Diagnosis and treatment of navigation technology based on the multi-modality image fusion for angioneoplasms

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Abstract - In this paper, we want to propose an original study of the 3D vascular registration based on the multi-modality image fusion (such as CT and MRI fusion). First, we combine the basic clinical knowledge technology into the three-dimensional image reconstruction of real human vascular model for the purpose of the practical treatment measurement. Diagnosis and treatment of navigation technology should be applied in Neural cerebrovascular disease interventional surgical operation assist system. Vascular interventional preoperative planning and training programmer could be help the Surgeon complete the Nerve of brain vascular interventional operation, and improve the development of the new Clinical application of cerebral aneurysms and other diseases. The aim of our research is to use feature extraction, optimal algorithm, wavelet transform realize the Multi modal image collection, registration and fusion process. In order to give the evaluation of image fusion performance parameters and so on, we make sure the preserving of the useful information and reduce noise pollution. To meet the needs of cardiovascular department of neurosurgery interventional construction of virtual reality system operation platform, we research on how to improve the authenticity and reliability of 3D reconstruction model for the Interventional neuroradiology.

Index Terms - Diagnosis and treatment of navigation technology, the multi-modality image fusion, Virtual Reality based Robotic Catheter System, Minimally Invasive Surgery (MIS).

I. INTRODUCTION

This paper is about the study of an original study of the 3D vascular registration based on the multi-modality image fusion (such as CT and MRI fusion), and as we know, cardiovascular and cerebrovascular disease could be the first “killer” of human, and more than 3000 million patients with these diseases died each year. Vascular surgical intervention has become the third pillar of modern medicine and MIS is widely accepted and applied in many medical fields and breakthrough of the space limitations of conventional surgery, and enhance the capacity expansion of medical experts. Surgical technique, surgeries are operated using precise medical devices and viewing equipments inserted by a small incision instead of making a large incision to expose the operation site. The advantage is to reduce the health tissue, reduce patients’ pain and scarring. Critical disadvantage of some surgery technique is complicated, when the arteries through which the catheter passes are extremely intricate and delicate, the technique requiring extensive training efforts of the surgeon to achieve the competency. For some reasons, realistic virtual reality simulators provides the possibility of promising a method compared to the other method of anesthetized animals, human cadavers. Also, A lot of diagnosis and medical surgery with an endoscope or a catheter are performed for minimum invasive surgery recently, A novel telerobotic system to remotely navigate standard electrophysiology catheters has been reported by E Marcelli et al. The teleoperation concepts in minimal invasive surgery has been reported by Carsten Preusche et al. [12].

Industry simulation training and model for greater patient safety had been developed[1]. It is difficult of getting the accurate 3D positioning information in the blood vessel, the damage from the X-ray in the CT scan process to the sick in the operation, and it is difficult for the surgeon to master the skill because most of the training system cannot imitate the reality operation and improve the experience so easily. So that we should change to VR equipment as the reason of the VR simulators enable novice unskilled doctors to learn basic wire or catheter handling skills and provide the expert practitioners the opportunities to new operating procedures before performing on the patient.

Diagnosis and medical surgery are performed for minimum invasive surgery recently, a case report on microscopic micromanipulator system “NeuRobot” in Neurosurgery: the authors proved the feasibility of the telesurgical usage of NeuRobot in private network. Some other product have been developed in a few years, one of the most popular products is a robotic catheter placement system called Sensei Robotic Catheter System [1]-[3] offered by Hansen Medical. The Sensei provides the physician with more stability and more force in catheter placement with the Artisan sheath compared to manual techniques, allowing for more precise manipulation with less radiation exposure to the doctor, multiple degrees of freedom, force detection at the distal tip is very hard. Catheter Robotics Inc. has developed a remote catheter system called Amigo has a robotic sheath to steer catheters which is controlled at a nearby work station, in a manner similar to the Sensei system. In April 2010, it was used to ablate artificial flutter in Leicester UK [4]. Simbionix ANGIO Mentor products are multidisciplinary endovascular surgical simulators that provide hands-on practice of endovascular procedures performed under fluoroscopy, in an extensive and complete virtual reality simulated environment. The ANGIO Mentor simulation result in a higher level of skills to provide patients the best care.
In this paper, we want to design the Catheter Virtual Reality System, combine the basic clinical knowledge technology into the three-dimensional image reconstruction of real human vascular model for the purpose of the practical treatment measurement. Diagnosis and treatment of navigation technology should be applied in Neural cerebrovascular disease interventional surgical operation assist system. The training system can generate the realistic virtual reality environment of blood vessels according to patient’s special computed tomography (CT) or magnetic resonance imaging (MRI), in addition, allow unskilled doctors to drive a real catheter for training courses directly and simulate surgeon’s operating skills, insertion and rotation in real surgery. This paper is organized to introduce the algorithms and vascular model, and the interactive simulation between blood vessels model and catheter model.

II. MULTI-MODALITY IMAGE

Neuroimaging includes how to use various techniques to either directly or indirectly image the structure. It is a relatively new discipline within medicine and neuroscience/psychology which is useful in the performance and interpretation of neuroimaging in the clinical setting. Neuroimaging follows a neurological examination in which a physician has found cause to more deeply investigate a patient with a neurological disorder. The likelihood of finding a cause in the central nervous system is extremely low and the patient is unlikely to benefit from the procedure. Simple syncope in which the patient's history does not suggest other neurological symptoms, the diagnosis includes a neurological examination but routine neurological imaging is not indicated.

The presence of migraine does not increase a patient's risk, a diagnosis of migraine which notes the absence of other problem of papilledema and not indicate a need for neuroimaging. In the course of conducting a diagnosis, the physician should consider whether has a headache other than the migraine and might require neuroimaging. Medical imaging is the most common application of Computed tomography (CT) or magnetic resonance imaging (MRI), Its cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines. CT scanning using a series of x-rays of the head taken from many different directions, and used for quickly viewing brain injuries, CT scanning uses a computer program that performs a numerical integral calculation (the inverse Radon transform) on the measured x-ray series to estimate how much of an x-ray beam is absorbed in a small volume of the brain. Typically the information is presented as cross sections of the brain. Digital geometry processing is used to generate a three-dimensional image of the inside of an object from a large series of two-dimensional radiographic images taken around a single axis of rotation.

As x-ray CT is the most common form of CT in medicine and various other contexts, the term computed tomography alone is often used to refer to x-ray CT, although other types exist (such as positron emission tomography [PET] and single-photon emission computed tomography [SPECT]). Older and less preferred terms that also refer to x-ray CT are computed axial tomography (CAT scan) and computer-assisted tomography. CT produces a volume of data that can be manipulated in order to demonstrate various bodily structures based on their ability to block the x-ray beam. Modern scanners allow this volume of data to be reformatted in various planes or even as volumetric (3D) representations of structures.

Magnetic resonance imaging (MRI) uses magnetic fields and radio waves to produce high quality images of brain structures without use of ionizing radiation (X-rays) or radioactive tracers. MRI has a wide range of applications in medical diagnosis and there are estimated to be over 25,000 scanners in use worldwide. It has an impact on diagnosis and treatment in many specialties although the effect on improved health outcomes is uncertain. However it does not use any ionizing radiation its use is recommended in preference to CT when either modality could yield the same information. MRI is in general a safe technique. The safety of MRI during the first trimester of pregnancy is uncertain, but it may be preferable to alternative options.

To perform a study the patient is positioned within an MRI scanner which forms a strong magnetic field around the area to be imaged. Most medical applications rely on detecting a radio frequency signal emitted by excited hydrogen atoms in the body (present in any tissue containing water molecules) using energy from an oscillating magnetic field applied at the appropriate resonant frequency. The orientation of the image is controlled by varying the main magnetic field using gradient coils. As these coils are rapidly switched on and off they create the characteristic repetitive noises of an MRI scan. The contrast between different tissues is determined by the rate at which excited atoms return to the equilibrium state. Exogenous contrast agents may be given intravenously, orally or intra-articularly. MRI requires a magnetic field that is both strong and uniform. The field strength of the magnet is measured in tesla – and while the majority of systems operate at 1.5T commercial systems are available between 0.2T–7T.
Most clinical magnets are superconducting which requires liquid helium. The lower field strengths can be achieved with permanent magnets, which are often used in "open" MRI scanners for claustrophobic patients.

CT scanning of the head is typically used to detect infarction, tumors, calcifications, haemorrhage and bone trauma. Hypodense (dark) structures can indicate edema and infarction, hyperdense (bright) structures indicate calcifications and haemorrhage and bone trauma can be seen as disjunction in bone windows. Magnetic resonance imaging (MRI) of the head provides superior information as compared to CT scans when seeking information about headache to confirm a diagnosis of neoplasm, vascular disease, posterior cranial fossa lesions, cervicomedullary lesions, or intracranial pressure disorders. It also does not carry the risks of exposing the patient to ionizing radiation. CT scans may be used to diagnose headache when neuroimaging is indicated and MRI is not available, or in emergency settings when hemorrhage, stroke, or traumatic brain injury are suspected. Even in emergency situations, when a head injury is minor as determined by a physician's evaluation and based on established guidelines, CT of the head should be avoided for adults and delayed pending clinical observation in the emergency department for children.

III. MULTI-MODALITY IMAGE FUSION

There are several advantages that CT has over traditional 2D medical radiography. First, CT completely eliminates the superimposition of images of structures outside the area of interest. Second, because of the inherent high-contrast resolution of CT, differences between tissues that differ in physical density can be distinguished. Finally, data from a single CT imaging procedure consisting of either multiple contiguous or one helical scan can be viewed as images in the axial, coronal, or sagittal planes, depending on the diagnostic task. This is referred to as multiplanar reformatted imaging. CT is regarded as a moderate- to high-radiation diagnostic technique. The improved resolution of CT has permitted the development of new investigations, which may have advantages; compared to conventional radiography, for example, CT angiography avoids the invasive insertion of a catheter. CT Colonography (also known as Virtual Colonoscopy or VC for short) may be as useful as a barium enema for detection of tumors, but may use a lower radiation dose. CT VC is increasingly being used in the UK as a diagnostic test for bowel cancer and can negate the need for a colonoscopy. The radiation dose for a particular study depends on multiple factors: volume scanned, patient build, number and type of scan sequences, and desired resolution and image quality. In addition, two helical CT scanning parameters that can be adjusted easily and that have a profound effect on radiation dose are tube current and pitch. Computed tomography (CT) scan has been shown to be more accurate than radiographs in evaluating anterior interbody fusion but may still over-read the extent of fusion.
although previous studies have demonstrated DNA damage associated with MRI, "the long-term biological and clinical significance of DNA double-strand breaks induced by MRI remains unknown". According to Fig.3, the image registration procession, we input the image first, and do the edge detection, feature point acquisition and normalization, then carry out the registration.

Iodinated contrast medium is routinely used in CT and the main adverse events are anaphylactoid reactions and nephrotoxicity. Commonly used MRI contrast agents have a good safety profile but linear non-ionic agents in particular have been implicated in nephrogenic systemic fibrosis in patients with severely impaired renal function. MRI is contraindicated in the presence of MR-unsafe implants, and although these patients may be imaged with CT, beam hardening artefact from metallic devices, such as pacemakers and implantable cardioverter-defibrillators, may also affect image quality. MRI is a longer investigation than CT and an exam may take between 20 - 40 mins depending on complexity.

IV. RECONSTRUCTION OF THE 3D VESSEL MODEL WITH DICOM FILES

We want to simulate the deformation of blood vessels with DICOM files. After the DICOM image segmentation, and we can use Open Scene Graph (OSG) to realize 3D graphics. The mass-spring model is a widely used mesh-free method in surgical simulation, and models the object as masses connected to each other with springs and dampers. Each mass is represented respectively by its own coordinate, acceleration and velocity and deforms under the influence of inertial, spring and damping forces and the forces applied by the surgical catheter.

Various integration schemes have been tested and integration emerged as the most suitable for application. As see the three-dimension reconstruction images of the blood vessels have been shown in Fig. 10. Catheter simulation algorithms can be classified as physical or geometrical methods. Thus, calculation rate of the virtual model using this algorithm is fast but without physical properties. The main physical approaches finite element modeling (FEM) methods describes a shape as a set of basic geometrical elements and the FEM is a suitable technique for solving the simulation problem. Based on the catheter structure, the guide wire is discretized as a chain of small and elastic cylindrical segments. Each one is connected to its neighbors at joints known as nodes. With these elements we can evaluate the deformation energy and the elastic force of the structure.

Another important topic when considering training based on virtual reality technology and that is collision detection and response. The difficulties bounded with soft bodies such as blood vessel walls stem from their complicated reactions to external influences. Bounding volume hierarchies (BVHs) are probably the most popular mechanisms to recursively subdivide the object of interest and bounding volume for each of the resulting subset of primitives. When checking for collisions, the hierarchy of the potentially colliding pair of objects is traversed from top to bottom. During the traversal, the bounding volumes are tested for overlap on every subdivision level. If no overlap is found, the objects surely cannot collide. If overlap is found, the algorithms traverse the hierarchy further, but only through the children nodes where an overlap was detected. Finally, when the traversal gets to the bottom level of the hierarchy and still detects overlaps, the primitives stored in these nodes are finally tested for mutual intersection. There are two stages are performed for collision detection, first checking to see if any vertex in the blood vessel model lies within the catheter model then again checking if a vertex of the catheter model lies within the virtual vascular model. We finally get the 3D model. As shown in Fig.11 and Fig.12.

We designed a series of collision experiments between the catheter and vessel to compare the simulation results of the physics-based modelling of the catheter with the real output of the force measured by contact force sensor in the slave side. The conceptual principle of the controller, the catheter can be subjected to two different sets of movement during manipulation: insertion/retraction and rotation. Catheter will be manipulated to reach different parts of the blood vessels. Finally, it sends the actual valu e of the displacement to the
computer. Measurement accuracy is typically limited to the pixel spacing of the imaging sensor located in the chip.

Fig. 5 Three-dimension reconstruction images of the blood vessels: (a) and (b) the mesh of the vessels

Fig. 6 Three-dimension reconstruction images used in VR system

Fig. 7 the catheter visual model inserting into the 3D vessel model

For the surgeon, he can operate the real catheter directly for their training courses and the measurement of displacement. We designed a series of operation experiments between the controller and catheter model in virtual reality environment to compare the operation results. The whole structure of training system based on virtual reality technology and the simulation result and force in contact has been shown in Fig. 13. The catheter in a virtual reality environment can insert or rotate catheter according to the controlling instructions from master side. If the catheter contacts the blood vessel, the force feedback can be detected, stored and transmitted to the surgeon’s hand. Based on the force feedback and monitoring image information, the virtual reality environment can be used for medical training.

V. CONCLUSIONS

In this paper, we proposed an original study of the 3D vascular registration based on the multi-modality image fusion (such as CT and MRI fusion). We combine the basic clinical knowledge technology into the three-dimensional image reconstruction of real human vascular model for the purpose of the practical treatment measurement. Diagnosis and treatment of navigation technology should be applied in Neural cerebrovascular disease interventional surgical operation assist system. Vascular interventional preoperative planning and training programmer could be help the Surgeon complete the Nerve of brain vascular interventional operation, and improve the development of the new Clinical application of cerebral aneurysms and other diseases. To meet the needs of cardiovascular department of neurosurgery interventional construction of virtual reality system operation platform, we research on how to improve the authenticity and reliability of 3D reconstruction model for the Interventional neuroradiology.

In the future works, we would do more experiment for surgeon to use the Virtual Reality System to improve their experience.

ACKNOWLEDGEMENTS

This research was supported by Beijing Institute of technology School Research Foundation 2014.

REFERENCES


