An Intelligent Apparatus for Cancer Visualization and Localization

Field of the invention

The present invention relates to a medical image based intelligent cancer visualization and localization apparatus to help surgeon finding cancer and then making the surgical plan and performing the surgical procedure for the cancer safely, accurately and effectively.

Background of the Invention

Cancer has been become the first killer for human being and the new cases will reach to 21.6 million per year with 13 million death on year 2030, double the number in year 2012 according to WHO. Therefore, it becomes very important issue for healthcare industry and needs to develop more effective way to find cancer and then treat it accurately, safely and effectively.

There are many methods to diagnosis and therapy of cancer. The most common method for diagnosis is using the medical images, such as ultrasound, CT, PET, MRI and so on, to find the suspicious location of cancer inside the human body and taking some samples in the suspicious location for pathologic examination. The suspicious cancers are mostly localized inside the human body and may not be enclosure within a clear boundary. Sometimes, the cancer cells or tissues could not be clearly identified by a single medical image on a two dimension image. It makes the diagnostic procedure very complex and quite difficult even for experienced radiologist and surgeon and may cause the delay or wrong treatment for the patient, so lose the life. Therefore, it is necessary to develop an accuracy in-body localization apparatus to help surgeon and radiologist positioning the suspicious cancer cells or tissues effectively and then validating it with the help of pathologist.

Knowing the accuracy locations and stages of cancers, the surgeon can work out a most effective therapy plan and handle the patient quickly and safely. For most cases, it will be no need to take out, partially or wholly, the organs through the open surgery if the locations and stages of cancers are clear. The focal therapy for most cases is possible through minimal invasive surgery or non-invasive surgery, which will be shorter the therapy and recovery time, so saving money. The most importance is that the minimal invasive surgery and non-invasive surgery can minimize the damage from surgery procedure and reduce the risk on the fail surgery, which is greatly depending on the accuracy of cancer localization and visualization.

Summary of the invention

The present invention aims to provide an intelligent cancer visualization and localization apparatus to arm a surgeon with the eyes viewing the unhealthy human organs inside the body and to help surgeon finding the suspicious cancer cells and tissues. It will then guide the surgeon to take some cell and tissue samples for pathological examination. After the pathological validation of the cancer stages, the apparatus will help the surgeon to perform the therapy procedure accurately, safely and effectively through minimal invasive or non-invasive surgery procedure.

In general, the present invention is an intelligent apparatus for cancer visualization and localization, which comprises three functional components:

- a three dimension medical image reconstruction component, which can real-time collect a stack of two dimension medical images from any medical image system with DICOM image data. The three dimension images from different system could be registered on one display to highlight the suspicious cells and tissues.

- a robotic arm with a nine axes Inertial Measurement Units (IMU) to hold a location device or an image device such as ultrasound transducer with the location markers on it.
- a floating table to hold the robotic arm and some display device with an on-board computer to process the relation images.

Three functional components supported by a knowledge-based specialist system build an intelligent cancer visualization and localization apparatus, enabling the complete cancer information, including the distribution, localization and stages of cancer cells and tissues inside the patient body stored in the digital format for reviewing the cancer stages, making therapy plan and executing the surgical procedure.

The three dimension medical image reconstruction component can process both two and three dimension medical images with DICOM data structure. All of image data are defined in unified image space which could be registered by means of location markers on the robotic arm, so transforming to the physical space which could be linked to the organs of patient. The transformation between the image and physical spaces are based on the image resolution of image data and encode resolution of localization of robotic arm, which are up to 10^{-3}mm scales.

The registration or fusion of images is also possible among the three dimension images in image space on real-time base. The off-line images from MRI, PET, CT or others could be registered with the real-time image from any image system, such as ultrasound image system which is cheapest image tool with lowest risk on damage the patient.

The robotic arm component provides a physical system to link the apparatus and patient. It does also provide a physical structure to carry some diagnostic and therapy devices, such as real-time ultrasound probe to enable the surgical

procedure on a real-time imaging guided procedure. The embedded nine axes IMU enables a space independent localization system, which has been integrated into the whole system defined in both image space and physical space.

The floating table component provides a very flexible operation platform for surgeon or radiologist to operate the apparatus near the patient and provides a safety structure for the system.

The apparatus could be installed on the top or side of surgical operating bed or put simple on a mobile table. For a patient with tight operation space such as urology therapy, a simple mobile cart as shown in FIG 13 could be used.

Brief Description of the Figures

An embodiment of the invention will now be illustrated for the sake of example only with reference to the following drawings, in which:

FIG 1 is an overall perspective view of the apparatus 100 according to an embodiment of the present invention. It composes three function components, i.e. PC based image reconstruction components 101, robotic manipulator 102, and floating table 103. Four mounting holes 104 are to fix the apparatus near the patient.

FIG 2 is a front view of the overall perspective view of the apparatus. It shows that the robotic manipulator is installed on the top of floating table 201.

FIG 3 is a side view of the overall perspective view of the apparatus. It shows that the PC based image reconstruction component is installed on an air-spring support arm 301. The all-in-one computer with LED monitor, 302 installed on the arm 301, which can move certain angles and certain distance of up and down.

FIG 4 is a top view of the overall perspective view of apparatus. It shows that there are three turning points, 401, 402 and 403 on the floating table. The floating table can turn 360° along the turning axis 402, the robotic manipulator can turn 360° along 401 and the PC based image reconstruction component can turn 360° along 403. All of three turning axes are passing through the same line 404.

FIG 5 is the main software structure of the PC based three dimension image reconstruction components.

FIG 6 shows the three views of the robotic manipulator, i.e. front view 601, top view 602 and section view 603. 604 is the adaptor of water filling balloon. 605 show the gears driven by motor 610 together with a gear box and a digital encoder. A potential meter 606 integrated on the shaft of gear box on front of motor. An easy locking adaptor 607 adds on the bottom of the manipulator. Two bearings 608 with the same centre line of adaptor 604 are to help alignment of the image kit such as ultrasound probe. 609 is a micro-

process based robotic control integrated with a nine axes IMU. The micro motor 610 integrated with a planetary gearhead and magnetic encoder. 611 is an adaptor slot for fixing other diagnostic and therapy modules. 612 is the main body of the robotic manipulator and 614 is the electronic box with cable out 614 and a control button 615. A cover 616 puts on the front of the robotic manipulator.

FIG 7 is the functional block diagram of the micro-processor based robotic control unit inside the robotic manipulator. The nine axes IMU has been integrated in the unit and a Web Camera can help surgeon to record the procedure for review. The robotic controller can control up to four motors for pitch, yaw, roll and linear movements.

FIG 8 is a perspective view of the floating table. It composes a three axes turning adaptor 801 to hold the robotic manipulator and a linear movement guide 802 below the turning adaptor 801. The turning adaptor and linear guide are supported on a turning mechanisms 805 fixed on the floating table plate 803. The whole system is support on a plate 804.

FIG 9 is the top view of the floating table. The multi turning and linear mechanism 901 with a handle 903 enables it turning 360° on the table support plate. The handle 903 has also a locking mechanism.

FIG 10 is the four views of multi-turning adaptor with main view 1001, left view 1002, right view 1004 and top view 1003. The adaptor can turn alone the axis at 1005, 1006 and 1007. A locking handle shows at 1008.

FIG 11 shows the apparatus invented with a multi-frequency convex ultrasound transducer.

FIG 12 shows the apparatus invented with a trans-rectal ultrasound transducer.

FIG 13 shows that the apparatus invented with a trans-rectal ultrasound transducer integrated with a three dimension robotic ultrasound platform **AmaKris**^{SR0} 1303 with main view 1301 and side view 1302.

FIG 14 is a support frame to hold the apparatus invented on the top of patient bed through two slots 1406 for T bars on patient bed. Support plate 1401 can move up and down by two bars 1402, which can be locked by two

nuts 1403. On two main support bars 1404, there are two T slots 1406 for fitting on the T bars on patient bed and then lock by two nuts 1405.

FIG 15 shows that the apparatus invented installed on the support frame shown in FIG 14. 1501 is the front view and 1502 is the top view. The whole system is to be fixed on the patient bed through two slots 1503.

FIG 16 is another support frame to hold the apparatus invented on the bed end through two slots 1602 for some therapy such as urology surgery. 1601 is the front view and 1603 is the top view. Support plate 1604 can move up and down. The frame can be locked by two nuts same as those shown in FIG 14.

FIG 17 shows that the apparatus invented installed on the support frame shown in FIG 16. 1701 is the top view and 1702 is the front view. The whole system is to be fixed on the patient bed through two slots 1703.

Detailed Description of the Embodiments

An intelligent cancer visualization and localization apparatus which is an embodiment of the invention will now be described with reference FIG 1 to FIG 17. The apparatus 100 as shown in FIG 1 comprises three functional components, i.e. image reconstruction unit, robotic manipulator, and floating table. The whole apparatus could be installed on the top of surgical operation bed as shown in FIG 15 or on the end of the surgical operation bed for urology procedure as shown in FIG 17. It can also be installed on a mobile cart or ultrasound device as shown in FIG 13.

The image reconstruction unit is a PC based 3D medical image reconstruction system as shown by 101 in FIG 1, which can real-time collect a stack of two dimension medical images from any medical image system with DICOM image data. The image data collected or imported will be processing according to the main software structure as shown in FIG 5. All of images are defined in the image space.

As shown by 102 in FIG 1, the robotic manipulator with a nine axes Inertial Measurement Units (IMU) to hold a location device or an image device such as ultrasound transducer with some location markers on it. It is a physical device with certain reference points defined in the physical space to localization the suspicious cells and tissues of cancer. The robotic manipulator includes a robotic controller as shown by 609 in FIG 6. The embedded controller as shown in FIG 7 can control up to four mini motors with encoders and move the image device such as ultrasound transducer to special location at the accuracy of 10^{-3}mm scale. The nine axes IMU enables the measurement of both the location and movement of the robotic manipulator at the physical space, which can be transformed to image space directly by the image reconstruction system.

The three dimension images from different system could be registered by means the markers in both image space and the physical space and then display on the monitor 302 in FIG 3 to highlight the suspicious cells and tissues. It will be very useful for surgeon to identify these cells and tissues and monitor them on the evolution after a certain period because the historical record can be fusion with the current ones.

Besides the magnetic encoders to monitor and control the movement of robotic manipulator, high accuracy potentiometer as shown by 606 in FIG 6 is also used to feedback the real location and to monitor the movement of the robotic manipulator together with some image kits. The whole robotic manipulator can be operated by hand using the button 615. It can also be installed on the floating table 201 in FIG 2 by a trapezoid adaptor 607 in FIG 6 quickly.

The floating table 103 as shown in FIG 1 is to hold the robotic arm and some display device with an on-board computer to process the relation images on-site. All-in one computer includes a monitor as shown by 302 in FIG 3. It is supported by an air-spring support arm 301, which can move up and down easily. It can also turn along a horizontal axis as shown in FIG 3. The arm 301 is fixed on the floating table with a turning axis at 403 in FIG 4. The whole floating table can turn 360° alone the axis at 401.

As shown in FIG 8, on the floating table there is turning mechanism 805 in FIG 8 with a handle 903 shown in FIG 9. There is also a linear movement mechanism shown by 802 in FIG 8. It enables the multi-turning adaptor 801 in FIG 8 moving along the linear mechanism. The multi-turning adaptor 801 can turn along the three vertical axes 1005, 1006 and 1007 as shown in FIG 10. The robotic manipulator can be simple put on the adaptor and locked by a spring handle 1008 in FIG 10.

As shown in FIG 4, all of components on the floating table can be turned along the three axes 401, 402 and 403 in FIG 4, which are at the same line 404.

The apparatus can carry any ultrasound transducers to perform the related procedure for cancer diagnosis and therapy. FIG 11 shows it carrying a multi-frequency convex transducer 1101 and FIG 12 shows a trans-rectal transducer 1201 for rectal, urology and uterus examination and therapy. It can also easily to perform other surgical procedures by taking suitable image transducers.

The apparatus can be mounted on a mobile vehicle or robot by four screws through four mounting holes 104 in FIG 1. As shown in FIG 13, the apparatus has been installed on a surgical image robot 1301 manufactured by Abacus Global Technology Pte Ltd in Singapore. It has been constructed a complete intelligent surgical robot for cancer diagnosis and therapy.

The apparatus invented can also be installed on the surgical operating bed by means of suitable frame such as these shown in FIG 14 and FIG 16. FIG 14 shows an adjustable frame to support the apparatus invented on the surgical operating bed through two T slots shown by 1406 and locked by 1405 in FIG 14. The apparatus invented can be installed on the frame as shown in FIG 15 and then the surgical operating bed to the position very near the patient for easy operation.

The apparatus invented can also be installed on the end of the surgical operation bed by means of frame shown in FIG 16. The support plate 1604 in FIG 16 can be adjusted to suitable place for such as rectal or urology procedure. FIG 17 shows the integration of the apparatus invented on the support frame.

The apparatus invented can make fusion for all of image data with DICOM format. Any useful information from the images will be possible of helping the surgeon to find the cancer cells and tissues. It can also help the surgeon to perform the surgical procedure accurately, safely and effectively.

Claims

1. An general apparatus for quick and smart cancer visualization and localization, the apparatus comprising:
   - a three dimensional quick capturing and real-time reconstructing unit for any medical image system with DICOM image data, which will be registered on one computer display device to highlight the suspicious cells and tissues;
   - a robotic arm to hold a surgical location device or an image device, which integrated with a nine axes Inertial Measurement Units (IMU) for both the device navigation and localization of suspicious cells and tissues;
   - a floating table with three turning and two linear axes to hold the robotic arm and the computer display device with an on-board computer to process the real-time images and information.

2. An apparatus according to claim 1, wherein the medical images are defined in the image space calibrated by pixels on computer display device with three fixed markers on the doctor's specified location of the image space, which have been directly linked with the physical markers fixed on the robotic arm and defined in the physical space with the coordination on the center of the floating table.

3. An apparatus according to claims 1 and 2, wherein the images with DICOM format from any image devices such as CT, MRI, PET are registered in the image space and then linked to the robotic arm defined in the physical space, such that any suspicious cells and tissues can be localized in the physical space for cancer visualization and visualization.

4. An apparatus according to claims 1 to 3, wherein the image reconstruction will be carrying out automatically after registration by means of three markers which links the features at both image and physical spaces.

5. An apparatus according to claim 1, wherein there is a robotic arm to locate a surgical devices or image transducer at the physical space and then linked to the image space.

6. An apparatus according to claims 1 and 5, wherein the robotic arm embedded with a nine axes Inertial Measurement Unit (IMU) to measure and monitor the position and movement of the robotic arm and link there markers in both image and physical spaces.

7. An apparatus according to claims 1, 5 and 6, wherein the surgical device carried by the robotic arm is controlled by a robotic controller with four DC motors integrated with both the potentiometer and encode for each motor to enable the quick localization.

8. An apparatus according to claims 1, 5 to 7, wherein the DC motors are controlled by means of both high accuracy encoders and high accuracy potentiometer for fast response and accuracy localization.

9. An apparatus according to claim 1, wherein a floating table is invented to hold all of components of the apparatus invented.

10. An apparatus according to claims 1 and 9, wherein there are three turning axes for localization of the robotic arm, three dimension image reconstruction unit and the floating table itself. The three turning axes are alignment on the same plane and parallel each other.

11. An apparatus according to claims 1, 9 and 10, wherein a linear movement mechanism on the floating table enables the robotic arm moving along the linear line on the center line of the surgical device and turning on the turning axis at a specified point on the surgical device.

12. An apparatus according to claims 1, 9 to 11, wherein a multi-turning adaptor fixed on a linear movement mechanism to hold the robotic manipulator enabling a flexible operation of both image capturing and surgical device for a surgical procedure.

13. An apparatus according to claims 1 to 12, wherein the apparatus will carry an ultrasound transducer to obtain ultrasound real-time images for cancer visualization and localization.

14. An apparatus according to claims 1 to 13, wherein the apparatus will be installed on any mobile vehicle or any medical image device for real-time operation of a surgical procedure.

15. An apparatus according to claims 1 to 13, wherein the apparatus will be installed on the top of surgical operating bed by using a height adjustable support frame with two standard clipping slots to support the apparatus.

16. An apparatus according to claims 1 to 13, wherein the apparatus will be installed on the end of surgical operating bed by using a height adjustable support frame with two side clipping slots to support the apparatus.