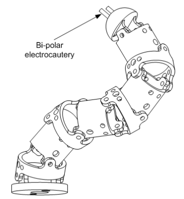
Robotics, Automation, and Medical Systems (RAMS) Laboratory

Director: Prof. Jaydev P. Desai

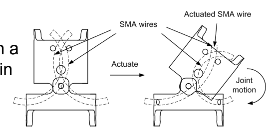
MRI-Guided Neurosurgical Intracranial Robot

Design:

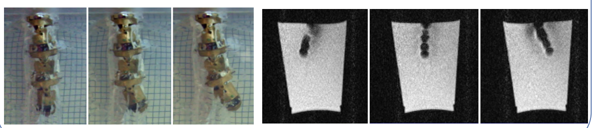


- The hollow core design enables us to route wirings inside the robot, which makes the robot more compact, safer and easier to shield.
- Two antagonistic SMA wires are used as actuators for each joint, so that each joint can move back and forth and be operated independently.

Results:

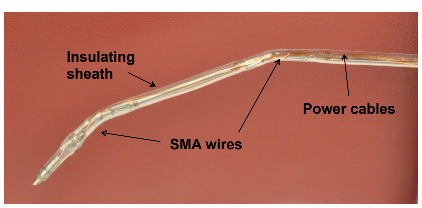


- The multi-DOF robot is able to move in a tightly enclosed environment (gelatin) in continuous MRI.



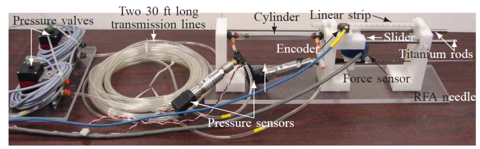
Steerable Needles

- In diagnostic and therapeutic procedures such as biopsy and radiofrequency-ablation, needle bending occurs due to needle and soft-tissue interaction, which can result in errors in targeting and hence lead to sampling errors and poor treatment outcomes.
- SMAs (Shape Memory Alloy) are attractive for applications, where large forces or displacements are required and limited space is available.
- SMA wires are employed to control bending angles to account for bending errors and for steering inside soft-tissue.
- SMA wires are trained to bend upon thermal actuation. SMA wires are heated via resistive (joule) heating.
- PWM controller with stereo image feedback is used for controlling the amount of bending at each joint.



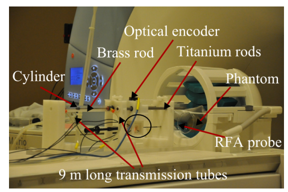
MRI-Guided Intervention for Bx/RFA of Breast Tumors

MRI-compatible Pneumatically Actuated Robot:



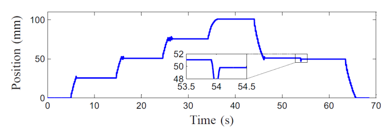
Challenges:

- Long pneumatic transmission lines up to 10 m are unavoidable because of MRI-compatibility issues of valves, resulting in:
  - Introduction of time delay;
  - Slow pressure dynamics from valve to the cylinder pressure.
- Friction along the motion range of the device is highly non-uniform.



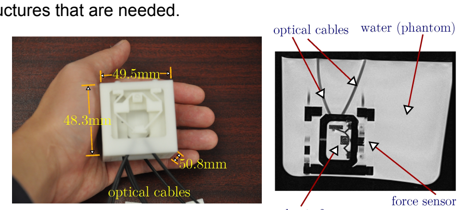
Sliding mode control (SMC):

- Non-uniform friction is treated as uncertainty by sat( )
- The sliding surface, *s*, determines the performance.
- Good estimation of maximum friction is needed.
- Satisfactory performance of the system is obtained.



Force sensor:

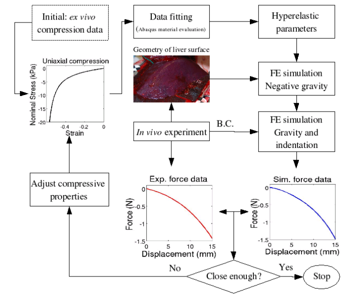
- Optical approach is inherently MRI-compatible as signals are transmitted in the form of light and electrical wires are eliminated.
- A force will cause a deformation in the elastic frame structure, resulting in a displacement in the reflector.
- By monitoring the reflected light intensity, the force acting on the loading point can be computed.
- A topology optimization technique is also used to provide a systematic algorithm aiding engineers in designing the elastic frame structures that are needed.



Soft-Tissue Modeling

Constitutive Model Generation:

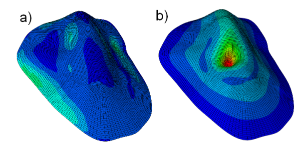
- *Ex vivo* tension, compression and pure shear testes were used to create a constitutive model for porcine liver.
- Modification to the *ex vivo* model based on *in vivo* probing tests resulted in a more accurate description of tool tissue contact for live tissue.



Constitutive model modification procedure

Surgical Simulation:

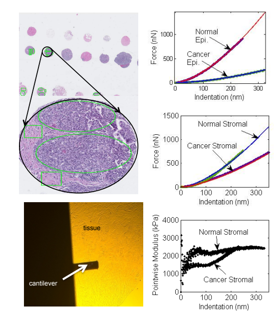
- The models generated from *ex vivo* and *in vivo* experiments are used in the simulation of tissue probing.



Simulation of a) gravitational loading and b) probing

AFM-Based Breast Tissue Characterization

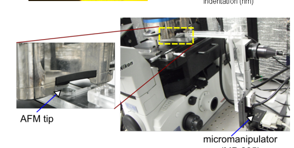
Tissue Characterization



- AFM allows quantification of cell and tissue mechanical properties at the micro-scale.
- Epithelial and Stromal sections in cancerous breast tissue histology specimens studied.
- We have observed decrease in stiffness in cancerous specimens compared to normal tissue

Automated Image-guided Tissue Characterization

- AFM based characterization is slow and low in throughput.
- AFM tip occludes location of sampling, hence image-guided specimen placement will improve throughput and accuracy of results.



This work was supported in part by NIH grant R01EB008713, NIH grant R01EB006615, NIH grant R21EB008796, NSF grant CCF0704138, NSF grant CMMI0826158, and STMD-Maryland Technology Development Corporation grant 08071517.