

APPARATUS AND METHOD FOR PROSTATE BIOPSY OR PARTICLE IMPLANTATION

FIELD OF THE INVENTION

[0001] The present invention relates to a medical apparatus and method for prostate biopsy or particle implantation.

BACKGROUND TO THE INVENTION

[0002] A prostate biopsy is recommended when prostate cancer is suspected. It is a surgical procedure in which a small sample of tissue is removed from the prostate gland and examined under the microscope by a pathologist, a doctor specializing in identifying disease through the study of cells, tissues and organs. The procedure takes about 15 minutes and is usually performed by an urologist with the use of a transrectal ultrasound (TRUS) probe. With the help of TRUS, a doctor guides a biopsy needle, a hand-held device with a spring-loaded, slender needle, through the wall of the rectum into the area of the prostate gland that appears abnormal.

[0003] The rectal wall is thin, so it is possible to place the needle accurately into the abnormal site of the prostate gland with the use of a biopsy needle with less injury to other tissues. When the biopsy needle is activated, the needle can remove a slender cylinder of tissue (about 1 mm by 18 mm), called a core, in a fraction of a second. Biopsy needles are small, only 1.2 mm in diameter and about 200 mm long. A sliding sheath on the gun opens once the needle enters the prostate, closes onto a sample of tissue for extraction and the needle is withdrawn.

[0004] It is understood that a small amount of bleeding is normal because the needle has entered the small vein area. Urine, semen, defecation and bleeding may occur intermittently for several days or several weeks. The two major risks of

biopsy are severe prostate or urinary tract bleeding and infection. These risks are very rare and occur in less than 1% of patients.

[0005] The diagnosis of prostate cancer is imprecise due to the imprecision of current devices used and the lack of management of the soft and mobile environment of the prostate. Improved precision is necessary to be capable of providing a more reliable and complete diagnosis, in particular with information on the localization of cancerous areas, which may also be used to plan and guide focus treatments.

[0006] The treatment of prostate cancer is intended to cure the patient by destroying diseased tissue while preserving the healthy surrounding tissue. It is therefore important to be able to deliver therapeutic agents (e.g. radioactive seed) in a precise manner to diseased or cancer tissue. If the therapeutic agent is placed with inadequate precision, it may act on healthy tissue, and potentially on functional structures such as the bladder, the rectum or the urethra. In these avoidable cases, the patient may suffer from conditions such as impotence or incontinence. Prostate treatments have been conducted in a general manner, on the entire gland rather than a highly localised area of the gland. The main reasons for this generality are the uncertainty of the localization of cancer tissue with the current diagnostic means and the multifocal nature of prostate cancer.

[0007] Therefore there is a serious need for diagnostic tools and therapeutic agents to be guided with maximum precision to the origin of the cancer, in order to improve the reliability of the diagnosis, and to minimize the adverse effects, recurrences and morbidity associated with the treatment.

[0008] For precise diagnosis and treatment of prostate cancer, the prior art has proposed various ways to improve the traceability of the organ for needle penetration areas, as well as the localization of cancerous areas.

[0009] WO2009071766 discloses a prostate imaging method comprising steps of recording and processing images acquired by the ultrasonic head of a rectal probe equipped with an active puncture guide. This method comprises steps of processing at least some of the images acquired by the probe in order to calculate transformations toward a reference image system with the initial position of the prostate. At least some of the images acquired during successive punctures including the localization of the different positions of the needle are recorded in order to show their representations in a single image including at least some of the prostate. WO2009071766 also relates to a prostate imaging system implementing said prostate imaging method. This improves the acquisition of graphic information on the prostate, and enables the matching of different images of the prostate, acquired with complementary imaging systems, as well as by a rectal probe integrated with the treatment needle. It therefore enables the guiding and localizing of the needle with respect to areas of interest in the prostate to be improved. This imaging system can be used for both devices manually held by a surgeon and automated devices. This also includes control methods, sometimes associated with automated devices for performing biopsies and prostate treatments.

[0010] US20070270687 discloses a registration method for obtaining updates between 3D ultrasound images in order to monitor the movement of an instrument in the image reference system by using the differences between the two images by subtraction. One application proposed is monitoring of the movement of the end of a brachytherapy needle in order to enable adaptive dosimetry and to overcome needle-positioning errors.

[0011] CA2654344 discloses a device and a method for the positioning and the insertion of a needle around a fixed point (remote centre of motion). This device and technique can be used to position a biopsy needle by visually comparing 3D ultrasound images in order to check the movement or swelling of the prostate after the needle is removed.

[0012] US6423009 discloses a system for guiding percutaneous tools for prostate therapy using 3D ultrasound images. An example of this technique involves the positioning of cryotherapy probes in prostate cryotherapy. In this example, a method for positioning probes while checking the proper positioning of the needles with respect to the plan is described.

[0013] WO2007085953 discloses a device and a method for inserting a needle according to a predetermined trajectory, and at a predetermined depth, in order to reach a target area of tissue of a soft organ, with control by ultrasound imaging. This method may be used for biopsy of the prostate or brachytherapy of the prostate. The method implements a conical approach area through the perineal wall. The needle passes through the patient's skin through a pivot point. The orientation of the needle support is ensured by spherical joints.

[0014] US6846282 discloses means for brachytherapy performed with a needle for injecting a radioactive product into an organ such as the prostate. Markers placed on the patient's body define a system of coordinates enabling the real-time analysis of the displacement of the needle within the reference system of the patient. An alternative consists of using anatomical markers.

[0015] EP1088524 discloses a system and a method for implementing prostate brachytherapy based on a reconstructed 3D ultrasound image, preoperative planning of the insertion of needles including segmentation of the surrounding organs and a peri-operative evaluation of the placement and deflection of the needles with respect to the plan. EP1088524 does not teach or suggest three-dimensional quantification of the movement of the prostate.

[0016] US20030018232 discloses an automated system for implanting radioactive seeds. The principle of positioning a needle at a width, height and depth in the organ, in order to insert a radioactive seed therein, is described. The system is calibrated with respect to the organ (the prostate) by the adjustment of a basic plane with respect to the organ seen in the ultrasound. The ultrasound

probe is interdependent with the robot and moved according to an axis parallel to the axis of insertion of the needles. During the insertion procedure, a plane-by-plane ultrasound acquisition of the organ can be sequenced so as to make a registration and consequently adapt the basic needle insertion plane. Similar to EP1088524, the 3D movement of the prostate during insertion of a needle is not taught or suggested in US20030018232 for the automatic and precise compensation of the plan with respect to organ movement.

[0017] US20070016067 discloses an automated system and method for puncture under peri-operative imaging but does not teach or suggest in its control loop, the relative position of the puncture tool with respect to the targeted organ.

[0018] There is a need, in light of the foregoing, for a medical apparatus and method for prostate biopsy and particle implantation that provides three-dimensional quantification of the movement of the prostate and provides automatic and precise compensation of the plan with respect to any movement of the prostate.

[0019] The prostate is a deformable and mobile organ. The prior art is adversely affected by modifications and movements of the organ and do not enable truly precise localization. The prior art does not take into account the movements of the prostate in an automatic sense or during the time the needle is inserted.

SUMMARY OF THE INVENTION

[0020] The inventive concept arises from a recognition that it is desirable to accurately control the insertion of the needle into the prostate in a predetermined direction and at a predetermined depth and compensates for the deformation and mobility of the prostate.

[0021] In one embodiment, the present invention provides a precise automatic quantification of the movement of the prostate obtained from a 4D probe and is a fully automated, flexible, accurate four-pole executive agency for puncture and implant operation.

[0022] The movements of the prostate consists of displacements and deformations result in different phenomena: (1) Under the pressure of a puncture or treatment needle, the prostate is deformed and is displaced within the human body; (2) The punctures cause lesions, inducing swelling of the prostate during the intervention. The movements of the patient, in particular the patient's breathing cycle, also produce deformations and displacements the prostate; and (3) To obtain a high-quality image, the rectal probe must come into contact with the rectal wall close to the prostate and exert a light pressure also producing deformation and displacement of the prostate.

[0023] In one embodiment, the present invention provides a high-precision, low-deformation, auto-operated, low-wound ultrasound-guided prostate biopsy and particle implantation system.

[0024] In one embodiment, the present invention generally provides a medical apparatus and method for prostate biopsy and particle implantation. The apparatus includes a 4D probe, movable bracket, scan-biopsy execution device, computer with two display screens. One end of the movable bracket is fixed on the operating table or the multi-tripod, and the other end of the movable bracket supports the scan-biopsy execution device. The scanning biopsy execution device is connected to the computer. Two display screens are connected to the computer to display images and 3D models generated by the 4D probe.

[0025] The movable bracket connects to a probe holder which is located at the bottom of scan-biopsy execution device. The 4D probe is held by the probe holder. The probe holder is connected to the puncture control module. The scan-biopsy execution device comprises a depth positioning module and a puncture

control module. The depth positioning module is fixed on the puncture control module. The depth positioning module is provided with a puncture hole/needle sheath and a needle holder. The puncture control module controls the direction of the puncture hole using rotational linkages actuated by a motor. The puncture hole and the needle holder in combination hold and adjust the angular direction of a biopsy needle.

[0026] The operative end of the 4D probe has an ultrasound scanning module. An internal motor controls rotation of an ultrasonic transducer. The transducer rotates within a predetermined angle and the computer records the scanning time. The 4D probe does not cause any tissue deformation after insertion into the rectum at the correct position because there is minimal or no relative movement between the exterior of the 4D probe (e.g. the housing of the 4D probe) and the patient.

[0027] The biopsy needle passes through the puncture hole. The biopsy needle is adjustable to any position within a predetermined range by adjusting the puncture hole. The needle holder defines the maximum insertion depth of the biopsy needle. The needle holder is movable in the axial direction of the depth positioning module.

[0028] After the 4D automatic rotating probe reaches a desired position via the patient's rectum there is no need of any relative movement or relative rotation between the external surface of the 4D probe and the patient's body. The internal transducer of the 4D probe automatically rotates and scans the prostate to ensure no tissue deformation caused by probe movement. At the same time, computer software processes the real-time images obtained by the 4D probe scanning to ensure accuracy of ultrasound images and 3D ultrasound model. A combination of the puncture control module and the depth positioning module provides accurate positioning and depth for the biopsy and implant operation. This greatly facilitates the operation of the doctor. The doctor is able to monitor the progress of the operation along the biopsy path in real time, and avoids tissue deformation

caused by relative movement of the exterior surface of the 4D probe with respect to the patient. The medical apparatus according to one embodiment assists in multi-point accurate sampling, reduces the probability of repeated sampling, improves the coverage of the sample, and further improves the detection accuracy.

[0029] The present invention, in one aspect, comprises a medical apparatus for prostate biopsy or radioactive particle implantation. The apparatus comprises a scanning and puncture assembly. The scanning and puncture assembly comprises an ultrasound probe having an internally rotatable ultrasonic transducer within a predetermined angular range to capture a series of sequential ultrasonic images in 3-spatial dimensions. The scanning and puncture assembly also comprises a needle for biopsy or for radioactive particle implantation. The scanning and puncture assembly also comprises a puncture control module to adjust an insertion angle of the needle. The scanning and puncture assembly also comprises a depth positioning module to adjust the insertion depth of the needle. The apparatus also comprises a support assembly to support the scanning and puncture assembly at a predetermined position relative to a patient. The apparatus also comprises a computer comprising a memory and a processor configured to execute computer executable instructions for controlling the scanning and puncture assembly including the adjustment of the insertion angle and the insertion depth of the needle according to a predetermined biopsy path.

[0030] The support assembly may comprise a plurality of articulated or rotatable joints to enable the support assembly to move to a predetermined position.

[0031] The support assembly may be connected to an examination table or a tripod.

[0032] The medical apparatus may further comprise a computer to execute the computer executable instructions.

[0033] The medical apparatus may further comprise two display screens connected to the computer to display the ultrasonic images captured by the ultrasound probe.

[0034] The support assembly may be connected to a probe holder of the scanning and puncture assembly.

[0035] The ultrasound probe may be held by the probe holder, and the probe holder is connected to the puncture control module, and the depth positioning module is connected to the puncture control module.

[0036] The depth positioning module may comprise: a puncture hole to control the position of a puncture hole using rotational linkages; and a needle holder to hold the needle.

[0037] The probe holder may be directly connected to the support assembly, and the probe holder is manually adjustable to a predetermined position and the probe holder is releasably fixable in the predetermined position.

[0038] The probe holder may be connected to a track and is moved by a motor according to the execution of the computer executable instructions.

[0039] The puncture control module may comprise a motor, rotational linkages and a housing.

[0040] The rotational linkages may comprise a lead screw, a slider and links.

[0041] The motor may drive the slider to move the links causing link ends of the puncture control module and the puncture hole to move to a predetermined position.

[0042] Each rotational linkage may be movable in a first plane independently to movement of another rotation linkage in a second plane, wherein the first plane is parallel to the second plane.

[0043] End portions of the rotational linkages may be connected to corresponding end portions of the puncture hole such that the direction and position of the puncture hole is adjustable.

[0044] The puncture hole may be a tubular structure having a predetermined length to permit the needle to pass therethrough.

[0045] The needle holder may define a maximum insertion depth of the needle, and the needle holder is movable in an axial direction relative to the depth positioning module.

[0046] The ultrasound probe may be a 4D probe and includes an ultrasound scanning module and an internal motor for internally rotating the ultrasonic transducer.

[0047] The present invention, in another aspect, comprises a method for prostate biopsy and particle implantation. The method comprises capturing a series of sequential ultrasonic images in 3-spatial dimensions using an ultrasound probe without relative movement of the ultrasound probe after insertion. The method also comprises executing computer executable instructions to adjust an insertion angle of the needle according to a predetermined biopsy path. The method also comprises executing computer executable instructions to adjust the insertion depth of the needle according to the predetermined biopsy path.

[0048] Other advantages and features according to the invention will be apparent to those of ordinary skill upon reading this application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049] Embodiments of the invention will be described with respect to the figures, in which like reference numbers denote like elements and in which:

[0050] Figure 1 is a schematic diagram of a medical apparatus according to an embodiment of the invention having a movable bracket fixed to an examination table;

[0051] Figure 2 is a schematic diagram of the movable bracket fixed to a multi-tripod;

[0052] Figure 3 is a schematic diagram of the scan-biopsy execution device;

[0053] Figure 4 is a perspective diagram of the puncture control module together with the depth positioning module;

[0054] Figure 5 is a top view of the scan-biopsy execution device depicted the puncture control module changing the angle of the biopsy needle;

[0055] Figure 6 is a bottom view of the scan-biopsy execution device;

[0056] Figure 7 is a front view of the puncture hole of the depth positioning module;

[0057] Figure 8 is a schematic diagram of the puncture hole of the depth positioning module;

[0058] Figure 9 is a schematic diagram of the depth positioning module without the biopsy needle;

[0059] Figure 10 is a schematic diagram of the puncture hole of the depth positioning module;

[0060] Figure 11 is a schematic diagram of the puncture control module;

[0061] Figure 12 is a cross-sectional diagram of the 4D probe; and

[0062] Figure 13 is a flow chart depicting computer executable instructions executed by a computer of the medical apparatus.

DETAILED DESCRIPTION OF THE INVENTION

[0063] A preferred apparatus according to the present invention is illustrated in Figs. 1 and 2 and shown generally at reference numeral 10. An examination table 1 is provided with stirrups for the patient to place their feet. With the patient's feet elevated and spread apart, access to the patient's rectum is easier.

[0064] The medical apparatus 10 for prostate biopsy or radioactive particle implantation generally comprises a scanning and puncture assembly 4. The scanning and puncture assembly 4 comprises: an ultrasound probe 7 having an internally rotatable ultrasonic transducer 72 within a predetermined angular range to capture a series of sequential ultrasonic images in 3-spatial dimensions (i.e. a live 3D video). The scanning and puncture assembly 4 also comprises a needle 8 for biopsy or for radioactive particle implantation. The scanning and puncture assembly 4 also comprises a puncture control module 42 to adjust the insertion angle of the needle 8 and therefore determine the trajectory path for the needle 8. The scanning and puncture assembly 4 also comprises a depth positioning module 43 to adjust the insertion depth of the needle 8.

[0065] The apparatus 10 also comprises a support assembly 3 to support the scanning and puncture assembly 4 at a predetermined position relative to a patient. The apparatus 10 also comprises a computer 6 comprising a memory and a processor configured to execute computer executable instructions for controlling the scanning and puncture assembly 4 including the adjustment of the

insertion angle and the insertion depth of the needle 8 according to a predetermined biopsy path.

[0066] The support assembly 3 is a movable bracket 3 in the form of linkages. The movable bracket is connected to and supports the scanning and puncture assembly 4 at one end. The scanning and puncture assembly 4 may also be referred to as a scan-biopsy execution device 4. In Fig. 1, the movable bracket 3 is connected to the examination table 1 at an opposite end. In Fig. 2 in another embodiment, the movable bracket 3 is connected to a multi-tripod 2 at the opposite end. The support assembly 3 supports the scan-biopsy execution device 4 in a predetermined position such that the scan-biopsy execution device 4 is in close vicinity to the patient prior to insertion of the 4D probe 7. The scan-biopsy execution device 4 is connected to a computer 6 wirelessly or via a cable. The computer 6 has two display screens 5.

[0067] Referring to Figs. 3, 4, 5 and 6, the scan-biopsy execution device 4 is depicted. The lower side of the scan-biopsy execution device 4 has a probe holder 41 that is connected to the movable bracket 3. The probe holder 41 holds an ultrasonic probe 7. The ultrasonic probe 7 may be a 4D probe 7. The probe holder 41 is connected to the puncture control module 42. The depth positioning module 43 is connected to the puncture control module 42.

[0068] Referring to Figs. 7 to 9, the depth positioning module 43 is provided with a puncture hole 431 (or needle sheath) and a needle holder 432. The puncture hole 431 is a hollow slender rigid cylinder that surrounds, guides and protects the needle 8. A generally cylindrical through-hole 433 extends along the central axis of the puncture hole 431 where the needle 8 moves through (see Figure 9). Moving, tilting and angling the puncture hole 431 in turn changes the needle insertion direction of the needle 8 at a very high level of accuracy.

[0069] Referring to Figs. 4, 10 and 11, the puncture control module 42 controls the position of the puncture hole 431 using rotational linkages 422, 423,

424. The rotational linkages 422, 423, 424 of the puncture control module 42 have link ends 425, 426 which are securely connected to the puncture hole 431 of the depth positioning module 43. The link ends 425, 426 have U-shaped contact members 427 that are shaped to partially surround the puncture hole 431 for greater surface contact with the puncture hole 431. In one embodiment, the link ends 425, 426 can rotate relative to the link 422. One end of the puncture hole 431 is fixed to the end of the rotational linkages. The other end of the puncture hole 431 is a free end. The needle holder 432 holds and supports a biopsy needle 8. In one embodiment, the needle holder 432 is U-shaped. The biopsy needle 8 is pivotable about the needle holder 432 to some degree. The biopsy needle 8 comprises an outer cannula. The outer cannula is about 1 to 2mm in diameter and is very thin. Therefore it is better to move the needle 8 to a predetermined angular direction or orientation by having the link ends 425, 426 connected to the needle sheath 431 rather than directly moving the more fragile outer cannula of the needle 8. There is a lower chance of damaging the outer cannula of the biopsy needle. The biopsy needle 8 also comprises a body portion and tissue sample holder for containing an extracted core. The biopsy needle 8 may also comprise a transverse tissue receiving aperture located proximally from a tissue piercing tip.

[0070] Referring back to Figs. 1 and 2, the computer 6 is able to make micro adjustments to the position, depth required and elevation/angle by controlling the puncture control module 42 and the depth positioning module 43 to actuate based on processing of the real-time ultrasound model generated by the 4D probe 7. These micro adjustments are very fine changes, for example, less than 5mm or less than 5°, or less than 1mm or less than 1°. Correct positioning compensates for any deformation or movement of the prostate and is carried out by the combination of the puncture control module 42 and the depth positioning module 43. When the correct position and angular direction has been reached, the biopsy needle 8 passes through the through-hole 433 of the puncture hole 431 and makes a puncture through the patient's skin. The puncture hole 431 functions as a needle guide or needle hub. By adjusting the elevation angle of the puncture hole 431 by moving the link ends 425, 426 of the puncture control module 42, the

trajectory of the insertion path of the needle 8 can be micro adjusted to a high accuracy. The link ends 425, 426 can be moved independently or together. To reduce the chances of needle damage and to improve accuracy for a sampling operation, the puncture hole 431 should have a sufficient predetermined length. In one embodiment, the length of the puncture hole 431 is about 27.5mm accounting for the apex angle and mechanical design.

[0071] Referring back to Fig. 4, a motor 421 controls the movement of a slider 423 using a lead screw 424. The movement of the slider 423 causes a link 422 to move and pivot. The lead screw 424 is a linkage to translate rotational motion into highly precise linear motion. Depending on the screw pitch of the lead screw 424, high precision and accuracy of the linear motion can be obtained. The lead screw 424, the slider 423, and the link 422 constitute a rotational linkage of the puncture control module 42 of the scan-biopsy execution device 4. In one embodiment, there are two rotational linkages provided to control the position of two link ends 425, 426, respectively, which adjusts the angular direction of the puncture hole 431. The two link ends 425, 426 are connected to the rotational linkage and located at distal ends of the rotational linkage. The direction of the central axis of the puncture hole 431 determines the puncture direction. The needle holder 432 controls the biopsy depth and prevents the doctor from inserting the needle 8 too deep beyond the target tissue or too shallow which does not reach the target tissue. The needle holder 432 moves in a linear motion parallel to the central axis of the needle 8 based on instructions from the computer 6. A motor in the depth positioning module 43 drives the motion for the needle holder 432 which adjusts the insertion depth of the needle 8. The puncture control module 42 and rotational linkages 422, 423, 424 are light-weight making them easy to move and actuate to specific positions. In another embodiment, there may be a single link end connected to the puncture hole 431 for adjusting the angular direction of the puncture hole 431.

[0072] Computer software comprising computer executable instructions is configured to control the rotational linkages 422, 423, 424 for controlling the

angular direction and position of the puncture hole 431, and in turn controls the angular direction of the biopsy needle 8. Many biopsy methods including parallel biopsy and conical biopsy can be implemented by the medical apparatus 10 because the direction and depth of the puncture can be much more freely set in a predetermined range. The computer executable instructions are executed by the computer 6 to instruct the movements and functionality of the scan-biopsy execution device 4.

[0073] Referring to Fig. 12, the operative end of the 4D probe 7 has an ultrasound scanning module. An internal motor 71 controls rotation of the transducer 72 internally within an external housing of the 4D probe 7. The transducer 72 rotates within a predetermined angle and the computer 6 records the time. The internal transducer 72 of the 4D probe 7 can automatically rotate and scan the prostate which ensures no tissue deformation is caused by avoiding movement of the 4D probe 7 relative to the patient after insertion.

[0074] The ultrasound scanning module of the 4D probe 7 is used to monitor the location, depth and orientation of the biopsy needle 8 in the patient's body.

[0075] Referring to Fig. 13, ultrasound images form an ultrasound 3D model and MRI images form an MRI 3D model. The MRI images are previously captured by an MRI scanner. The ultrasound 3D model can be fused with the MRI model. Prior to the biopsy treatment, the patient is likely to have undergone a prostate examination with ultrasound and/or MRI. The patient's doctor analyses all the images/slices (MRI and/or ultrasound) or the 3D models to determine where the lesions are located. Computer software is used to build a prostate model and a tumour model to position the puncture point according to the experience of the doctor. The biopsy plan is constructed by the computer software. When puncturing, the computer software guides the puncture control module 42 and the depth positioning module 43 to implement and execute the biopsy plan with high accuracy notwithstanding movements or deformation of the prostate.

[0076] The medical apparatus 10 uses a 4D automatic rotating probe 7. After the probe 7 is inserted in the rectum and reaches its desired position, there is no need for further movement or external manual rotation of the probe 7. In other words, the external surface of the probe 7 does not move relative to the patient's body after insertion and until treatment is completed when the probe 7 is removed from the patient's body. The 4D probe internal transducer 72 can automatically rotate and scan the prostate which ensures no tissue deformation is caused by probe movement. The 4D probe 7 is scanning continuously during treatment which allows the doctor to check and confirm the planned biopsy path before puncture and during the biopsy procedure. This also ensures accuracy of the ultrasound images captured by the 4D probe 7. The puncture control module 42 and the depth positioning module 43 provide accurate positioning for the biopsy and/or implant procedure. This greatly facilitates the operation of the doctor, which allows them to monitor the biopsy path in real time and completely avoids tissue deformation that is typically caused by movement of the probe 7. The apparatus 10 can assist in multi-point accurate sampling (taking more than one tissue sample at different sites), reduces the probability of repeated sampling, improves the coverage of the sample, and further improves the accuracy of detection.

[0077] Referring to Fig. 13, the computer 6 has a processor to execute computer software comprising computer executable instructions configured to construct (603) a 3D model based on images captured (601, 602) by an ultrasound scanner or MRI scanner. The computer software registers (604) the real-time ultrasound 3D model and previous ultrasound 3D models. The captured images are modelled (603) to generate the MRI model and ultrasound model. The computer software can register (607) MRI model and ultrasound model which are used to visualise and execute the predetermined biopsy path. MRI images are higher quality (as they are higher in image resolution) than ultrasound images. Prior to the biopsy procedure, the doctor defines an edge of the prostate in each image and the computer software builds the 3D model using the images (or slices). The doctor chooses a target for the biopsy and develops (605) a therapy plan or biopsy path. The therapy plan is executed by the computer software

during the procedure (608). The computer software controls the operation of four linear motors for the lead screw shaft 424. The slider 423 is on the lead screw shaft 424 and can move upon instruction by the computer 6 to the motor 421. Controlling the position of the slider 423 means that the rotational linkages 422, 423, 424 are controlled as the length of the link 422 is fixed.

[0078] In a typical scenario, the doctor inserts the 4D probe 7 in the correct position and then rotates a knob of the movable bracket 3 to fix the position of the 4D probe 7 when it has reached its correct position. The doctor then initiates the insertion of the needle 8 but the direction and depth of insertion has been predetermined. Then a tissue sample is obtained or the radioactive particle (rice sized) is deposited via the needle 8. Finally, the doctor removes the probe 7 from the patient and the treatment is completed. These are the only steps that the doctor is required to perform.

[0079] Although a 4D probe has been described, it is envisaged that a 3D probe or 5D probe may be used.

[0080] When a particular material is identified as being preferably used to construct a component, obvious alternative materials with similar properties may be used as a substitute. Furthermore, unless specified to the contrary, any and all components herein described are understood to be capable of being manufactured and, as such, may be manufactured together or separately.

[0081] Moreover, in interpreting the disclosure, all terms should be interpreted in the broadest reasonable manner consistent with the context. In particular, the terms “comprises” and “comprising” should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced.

[0082] The subject headings used in the detailed description are included only for the ease of reference of the reader and should not be used to limit the subject matter found throughout the disclosure or the claims. The subject headings should not be used in construing the scope of the claims or the claim limitations.

[0083] Although the technology herein has been described with reference to particular examples, it is to be understood that these examples are merely illustrative of the principles and applications of the technology. In some instances, the terminology and symbols may imply specific details that are not required to practice the technology. For example, although the terms “first” and “second” may be used, unless otherwise specified, they are not intended to indicate any order but may be utilised to distinguish between distinct elements.

[0084] It is therefore to be understood that numerous modifications may be made to the illustrative examples and that other arrangements may be devised without departing from the spirit and scope of the technology.

CLAIMS:

1. A medical apparatus for prostate biopsy or radioactive particle implantation comprising:

a scanning and puncture assembly comprising:

an ultrasound probe having an internally rotatable ultrasonic transducer within a predetermined angular range to capture a series of sequential ultrasonic images in 3-spatial dimensions,

a needle for biopsy or for radioactive particle implantation;

a puncture control module to adjust an insertion angle of the needle;

and

a depth positioning module to adjust the insertion depth of the needle;

a support assembly to support the scanning and puncture assembly at a predetermined position relative to a patient; and

a computer comprising a memory and a processor configured to execute computer executable instructions for controlling the scanning and puncture assembly including the adjustment of the insertion angle and the insertion depth of the needle according to a predetermined biopsy path.

2. The medical apparatus according to claim 1, wherein the support assembly comprises a plurality of articulated or rotatable joints to enable the support assembly to move to a predetermined position.

3. The medical apparatus according to claim 1, wherein the support assembly is connected to an examination table or a tripod.

4. The medical apparatus according to claim 1, further comprising a computer to execute the computer executable instructions.

5. The medical apparatus according to claim 4, further comprising two display screens connected to the computer to display the ultrasonic images captured by the ultrasound probe.
6. The medical apparatus according to claim 1, wherein the support assembly is connected to a probe holder of the scanning and puncture assembly.
7. The medical apparatus according to claim 6, wherein the ultrasound probe is held by the probe holder, and the probe holder is connected to the puncture control module, and the depth positioning module is connected to the puncture control module.
8. The medical apparatus according to claim 1, wherein the depth positioning module comprises:
 - a puncture hole to control the position of a puncture hole using rotational linkages; and
 - a needle holder to hold the needle.
9. The medical apparatus according to claim 6, wherein the probe holder is directly connected to the support assembly, and the probe holder is manually adjustable to a predetermined position and the probe holder is releasably fixable in the predetermined position.
10. The medical apparatus according to claim 6, wherein the probe holder is connected to a track and is moved by a motor according to the execution of the computer executable instructions.
11. The medical apparatus according to claim 8, wherein the puncture control module comprises a motor, rotational linkages and a housing.

12. The medical apparatus according to claim 11, wherein the rotational linkages comprise a lead screw, a slider and links.
13. The medical apparatus according to claim 12, wherein the motor drives the slider to move the links causing link ends of the puncture control module and the puncture hole to move to a predetermined position.
14. The medical apparatus according to claim 12, wherein each rotational linkage is movable in a first plane independently to movement of another rotation linkage in a second plane, wherein the first plane is parallel to the second plane.
15. The medical apparatus according to claim 13, wherein end portions of the rotational linkages are connected to corresponding end portions of the puncture hole such that the direction and position of the puncture hole is adjustable.
16. The medical apparatus according to claim 8, wherein the puncture hole is a tubular structure having a predetermined length to permit the needle to pass therethrough.
17. The medical apparatus according to claim 8, wherein the needle holder defines a maximum insertion depth of the needle, and the needle holder is movable in an axial direction relative to the depth positioning module.
18. The medical apparatus according to claim 1, wherein the ultrasound probe is a 4D probe and includes an ultrasound scanning module and an internal motor for internally rotating the ultrasonic transducer.

19. A method for prostate biopsy and particle implantation, the method comprising:

capturing a series of sequential ultrasonic images in 3-spatial dimensions using an ultrasound probe without relative movement of the ultrasound probe after insertion,

executing computer executable instructions to adjust an insertion angle of the needle according to a predetermined biopsy path; and

executing computer executable instructions to adjust the insertion depth of the needle according to the predetermined biopsy path.