# Neuro-Needle Brain Deformation Quantification by Magnetic Sensor System

Anirvan Komath Majumdar[1], Sayemul Islam[1], Sai Teja Reddy Gidde[1], Byoung Gook Loh[2], Parsaoran Hutapea[1], and Albert Kim[1]
[1]Temple University, Philadelphia, PA, [2]Hansung University, Seoul, Korea, Republic of

**Introduction:** Intraoperative brain deformation from neurosurgical needles or other load applying procedures can risk traumatic brain injury. Soft tissue, like the brain, is easily deformed even by light touch. Needle insertion leads to tissue rupture causing a sudden release of strain energy and the propagation of micro-cracks around the puncture site. The released strain energy is propagated along these cracks, causing neuronal and microvascular damage [1]. Current image-guided neurosurgical procedures desperately lack information regarding micro level brain deformation, especially at the distal region of the needle penetration. As an imminent solution, collaborative approaches between current imaging technology and various brain deformation models have been reported. Unfortunately, computational models of brain deformation are unable to sufficiently account for the observed neuronal and microvascular damage. Thus, we report an implantable brain deformation sensing system that leads to a new micro level empirical brain deformation model. The hope is that our new empirical model will help better understand and mitigate tissue deformation at the distal region of the needle penetration site.

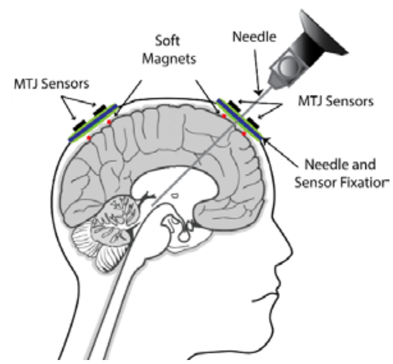


Figure 1: Schematic of implantable brain deformation sensing system.

**Materials and Methods:** The sensing system consists of a soft magnet paired with a magnetic tunnel junction (MTJ) sensor. Figure 1 shows an implantable brain deformation sensing system. The small soft magnet can be implanted on the surface of the dura to follow dynamic brain deformation. When a needle is inserted, the brain deforms, causing the relative magnetic strength of the soft magnet to change. This can be measured by an externally fixed MTJ sensor. The MTJ sensor can detect magnetic field strength change as a change in its resistance. Therefore, the sensing system tracks the resistance change as a function of the position of the soft magnet, which is identical to the brain deformation in Cartesian coordinate: $P(x, y, z) = f\left(\Delta R_{MTJ}\right)$.

Ecoflex® was used to fabricate the soft magnet to ensure that the magnet is more compliant than the surrounding brain tissue. A pre-gel solution was mixed with iron (II) oxide particles ($Fe_2O_3$, size < 5μm) at 40 wt% and placed in a disc mold. Two neodymium (NdFeB) magnets were applied from the top and bottom during curing to magnetize the mixture. The resultant soft magnet is $2mm^3$ in dimensions. To characterize the sensing technique, the soft magnet was mounted on a manipulator and is scanned over an area of $20mm^2$ over the MTJ sensor with a resolution of 100μm. Five planes were scanned at vertical heights of z = 0, 1, 2, 3 and 5mm as shown in Figure 2.

**Results and Discussion:** The soft magnet exerts changes in relative magnetic strength over the MTJ sensor. As observed from the center of the MTJ sensor, changing magnetic strength caused a positive resistance change on one side, and a negative resistance change on the other. On the zero-mm plane, the maximum change of resistance was approximately 10Ω. Magnetic strength is confirmed to decrease as an inverse square law. At 5-mm height, the maximum resistance change was 2Ω. The sensitivity was 10mΩ/μm. The results indicate that brain deformation at the distal region of the needle insertion is instantly registered by the sensors and can be mapped. It is expected that a machine learning method such as a spatial mapping algorithm [2] can be utilized to continuously find position vectors. This method provides approximate position of the soft magnet (i.e., brain deformation) quantization data by real time spatial mapping.

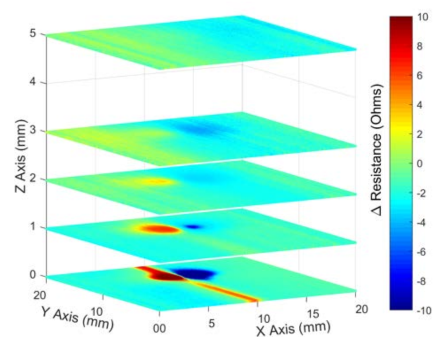


Figure 2: Magnetic strength of soft magnet at different location

**Conclusions:** The practice of neurosurgery requires high precision dynamic control for needle insertion to minimize local tissue damage and reduce deep tissue micro-cracks. By implementing our novel dynamic response sensing technique, further reduction of traumatic brain injury can be accomplished while improving needle-brain interaction. In addition, precision of robotics assisted neurological surgeries can be improved by incorporating feedback received from the sensing system.

**References:**

[1] Mahvash, M., & Hayward, V. (2001). Haptic rendering of cutting: A fracture mechanics approach.

[2] Corcoran, T., Zamora-Resendiz, R., Liu, X., & Crivelli, S. (2018). A Spatial Mapping Algorithm with Applications in Deep Learning-Based Structure Classification. *arXiv preprint arXiv*:1802.02532.