Medical Image Display and Analysis Projects

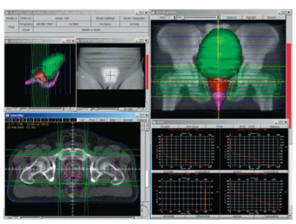
Department of Computer Science University of North Carolina at Chapel Hill March 2003

Model-based Object Extraction for Radiation Treatment Planning

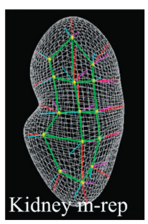
Participating Depts: Computer Science, Radiation Oncology, Psychiatry
Leaders: S.M. Pizer, E.L. Chaney, S. Joshi

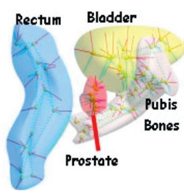
In radiation oncology cancerous tumor tissue is to be destroyed by radiation while sparing tissue of nearby normal organs. Planning how to form and aim the radiation beams therefore requires knowing where the tumor and the normal organs in the patient to be treated are. This information as to where the tumor and normal organs are is available in 3D CT or MRI images of the patient but must be extracted from the images to be usable for planning the beams.

M-reps are a form of geometric model that we have invented to represent deformable objects by their interior and to study populations of objects probabilistically. They lead to efficient and effective methods to deform atlases into individual patients measured by their 3D images and thus to extract the organs needed in treatment planning from the patient image. M-reps also allow following individuals as they change shape or measuring the shape differences between well and ill patient classes (see section on right).



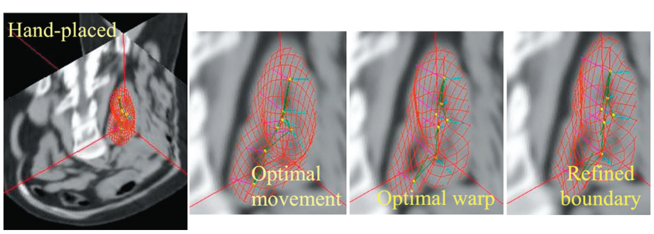
PlanUNC, built by Radiation Oncology based on MIDAG research, is the radiation treatment planning tool in clinical use there.



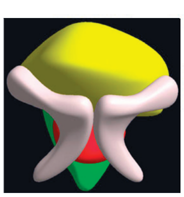


Male pelvis multi-object m-rep

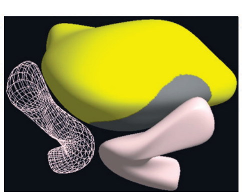
As illustrated in the PlanUNC panel, radiation treatment planning requires the extraction of anatomic objects, which can be modeled by m-reps.



Stages of extraction of kidney from CT in planning treatment of abdominal cancer. Kidney model thereby deforms into the CT image data.



Pelvic structures implied by m-rep model



Grey shadow shows part of bladder affected by position of nearby bone

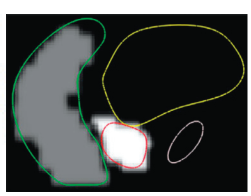
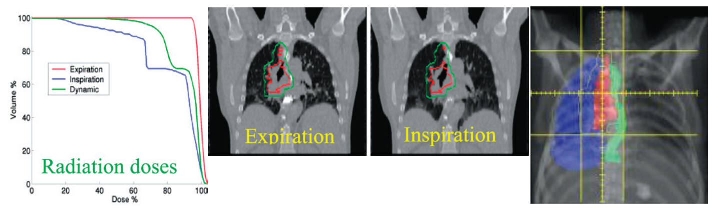


Image slice of result of experiment on inter-object geometry. Legend: rectum, prostate, bladder, bone.

Stages of extraction of male pelvis structures in planning treatment of prostate cancer.



Reconstructed radiograph and respiratory organs

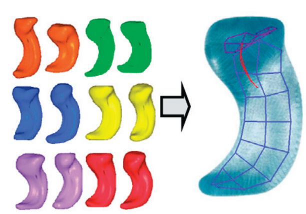
Planning radiation treatment of lung cancer, recognizing breathing motion.

Morphology of Brain Structures in Psychiatric Illness

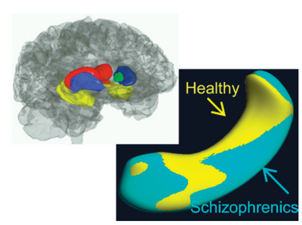
Participating Depts: Computer Science, Psychiatry, Radiology
Leaders: G. Gerig, J.A. Lieberman, J. Piven, S. Joshi, S.M. Pizer

Improved understanding of disease mechanisms in psychiatric illness is a key factor for early diagnosis, better treatment, and development of new drug therapies. Measurements of morphologic change of brain structures imaged in 3D by MRI illuminate the nature of neurodegenerative diseases and/or disorders of abnormal neurodevelopment. We study the whole age-range to provide a broad picture of neurodevelopmental and neurodegenerative aspects of illness, especially schizophrenia.

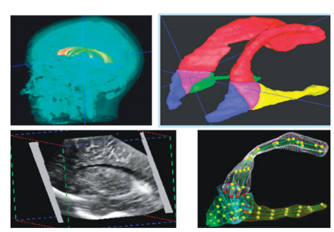
We compare the size and shape of brain structures between healthy subjects and patients with or at risk for schizophrenia. We also measure disease progress by observing these changes over time. Our 3D model deformations efficiently extract anatomical structures, reducing time from several hours to a few minutes. New measures of shape statistics using m-reps provide insight into the natural variability of brain structures and thus help to describe difference from normal in clinical terms such as local growth and thinning, widening, or bending.



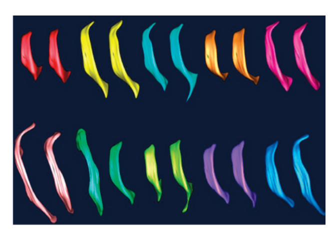
Creation of a statistical model template of the hippocampus from a shape population



Overlay of shapes of the healthy hippocampus (curved) and its alteration (flat) in schizophrenia



Neonatal brain ventricles with m-rep and with subparts extracted from MRI and 3D ultrasound imaging

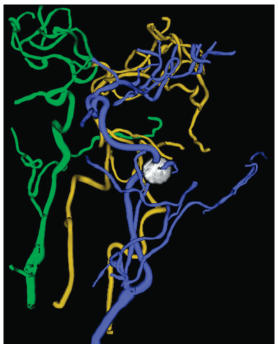


Shape variability of brain ventricles of identical twin pairs (top row) and nonidentical twin pairs (bottom row).

Patient-Specific Vascular Models for Surgical Planning and Guidance

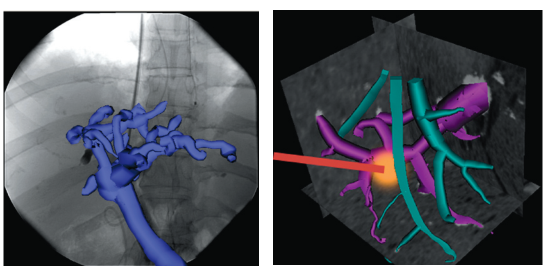
Participating Depts: Surgery, Radiology, Computer Science, Radiation Oncology
Leaders: E Bullitt, S Aylward

Many surgical and all endovascular procedures require understanding the locations and connectivity of a patient's blood vessels. Our projects extract patient-specific vascular networks from 3D image data, to aid vascular procedures.

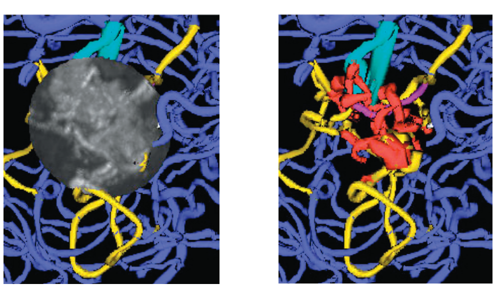


Tumor (white) segmented from MRA and shown in relationship to color-coded vessel trees. Some vessels pass through the tumor to supply normal brain, which is important to know for surgical planning.

Projects include 1) interactive 3D visualizations for neurosurgical planning, 2) registration of high-resolution 3D pre-operative images with 2D intra-operative images for guidance of intra-vascular procedures, 3) definition of cutting planes for liver donors, 4) overlaying pre-operative findings and surgical plans onto intra-operative 3D ultrasound to guide biopsies, 5) delineation and hybrid surface/volume visualization of tumors and their surrounding/feeding vasculature, and 6) judging malignancy and extent of tumors via the pattern of blood vessels within and surrounding the tumor. More information can be found at http://casilab.med.unc.edu and at http://caddlab.rad.unc.edu.



Left: Pre-operatively defined portal vessels (blue) are registered with a 2D image obtained during an endovascular procedure. **Right:** Lesion (orange), defined from a pre-operative CT, is superimposed upon an intra-operative 3D ultrasound image to enable fast and accurate ultrasound guided biopsy.

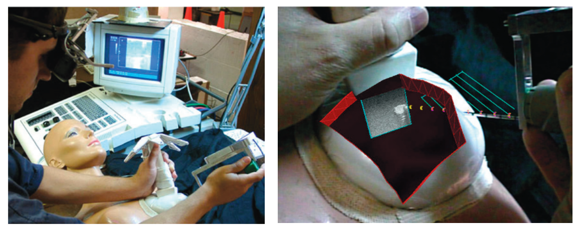


Blood vessels in relation to a tumor. Their structure can help extract which tissue is tumor and diagnose malignancy.
Legend: tumor region, vessels in tumor, outside tumor, traversing tumor, entering tumor, exiting tumor.

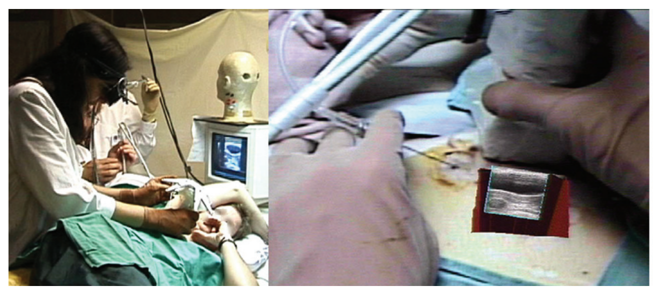
Medical Augmented Reality

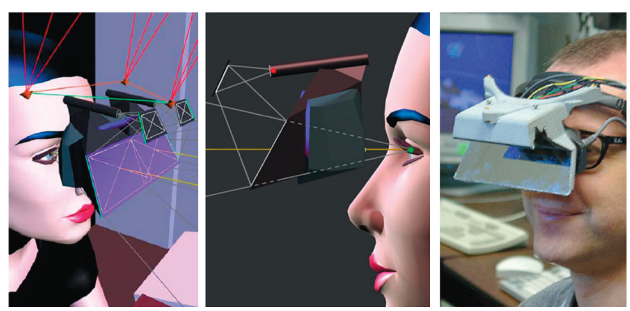
Participating Depts: Computer Science, Radiology, Surgery
Leaders: H Fuchs, ED Pisano

We aim to enable physicians to achieve more accurate miminally invasive access to internal patient structures by viewing real-time medical data registered with the patient. These visualization methods use images such as ultrasound echograms or laparascopic video and augmented reality technology such as see-through head-mounted displays (HMDs) and motion trackers. The physician sees a dynamic, stereoscopic image of the patient, enhanced with registered live intra-operative imagery. Our work reaches from the design and construction of video see-through HMDs and prototype 3D laparoscopes to human subject studies comparing conventional and AR methods for ultrasound-guided breast biopsies. More information can be found at http://www.cs.unc.edu/~us/



AR guidance system in use on a breast biopsy model (above) and on a human subject (below).





Parametric design tool for video see-through HMDs (left), resulting design (center) and finished device (right): Camera and eye positions are matched geometrically via mirrors.

The Medical Image Display & Analysis Group (MIDAG) is a multidisciplinary UNC research group. MIDAG publications and research descriptions, with illustrations, as well as the history of MIDAG and lists of MIDAG members can be found on the group's web site.

http://midag.cs.unc.edu