An Electrical Impedance Tomography device for low cost functional imaging

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ABSTRACT

Non-invasive BCI techniques have previously been limited to EEG, NIRS or less portable and more expensive MRI technologies. We propose that Electrical Impedance Tomography (EIT) has advantages over previous techniques as a portable research tool for non-invasive research into functional networks of the brain. We are presenting a small, wireless device similar to an EEG amplifier, based on open source software to encourage the use of this portable and inexpensive technique in non-invasive BCI research.

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PHYSIOLOGICAL MEASUREMENTS POSSIBLE FROM EIT

Electrical Impedance Tomography (EIT) measures spatially localized dielectric spectrums using small and safe (IEC60601-1 standards compliant) AC currents and has several advantages over electroencephalography (EEG), whilst maintaining the functional time resolution advantages. EIT converges to a far more robust tomographic spatial reconstruction than EEG, and adds a layer of contrast resolution by reporting a dielectric spectrum at every voxel. Although EIT is unlikely to reach the spatial resolution of MRI, it is small, affordable and portable, enabling it's use in a greater range of studies.

Recent studies in EIT show that functional dielectric changes in materials such as bloodflow through the heart[1] or airflow thorugh lungs can be determined non-invasively, suggesting this same technique can be used in brain research[2]. Further studies in this area, including recent research using ECoG arrays in rodents has shown the potential to observe measurable impedance changes triggered by action potentials non-invasively[3]. Although promising, many hurdles remain including navigating the SNR challenges of the skull[4].

PHANTOM BASED EIT RESULTS

We have developed a portable EIT device capable of performing real-time tomographic reconstruction of dielectric spectrums in conductive bodies. Our wireless 32-electrode device sends and receives AC currents between 100Hz and 80kHz and is only 2" square.

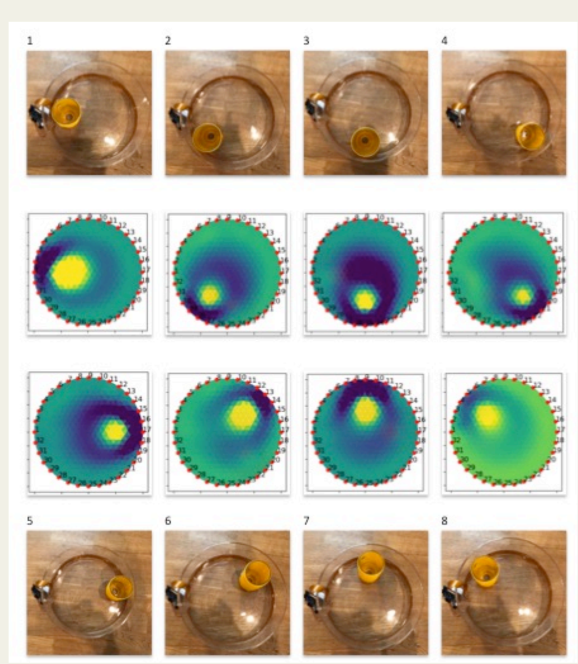

Figure 1. Anticlockwise movement of cup tracked in phantom with tomographic spatial reconstruction.

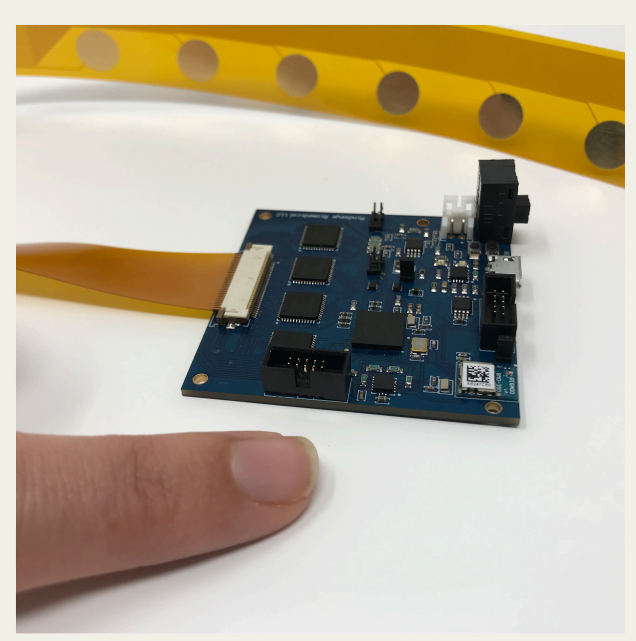

Figure 2. EIT device shown with finger for scale.

PHYSIOLOGICAL RESULTS TO DATE

Spatial topologies are reconstructed using Back Projection, or Gauss Newton estimation methods. In time series, we have shown detection of blood flow through the heart as well as lung expansion and contraction

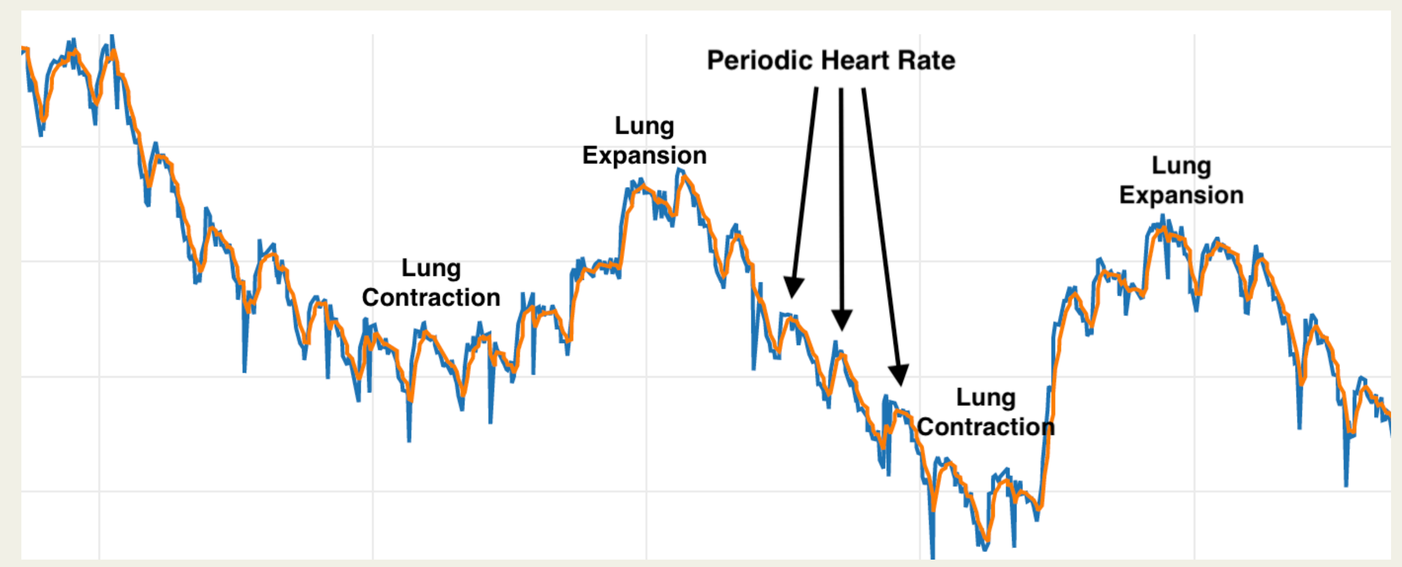

Figure 3. Time series impedance measures of heart and lung changes.
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We have also been able to reconstruct a physiologic cross-section of lung in real-time. We believe this technique will transpose to to the brain, although will likely suffer from SNR issues due to the presence of the skull.

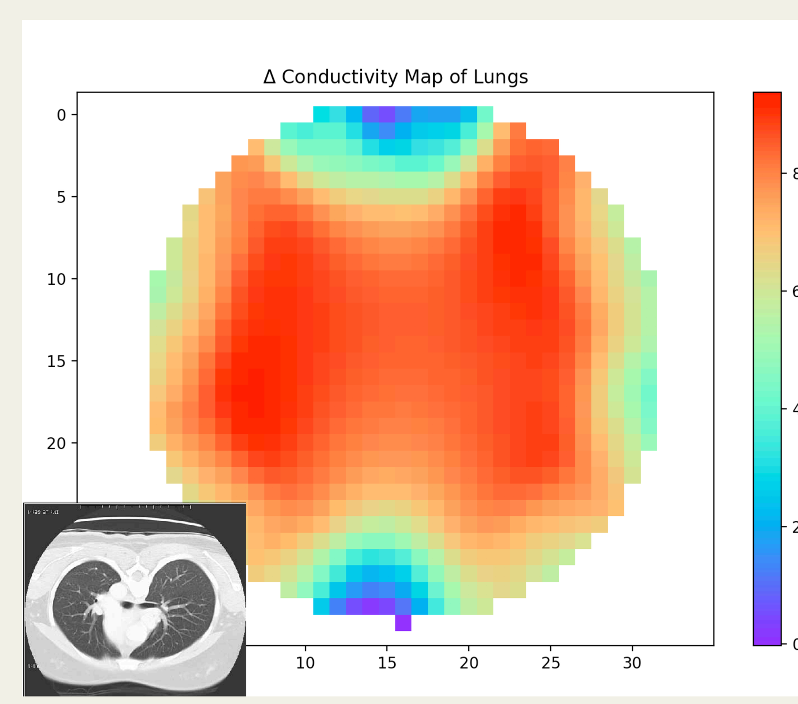

Figure 3. Lung Cross-Section at a single 50kHz frequency

We have validated the claim of recreating spatially localized dielectric spectrums, enabling functional monitoring of material changes in biological specimens. Future work includes translational studies on animals and humans aimed at developing better non-invasive neuroimaging tools. OpenEIT is an open source project available at https://github.com/openeit

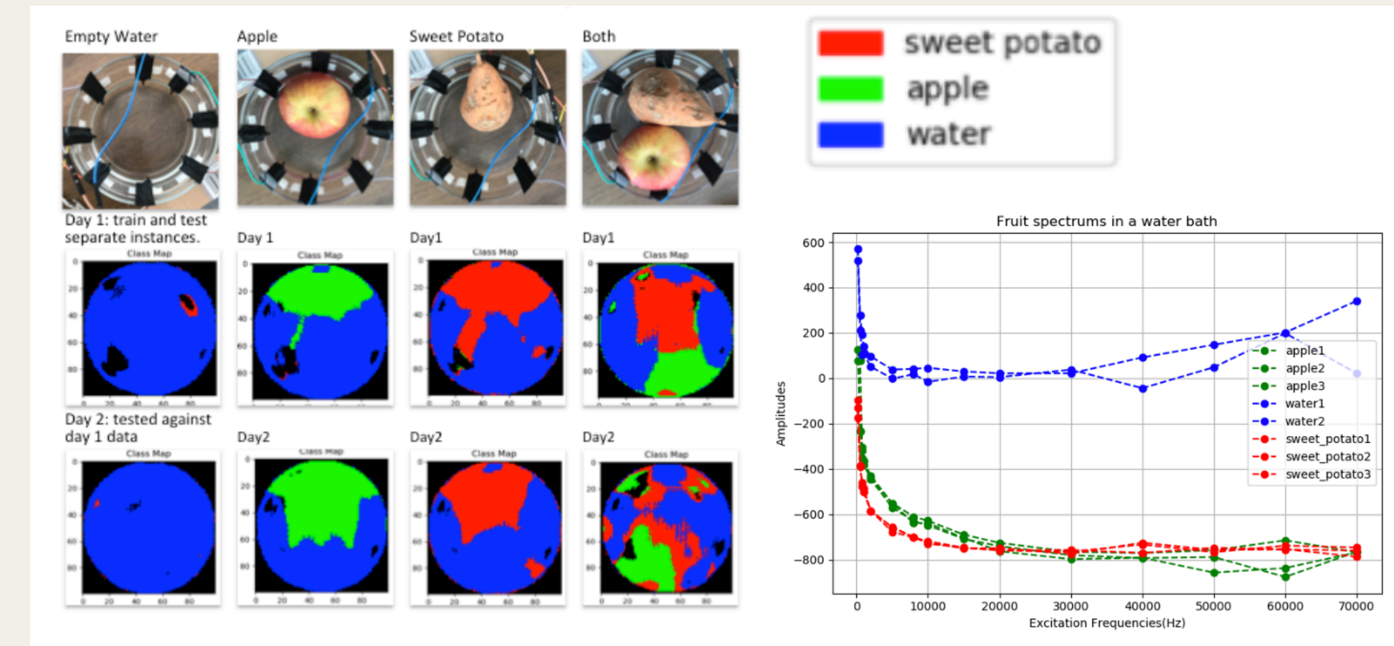

Figure 4. Classifying biological material into 3 classes in space, based only on their dielectric spectrum shown on lower right.

CONCLUSIONS

EIT has great promise as an alternative to EEG as a functional imaging modality, that provides both more spatial resolution as well as dielectric material information at each voxel whilst maintaining time resolution. Further testing is required on the device we have created, although previous work in fEITER[5][6] suggests ERP's can be quantified using the technique, giving it great promise as a non invasive BCI tool.

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REFERENCES

1. Nguyen DT, "A review on electrical impedance tomography for pulmonary perfusion imaging" Physiological Measurement, Volume 33, Number 5; 695-706, April 24 2012
2. Barry McDermott, "Classification Applied to Brain Haemorrhage Detection: Initial Phantom Studies using Electrical Impedance Measurements", 19th International Conference on Biomedical Applications of Electrical Impedance Tomography (EIT 2018), Edinburgh
3. Kirill Y. Aristovich, et al, "Imaging fast electrical activity in the brain with electrical impedance tomography", Neuroimage, Volume 124, Part A, 1 January 2016, Pages 204-213
4. Markus Jehl, et al, "Are patient specific meshes required for EIT head imaging", Physiological Measurement, Volume 37, Number 6, 20 May 2016
5. J. L. Davidson, P. Wright, S. T. Ahsan, R. L. Robinson, C. J. D. Pomfrett, and H. McCann, "FEITER-a new EIT instrument for functional brain imaging," *J. Phys. Conf. Ser.*, vol. 224, no. 1, 2010.
6. J. L. Davidson *et al.*, "Fusion of images obtained from EIT and MRI," *Electron. Lett.*, vol. 48, no. 11, pp. 617–618, 2012.