Fusion between pre-operative and intra-operative brain MRI for neurosurgical navigation (Tel Hashomer)
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Fusion between pre-operative and intra-operative brain MRI for neurosurgical navigation

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Background of the Invention

Preoperative high-resolution MRI is commonly used as anatomical reference for navigation during open-brain surgery. It can be enhanced by overlaid preoperative Functional MRI (fMRI) and diffusion tensor imaging (DTI) data that localize critical grey and white matter areas in the vicinity of the targeted lesion. The use of preoperative images implicitly assumes that the brain remains immobile with regard to the skull during the entire procedure. In practice, this assumption has only a limited validity in time.

When the skull is opened (craniotomy) at the brain drift progressively with regard to the skull. This well-known effect is called brain shift. As surgery progresses, local deformations caused by ongoing tissue resection further increase the discrepancy between preoperative MRI and the actual brain anatomy.

Pre-operative planning and intra-operative guidance in neurosurgery require detailed information about the location of functional areas and their anatomo-functional connectivity. In particular, regarding the language system, post-operative deficits such as aphasia can be avoided.

During the last decade, low field (~0.15 Tesla) interventional MRIs (iMRI) has been developed to provide updated MR images during surgery, thereby helping to compensate for brain shift. It has been shown that iMRI guided Glioma surgery helps surgeons provide the optimum extent of tumor resection. In practice, however, due to magnetic field and physical size limitations, intra-operative MRI cannot provide images comparable to the pre-surgical images obtained on a full size, high field scanner. The field of view is limited to an ellipsoidal window that is usually too small to contain the whole brain and whose position and orientation are unknown a-priori, and it is not possible to acquire functional MRI (fMRI) or diffusion tensor imaging (DTI) intra-operatively.

Currently, no existing solution gives the neurosurgeon an image quality comparable to pre-operative MRI with the compactness, ease of use and low cost of low field MRI.

We developed and validated an algorithmic framework to perform accurate and robust registration

between high quality pre-surgical MRI and noisy intra-operative MRI images. On completion of successful registration, pre-operative anatomical, functional and DTI tractography maps shall be projected onto the intraoperative MRI images, thereby providing fusion between preoperative (anatomical, DTI tractography and fMRI) and intra-operative MRI.

The Need

There is major need for Precision guidance system for surgeon with real-time updated information of target condition . Computer Assisted Surgery based on Intraoperative Information and Navigation Technology is in great demand for several reasons:

1. Patient safety

2. Evaluation of performance of surgeon/procedure/device

-Record, Analyze, Visualize

-By human: hard task, long time, high cost, error

-Do not disturb surgical procedure

3. Demand for Automatic Recording/Analysis/Visualization

-Quantitative digital data for computer processing

-No effect on surgical procedure and environment

4. Automatic analysis using navigation information

Advantages:

* Platform technology for accurate medical image Fusion.

* Improved patient safety and procedure outcome.

* The technology can be applied to MRI and iMRI images generated by equipment produced by different vendor.

* The software can be standalone and load standard DICOM images dirtectly from the imaging devices or from a picture archiving and communication system (PACS).

* The software can be fully integrated to existing iMRI navigation systems in collaboration with the vendor.

Potential Applications

The developed deformable registration between modalities with different field-of-view, such as iMRI-MRI fusion application - is applicable to other scenarios in image guided interventions. For example, the **registration between preoperative MRI images and intraoperative optical microscope or endoscope images** can benefit of our ability to deal with partial field-of-views (here for the microscope).

The resulting product may prove particularly useful as the intrasurgical microscope provides real-time updates while iMRI can only provide snaphots at a given time.This is applicable not only for Brain but virtually to any form of **micro-surgery performed under microscope or endoscope.**

The developed technology can be applied to the **registration between MRI and CT required for** the accurate planning of **image guided cancer radiotherapy**. The potential use of this application is very widespread since image guided radiotherapy is performed on a multitude of organs affected by cancer. Accuracy is a critical factor in radiotherapy as it ensures proper delivery of radiation to the target while sparing surrounding healthy tissues.

The developed technology can also be applied to **PET-CT or PET-MRI fusion**. The significant difference in SNR between these modalities is similar to the iMRI - MRI problem addressed specifically in our research. Here again, the potential use is very important as PET-CT / MRI is the method of choice for cancer metabollic imaging

The Market

Neurosurgery is a complex surgical procedure that involves diagnosis, treatment, and rehabilitation of disorders affecting any region of the nervous system. Some of the common neurosurgeries are endovascular neurosurgery, stereotactic neurosurgery, oncological neurosurgery, craniotomy, and neuroendoscopy. In all neurosurgery procedures, Image navigation in real time is mandatory with millimeter accuracy. Advanced imaging maps of the brain structure and function, using intraoperative MRI with This allows our surgeons to perform brain surgery with precision and real-time imaging information, helps surgeons identify vital areas of the brain, and these are key success factors. Brain Tumors pose particular challenges because of edema, displacement effects on brain tissue and infiltration of white matter. Under these conditions, standard fiber tracking methods reconstruct pathways of insufficient quality. Therefore, robust global or probabilistic approaches are required.

The global MRI market is currently valued in the region of US$5.5 billion (2010) and is estimated to rise to US$7.5 billion by the year 2015. Of this the US market is estimated at US4.5 million (2010) rising to US$5.8 million by 2015 (GIA, 2010; Reportlinker 2010). The leading MRI producers are GE (Signa brand), Siemens (Magnetom), Philips (Achieva, Intera, Panorama), Hitachi (Aaltaire, Airis) and Toshiba (Vantage, Opart, Ultra). Products range from Low Field systems (