the point of the probe is not moving sideways.

[0015] In both control systems, the medical expert need not control the individual movements about the axes I-VI but he simply uses the joystick to move the probe.

[0016] The programming is not described since it can be carried out in various ways by any skilled programmer.

Description of the operation of the illustrated robot in a telemedicine examination.

Step 1:

[0017] The assistant on site helps the patient to right position for the examination and moves the robot to position and locks the wheels of the robot. The medical expert may have real time video contact so that he/she can instruct the assistant.

Step 2:

[0018] The medical expert remote controls the robot and chooses the pre-programmed start position suitable for the examination to be carried out.

Step 3:

[0019] The expert chooses the cartesian control system and moves the robot arm by means of the joystick and chooses a suitable force applied by the probe to the patient. When the point of the probe is at the right place, the expert switches to the Euler angle control system and adjusts the direction of the probe with the probe point not moving sideways. The expert may also alternate between the two control systems several times for carrying out an examination in order to get the best possible positioning and to get the desired images. The distance between the axis V and the point of the probe is small, which facilitates its positioning. He may also switch to another pre-programmed start position and start over again with the probe at another position on the patient.

Claims

1. A robot for medical ultrasonic examination comprising:

- an articulated robot arm comprising a plurality of arm units (14-16) successively mounted one on the other to be pivotable one on the other,
- a carrying member (17,18,19) forming part of the outermost one of the arm units (16) so as to be rotatable about the longitudinal first axis (IV) of the carrying member,
- a probe holder (20) carried by the carrying member so as to be pivotable about a second axis (V) perpendicular to said first axis (IV) and comprising a holder sleeve (25) which carries the probe (40) and is rotatable about its longitudinal third axis (VI) which is perpendicular to said second axis (V),

said first, second and third axes intersecting each other at a single point, and

- a computerised system (34) for controlling the movements of the arm,

characterised in that

the probe holder (20) comprises a housing (21) pivotable about the second axis (V), in which housing the probe holder sleeve (25) is positioned, and the probe holder housing (21) has an opening (42) through which the probe (40) is insertable from the back into the probe holder and is to be locked in position in the holder sleeve (25).

2. A robot according to claim 1, **characterised in that** the holder sleeve (25) has an insert (26) adapted to the form of the probe so as to hold the probe (40) fixed in it, said insert being configured to be pushed out of the holder sleeve (25) with the probe (40) and to be separated from the probe (40).

3. A robot according to claim 2, **characterised in that** the insert (26) is split into longitudinal parts so that it holds the probe.

4. A robot according to anyone of the preceding claims, **characterised in that** said carrying member (17,18,19) has a lateral opening (32) through which a cable (41) from the rear end of the probe (40) extends when the probe is mounted.

5. A robot according to anyone of the preceding claims, **characterised by** a force sensor (31) in the housing (21) arranged to sense the axial force on the probe (40).

6. A robot according to 5, **characterised in that** the holder sleeve (25) is axially movable in the housing (21) and the force sensor (31) is coupled between the holder sleeve (25) and the housing (21).

Patentansprüche

1. Roboter für medizinische Ultraschalluntersuchungen, umfassend:

   - einen Gelenkroboterarm, umfassend eine Vielzahl von Armeinheiten (14 bis 16), die nacheinander aneinander montiert sind, um aneinander schwenkbar zu sein,
   - ein Trägerelement (17, 18, 19), das einen Teil der äußersten der Armeinheiten (16) bildet, damit es um die erste Längsachse (IV) des Trägerelements drehbar ist,
   - einen Sondenhalter (20), der vom Trägerelement getragen wird, damit er um eine zweite Achse (V) senkrecht zu der ersten Achse (IV) schwenkbar ist, und der eine Halterhülse (25) umfasst, die die Sonde (40) trägt und um ihre dritte Längsachse (VI) drehbar ist, die senkrecht zu der zweiten Achse (V) verläuft,
   wobei die erste, zweite und dritte Achse einander in einem einzigen Punkt schneiden, und
   - ein computergestütztes System (34) zum Steuern der Bewegungen des Arms,

   dadurch gekennzeichnet, dass
   der Sondenhalter (20) ein Gehäuse (21) umfasst, das um die zweite Achse (V) schwenkbar ist, wobei in dem Gehäuse die Sondenhalterhülse (25) platziert ist, und das Sondenhaltergehäuse (21) weist eine Öffnung (42) auf, durch die die Sonde (40) von hinten aus in den Sondenhalter schiebbar ist und in ihrer Position in der Halterhülse (25) arretiert werden soll.

2. Roboter nach Anspruch 1, **dadurch gekennzeichnet, dass** die Halterhülse (25) einen Einsatz (26) aufweist, der an die Form der Sonde angepasst ist, um die Sonde (40) fest darin zu halten, wobei der Einsatz eingerichtet ist, mit der Sonde (40) aus der Halterhülse (25) geschoben zu werden und von der Sonde (40) getrennt zu werden.

3. Roboter nach Anspruch 2, **dadurch gekennzeichnet, dass** der Einsatz (26) in Längsteile aufgeteilt ist, sodass er die Sonde hält.

4. Roboter nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Trägerelement (17, 18, 19) eine seitliche Öffnung (32) aufweist, durch die ein Kabel (41) vom hinteren Ende der Sonde (40) verläuft, wenn die Sonde montiert ist.

5. Roboter nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** einen Kraftsensor (31) im Gehäuse (21), der angeordnet ist, um die Axialkraft auf die Sonde (40) zu erfassen.

6. Roboter nach Anspruch 5, **dadurch gekennzeichnet, dass** die Halterhülse (25) in dem Gehäuse (21) axial beweglich ist und der Kraftsensor (31) zwischen der Halterhülse (25) und dem Gehäuse (21) gekoppelt ist.

Revendications

1. Robot d'examen ultrasonore médical comprenant :

   - un bras robotisé articulé comprenant une pluralité d'unités de bras (14 à 16) montées successivement les unes sur les autres pour pouvoir pivoter les unes sur les autres,
   - un élément porteur (17, 18, 19) formant une partie de l'unité de bras (16) la plus à l'extérieur de façon à être rotatif autour du premier axe longitudinal (IV) de l'élément porteur,
   - un support de sonde (20) porté par l'élément porteur de façon à pouvoir pivoter autour d'un second axe (V) perpendiculaire audit premier axe (IV) et comprenant un manchon de support (25) qui porte la sonde (40) et est rotatif autour de son troisième axe longitudinal (VI) qui est perpendiculaire audit second axe (V),
   lesdits premier, second et troisième axes s'entrecoupant les uns les autres à un point unique, et
   - un système informatisé (34) pour contrôler les mouvements du bras,

   caractérisé en ce que
   le support de sonde (20) comprend un boîtier (21) pouvant pivoter autour du second axe (V), le manchon de support de sonde (25) étant positionné dans ledit boîtier, et le boîtier (21) de support de sonde

présente une ouverture (42) à travers laquelle la sonde (40) peut être insérée par l'arrière dans le support de sonde et doit être verrouillée en position dans le manchon de support (25).

2. Robot selon la revendication 1, **caractérisé en ce que** le manchon de support (25) présente un insert (26) adapté à la forme de la sonde de façon à maintenir la sonde (40) fixée dans celui-ci, ledit insert étant configuré pour être poussé hors du manchon de support (25) avec la sonde (40) et pour être séparé de la sonde (40).

3. Robot selon la revendication 2, **caractérisé en ce que** l'insert (26) est divisé en portions longitudinales de sorte qu'il maintient la sonde.

4. Robot selon l'une quelconque des revendications précédentes, **caractérisé en ce que** ledit élément porteur (17, 18, 19) présente une ouverture latérale (32) à travers laquelle un câble (41) s'étend depuis l'extrémité arrière de la sonde (40) quand la sonde est montée.

5. Robot selon l'une quelconque des revendications précédentes, **caractérisé par** un capteur de force (31) dans le boîtier (21) agencé pour capter la force axiale sur la sonde (40).

6. Robot selon la revendication 5, **caractérisé en ce que** le manchon de support (25) est mobile axialement dans le boîtier (21) et le capteur de force (31) est couplé entre le manchon de support (25) et le boîtier (21).

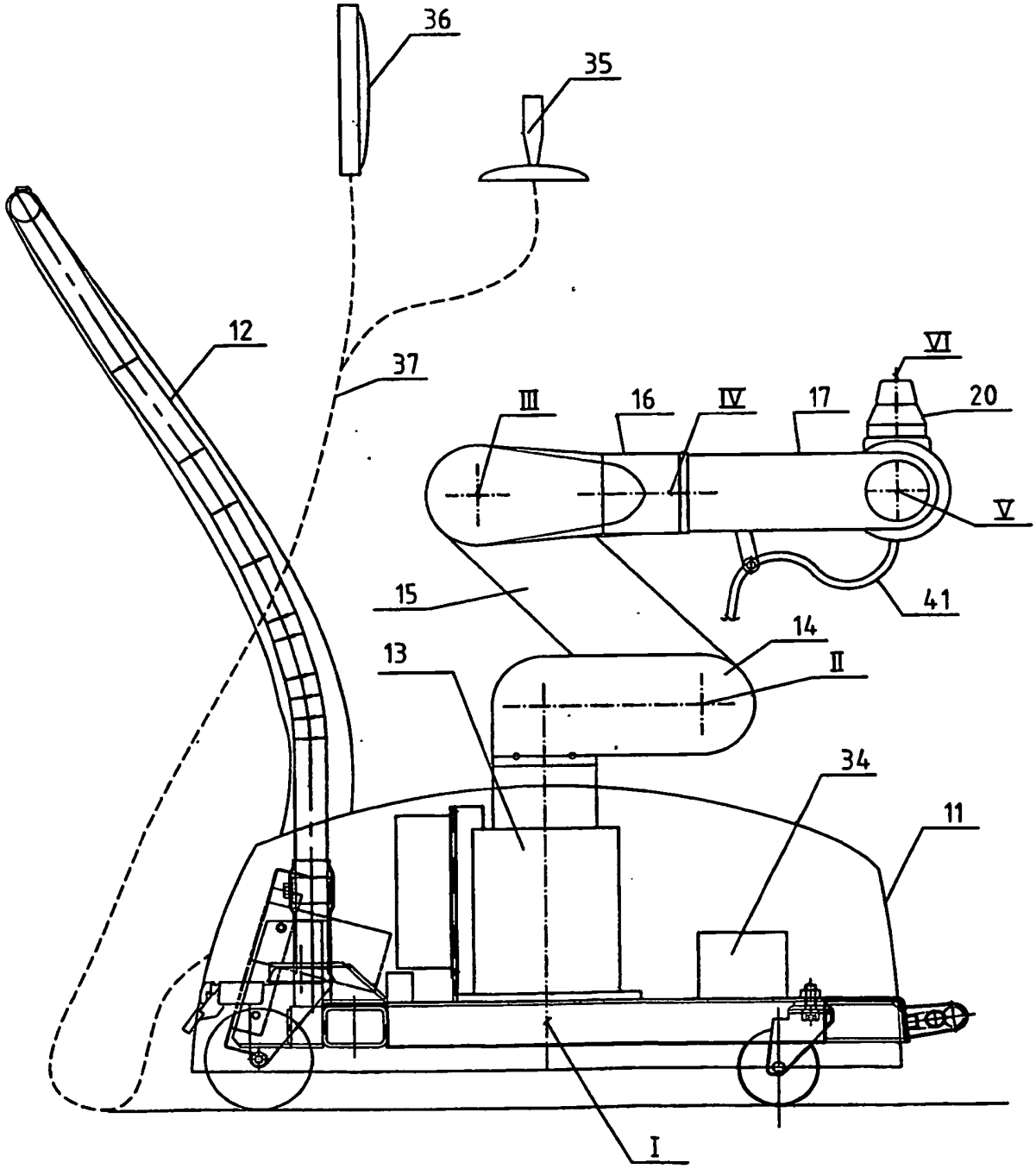

Fig.1

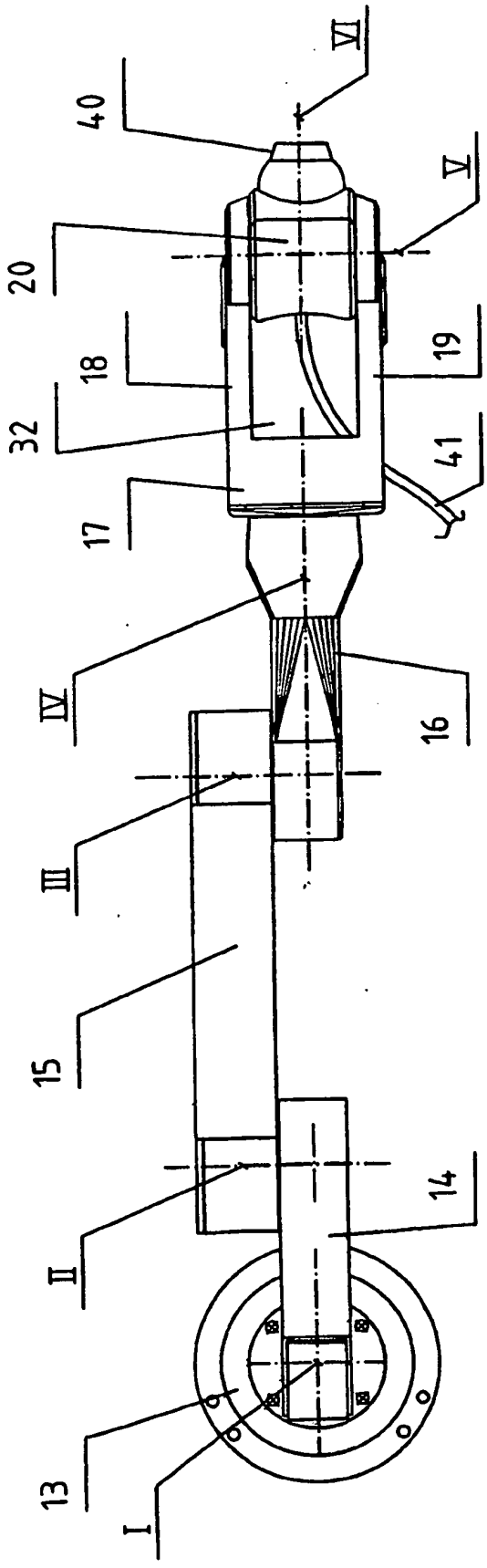

Fig. 2

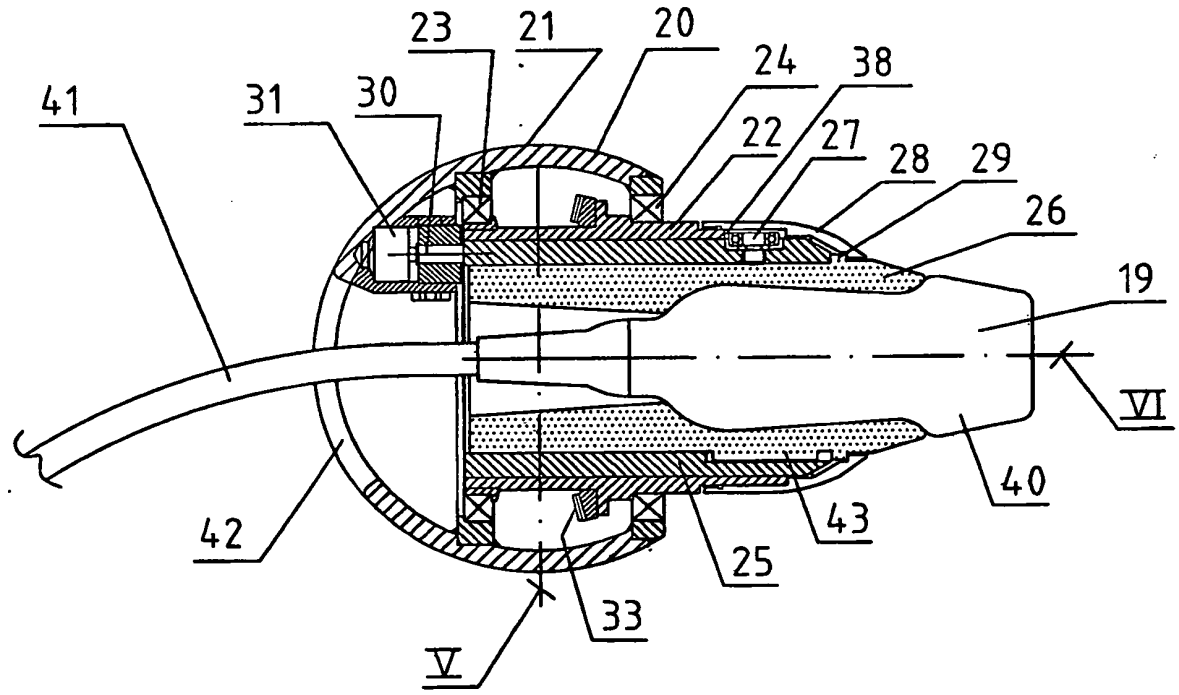

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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摘要(译)

一种用于医学超声波检查的机器人包括：多关节机器人臂，其具有多个臂单元（14-16），所述臂单元一个接一个地安装在另一个上以便可枢转，以及用于控制臂的运动的计算机化系统，最外面的臂单元（16））被安排来携带探针（40）。最外面的臂单元（16）具有可绕其纵向轴线（IV）转动的承载构件（17），并且承载探针保持器（20），该探针保持器（20）可绕垂直于所述纵向轴线的横向轴线（V）枢转。探针支架（20）包括可绕所述横向轴线枢转的壳体（21）和可绕其纵向轴线（VI）转动的保持器套筒（25），并且所有三个轴线（IV，V，IV）相交。探头支架（20）具有侧向开口，当探头安装时，来自探头（40）后端的电缆（41）延伸穿过该侧向开口，并且承载构件允许探头插入穿过侧孔并且从探头支架的后部进入探头支架。

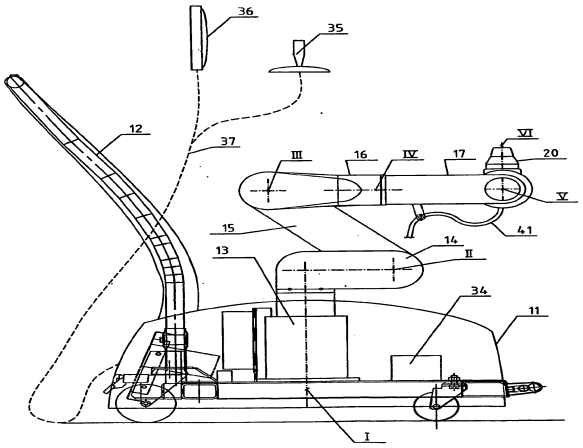

Fig.1