



CASMIP Lab



Computer Aided Surgery and Medical Image Processing Laboratory

School of Engineering and Computer Science

The Hebrew University of Jerusalem, Israel

<http://www.cs.huji.ac.il/~casmip/site>

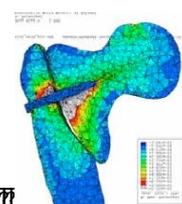
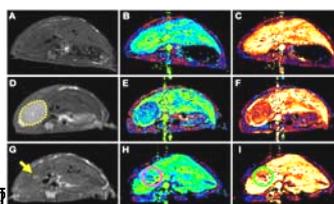
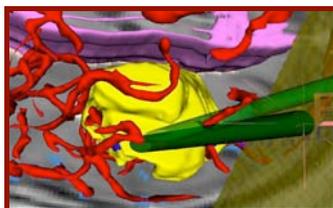
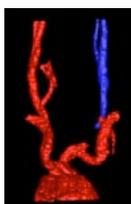
Director: Prof. Leo Joskowicz (josko@cs.huji.ac.il, +972-2-549-4544)

The goal of the CASMIP lab is to conduct groundbreaking interdisciplinary research to develop innovative computer-based methods for assisting clinicians in the diagnosis, planning, execution, and evaluation of medical and surgical procedures. We follow a synergistic methodology, which consists of developing the basic building blocks for computer-aided diagnosis and surgery while simultaneously developing solutions for specific clinical applications. The CASMIP lab conducts basic and applied interdisciplinary research in close collaboration with the Hadassah University Hospital in Ein-Karem, Jerusalem, and with other leading hospitals, universities, and companies in Israel and abroad.

The main clinical areas of interest include Diagnostic and Interventional Radiology, Neurosurgery, and Orthopaedics. The technical areas include surgical navigation, medical robotics, multimodal registration, anatomical segmentation, medical image processing, and patient-specific medical modeling, among others.

Current projects include:

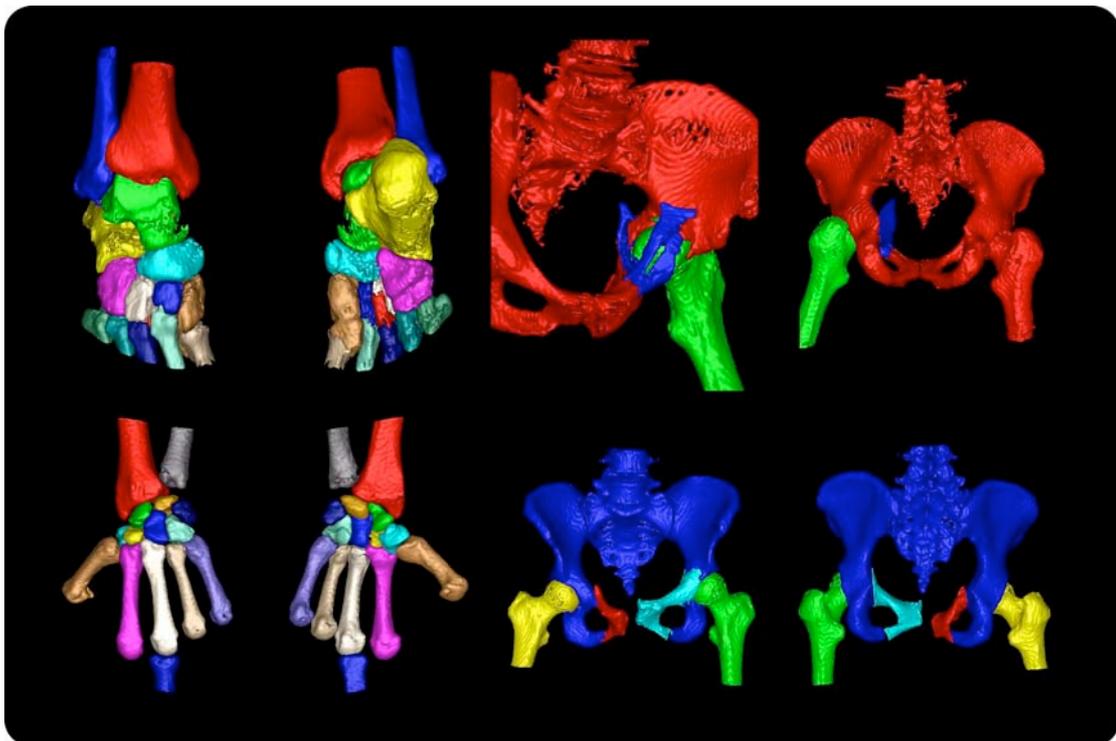
- Minimally invasive neurosurgery planning
- Accuracy and optimization of neuronavigation
- Generic segmentation of organs and pathologies
- Patient-specific endovascular structures modeling
- Brain tumors delineation and follow-up
- Preoperative planning for pelvic fractures
- Quantitative patient-specific fracture fixation evaluation
- Rigid and deformable registration of X-ray, CT, MRI, and fMRI images



Robust segmentation of organs/pathologies

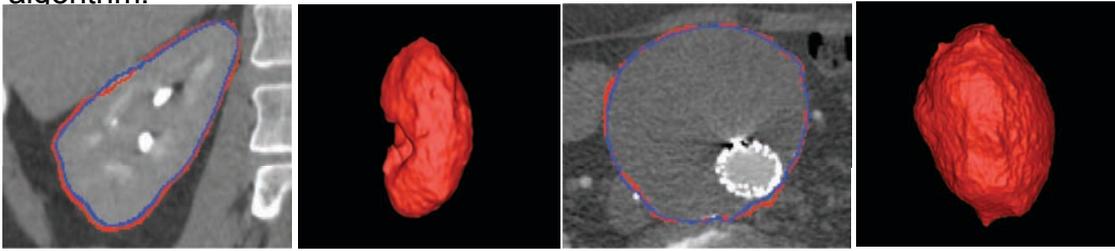
Generic methodology: Fuzzy boundaries of anatomical structures make segmentation a challenging task. We develop a new segmentation framework that explicitly deals with the fuzzy boundary problem. Our framework is applicable as a stand-alone segmentation tool or as a post processing module for the correction of other segmentation methods errors. We demonstrate our segmentation framework on several challenging segmentation tasks including segmentation of bones fragments, kidney (without contrast agent), abdominal aortic aneurysm, lungs contusions and liver tumors.

Interactive bones fragments segmentation: We present a new method for the segmentation of bones and bones fractures in CT images. Our method incorporates both intensity and local shape features information together with user provided scribbles to segment the bones. We tested our method on segmentations of the foot, wrist, hip, and femur including fractures with a good success.



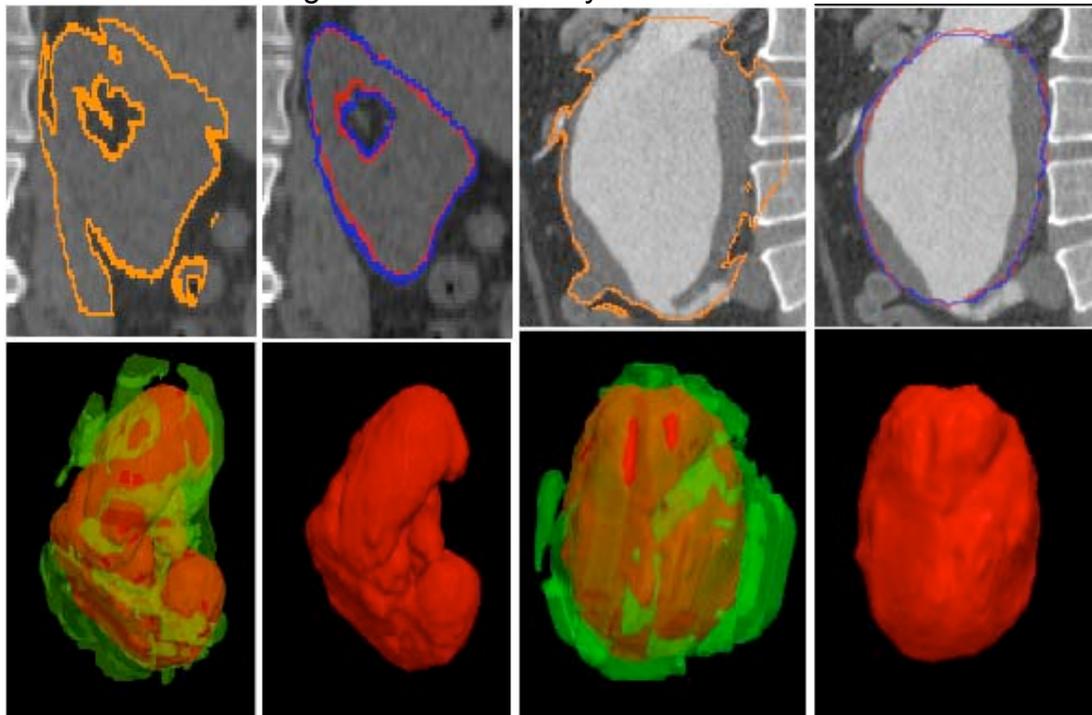
One-click segmentation of abdominal aortic aneurysm (AAA) thrombus: AAA is a potentially life threatening pathology of the aorta. We present a new method for the segmentation of AAA in CT images. Our method incorporates local shape features with a user provided seed-point to explicitly find the fuzzy boundaries of the AAA thrombus, and thus to avoid segmentation leaks. Testing our method on 16 AAA cases yield a volumetric overlap error (VOE) of 12%. Applying our method on segmentation of 23

kidneys in CT images yielded a VOE of 12.5%, without any modification to the algorithm.



Pulmonary contusions segmentation: Pulmonary contusions is the most common type of potentially lethal chest trauma. While segmentation of the healthy lung is a relatively easy task, segmentation of the pathological lung is challenging due to the existence of fuzzy boundaries between the contusions and the surrounding tissue. We develop a new method for the segmentation of lungs contusions. Our method segment the lung based on features taken from the general anatomy of the chest, without using any assumption on the intensity value of the lung itself. Initial evaluation of our method show promising results.

Segmentation leaks correction: A common segmentation error occurs when the segmentation volume expands outside the target surface into neighboring structures due to fuzzy boundaries of the target structure of interest. We present a method to automatically detect and correct segmentation leaks. Our method differentiates between the correct and faulty segmentations and estimates the true boundary based on smoothness and continuity constraints. Addition of our method as a post processing module to min-cut and level-set based segmentation methods yield a reduction of 50% in the VOE for the segmentation of kidney and AAA.

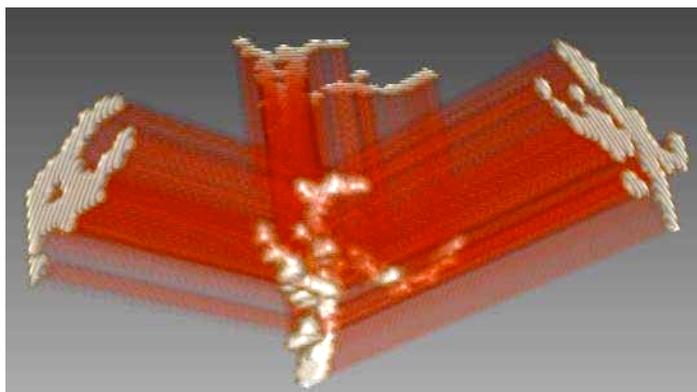
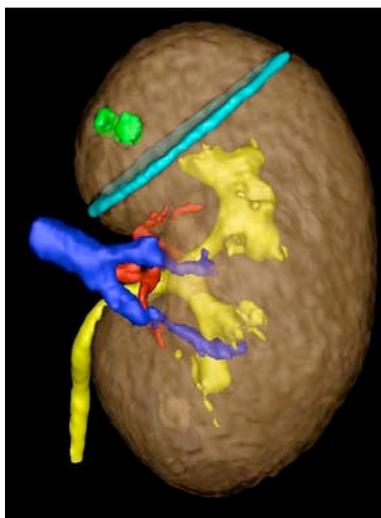
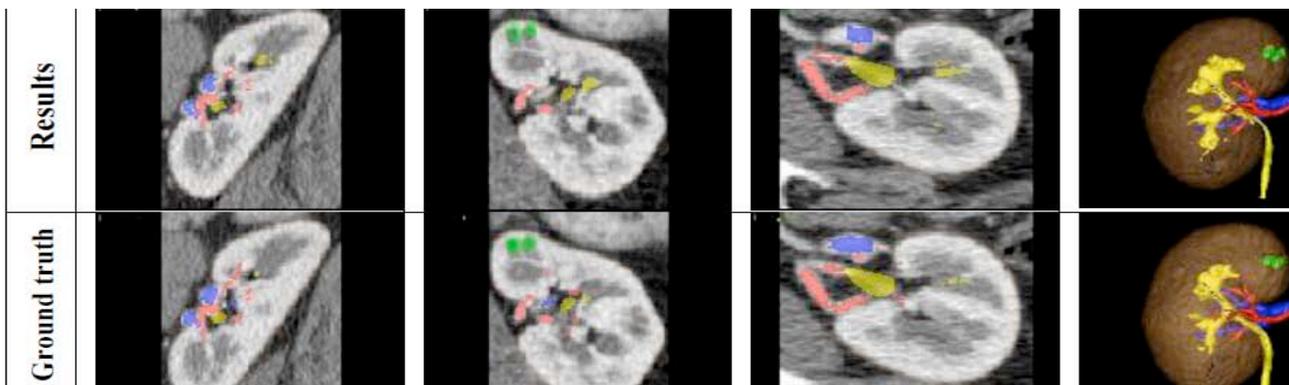


Kidney and internal structures from 4-phase CT

We present novel semi-automatic methods for the creation of patient-specific kidney models from four-phase CT studies. The kidney models include the kidney outer contour, kidney arteries, veins, urine collecting system and tumors when present.

The kidney segmentation methods rely on the mutual intensity distribution between the CT scan phases, region-growing, and morphological operations. The vessels segmentation method uses a new concept called 'volume rendering back projection' and region growing.

A validation study on three four-phase CT sequences comparing automatic vs. manually segmented models of the kidney and its internal components yields a mean overlap error 1.7% for the kidney contour, 14.1% for the ureter, and 25.65% for the blood vessels.



Interactive delineation of complex tumors

We present a novel method for semi-automatic tumor segmentation based on classification of local histograms. The required input to this method is a simple mouse stroke which indicates the location of one or more tumors. An intensity histogram of the marked area is computed and matched against a pool of model tumor environment histograms. The most similar model histogram indicates the expected intensity range of tumors in the given input. This information is applied in the vicinity of the marked area to locate and segment all nearby tumors.

This method was tested in Tel Aviv Sourasky Medical Center on 30 MRI scans of patients having tumors of type Plexiform Neurofibromatosis (PN). These large benign tumors involve different parts of the body, and are characterized by complex irregular shapes and bright appearance in STIR MRI scans. Results show our method has good segmentation repeatability: the inter-observer variability of measured volume is only 4%. Furthermore, this method achieves a significant improvement of work duration compared with the general-purpose segmentation software traditionally used in that hospital (Analyze Direct Software, Mayo Clinic, Rochester, MN, USA). The average segmentation time was reduced from approximately 12 minutes to 7.5 minutes, meaning the work output can be increased from 5 segmentations per hour to 8 segmentations per hour.

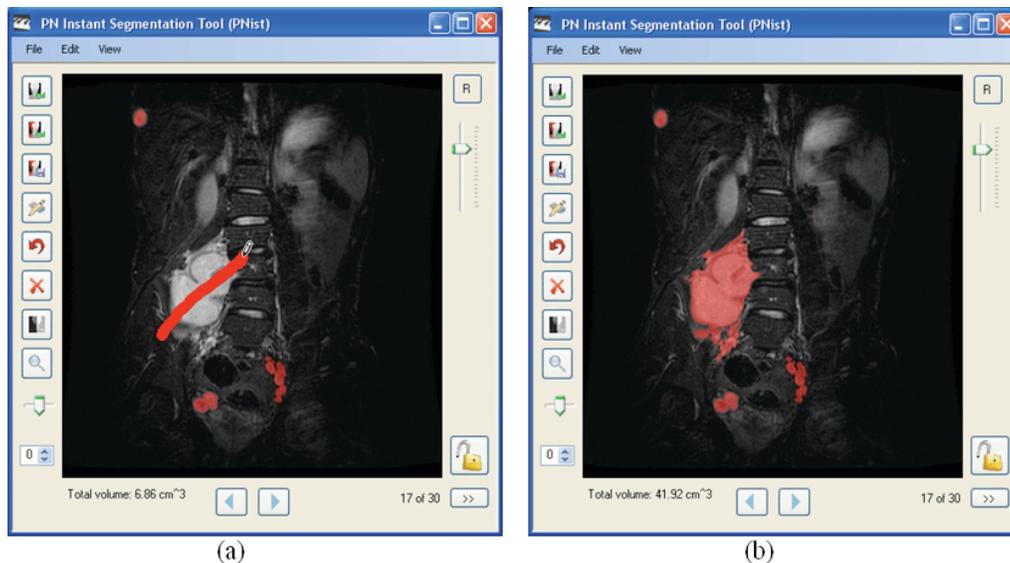


Figure 1: A screenshot of the program PNist (Plexiform Neurofibromatosis Instant Segmentation Tool). The viewing area displays an abdominal coronal MRI scan of a patient having PN lesions (marked with red). (a) The input to our method is marked by the red opaque line. (b) Resulting segmentation for the input in (a).

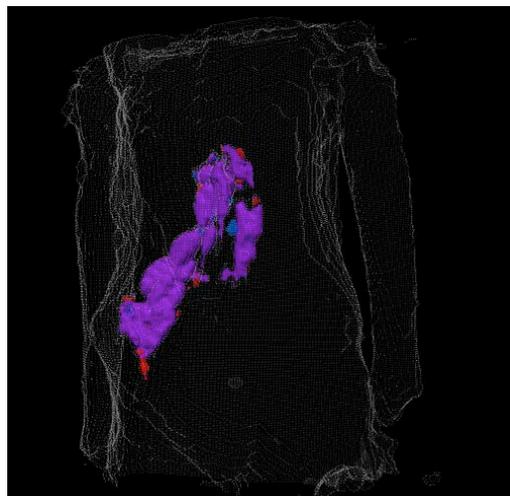
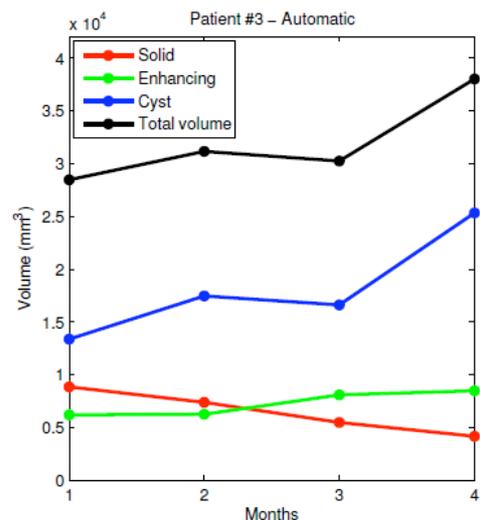
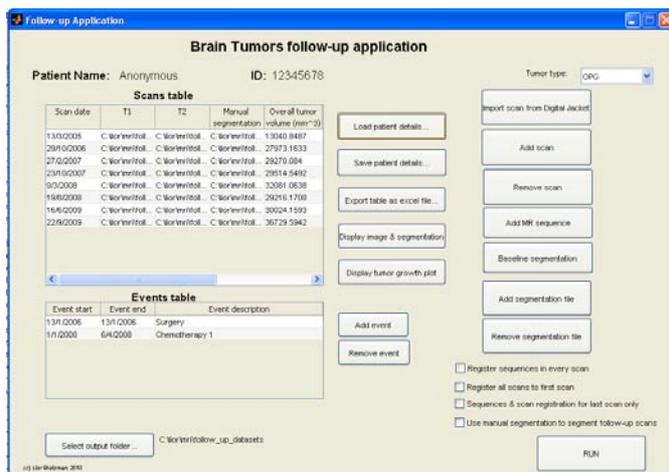
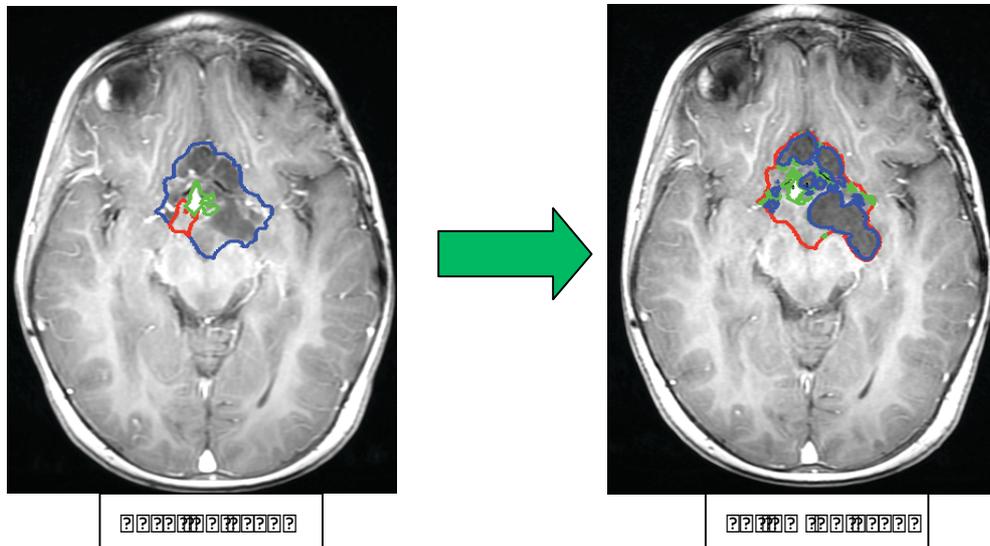


Figure 2: Volume rendering of abdominal Plexiform Neurofibroma

Follow-up of brain tumors progression from MRI

Abstract: We present a novel semi-automatic method for a repeatable, prior-based segmentation and internal classification of brain tumors in longitudinal MR scans. Our method effectively incorporates delineation and internal classification of the baseline scan in the time-series as a prior to segment and classify a series of follow-up scans. The method obviates the pulse sequences normalization as it estimates the unknown parameters from the follow-up scan itself. As the important factor for treatment efficacy evaluation is the tumor volume change over time, the method is designed to provide a repeatable delineation of the tumor boundaries in a set of follow-up scans of the same patient. Experimental results on 32 datasets yield a mean surface distance error of 0.29mm and a mean volume overlap difference of 14.1% as compared to manual segmentation by an expert radiologist. A Graphical user interface was developed to manage the follow-up studies and to track the progression of the tumor and its components over time.



References:

1. L. Weizman et al. "Automatic segmentation, internal classification, and follow-up of optic pathway gliomas in MRI," *Medical Image Analysis*, Vol. 16, pp. 177-188, 2012.
2. L. Weizman et al. "Longitudinal assessment of brain tumors using a repeatable prior-based segmentation," Proceedings of the 18th IEEE International Symposium on Biomedical Imaging (ISBI) pp, 1733-1736, 2011.

Initial delineation and follow-up of liver tumors from CT

Abstract: We present a novel fully-automatic method for a repeatable, prior-based segmentation of liver tumors in CT scans. Our method effectively uses delineation of the baseline scan in the time-series as a prior to segment and classify a series of follow-up scans. As the important factor for treatment efficacy evaluation is the tumor volume change over time, the method is designed to provide a repeatable delineation of the tumor boundaries in a set of follow-up scans of the same patient. Preliminary Experimental results on 2 datasets yield radiologist-approved results.

For the delineation of the baseline scan, we propose a novel semi-automatic segmentation tool, with a convenient GUI for its seeding process.

Figure 1: (Right) semi-automatic segmentation toolbox for liver tumors on baseline scan.

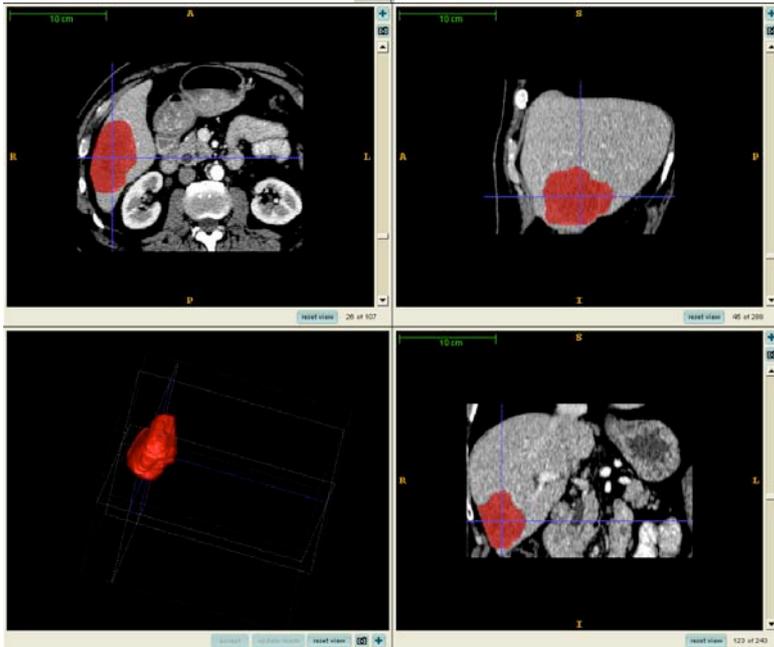
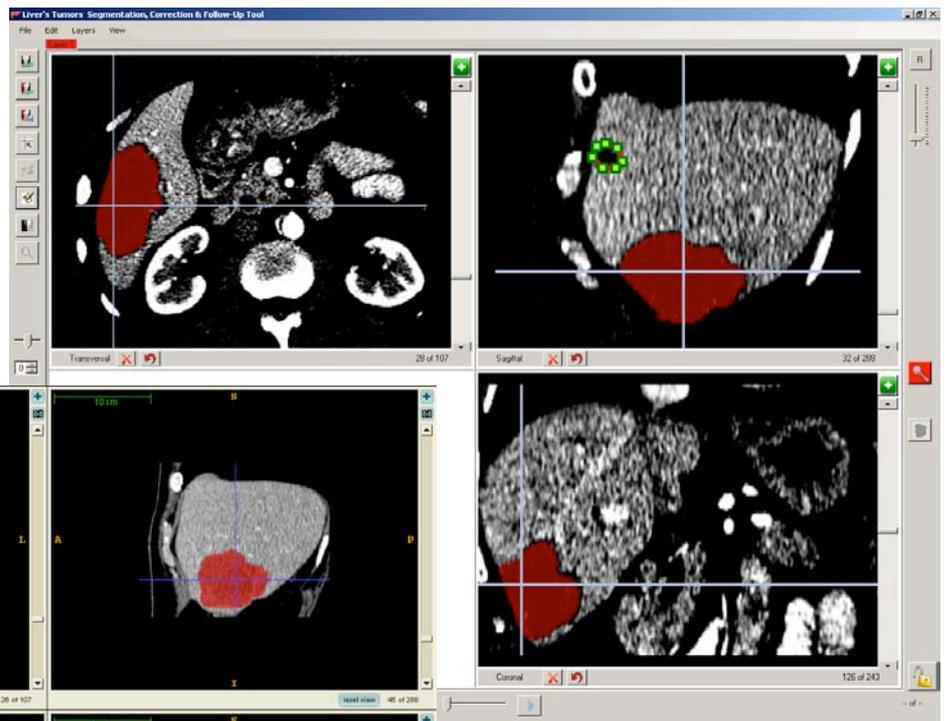


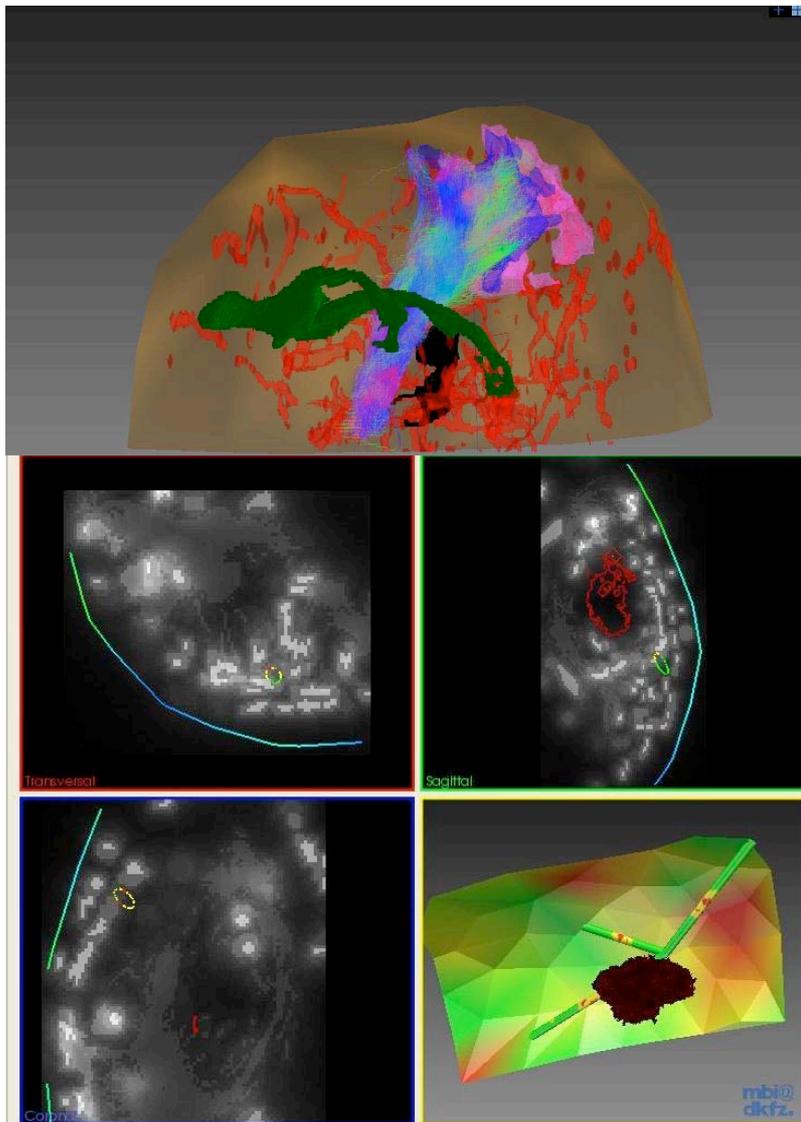
Figure 2: (left) result of fully automatic segmentation process on follow-up scan.

Minimally invasive neurosurgery planning

Abstract:

Many image-guided keyhole neurosurgery procedures require the precise targeting of tumors and anatomical structures with a surgical tool inside the brain based on pre-operative CT/MRI images. A misplacement of the surgical tool from the planned trajectory may result in non-diagnostic tissue samples and/or severe neurological complications. Consequently, it is desired to select a trajectory that is at a safe distance from critical structures such as blood vessels, ventricles and functional areas: DTI (fibers) and fMRI such as motor, speech and sensory areas.

We present a novel preoperative straight trajectory planning method for image-guided keyhole neurosurgery. Our method quantifies the risks of multiple candidate trajectories and presents them on the outer head surface to assist the neurosurgeon in selecting the safest path. For visualization, we color-code all the trajectories according to their associated risk level and present them all at once on the relevant parts of the outer head surface.



Brain model consists of several segmentations:

tumor, ventricles, blood vessels, DTI (fibers) and a corresponding fMRI of motor left leg, motor left hand and sensory left hand.

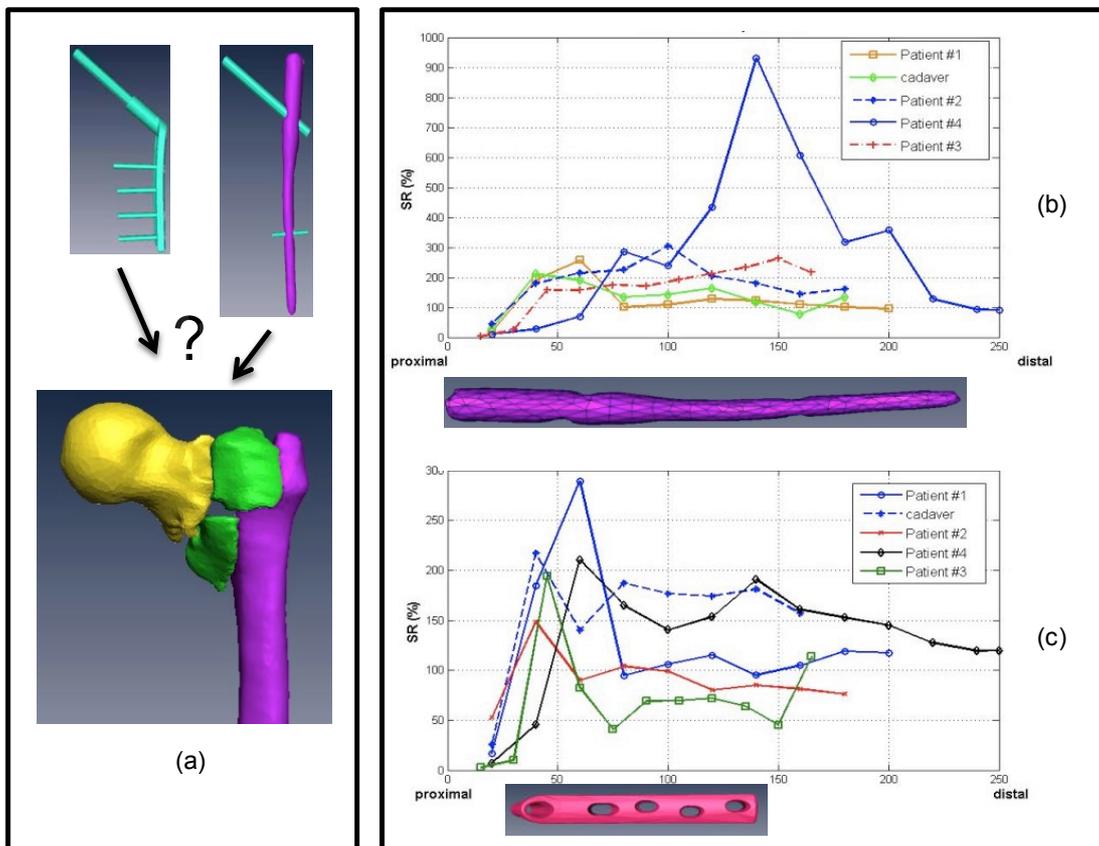
Optimal trajectories selection:

The colored surfaces represent the calculated risks on three distant optimal trajectories and scalp.

Patient-Specific Quantitative Analysis of Bone Fracture Fixations

Choosing and executing an optimal treatment plan for skeletal fractures in clinical practice is a complex procedure. Treatment decisions are often qualitative, based on general guidelines and experience/training of the orthopedic surgeons. Despite its potential to assist in quantifying fracture fixation and thus improve patient outcome, computational patient-specific modeling for selection and planning of fracture treatments is limited at present.

We have developed a new preoperative planning and analysis method for the quantitative assessment of fracture reduction and fracture fixation. The computerized method provides clinically relevant biomechanical information that allows the surgeon to compare and choose between alternative reduction and fixation alternatives. The method is based on Finite-Elements Analysis (FEA)



Examples of 3D models of the extra-medullary DHS and intra-medullary PFNA fixation devices (top), and multi fragmental fracture (bottom); (b-c) Strain Ratios (SR) computed from FE analysis for all five cases for each fixation device (PFNA top, DHS bottom). The horizontal axis indicates the region in which the SR was measured (femur head, proximal, medial, and distal femur shaft). The vertical axis indicates the SR as a percentage of with respect to the intact bone maximum principal strain. Note the significant differences between patients, regions, and fixation devices.