

# A two-layer Micro-Electrical Impedance Tomography Platform for Three-Dimensional Image Reconstruction using Machine Learning

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## Summary:

We present a two-layer micro-electrode system enabling three-dimensional (3D) electrical impedance tomography (EIT) for label-free observation of micro-scale biological samples. The system employs two facing 16-electrode rings with 1 mm diameter and 0.5 mm spacing for high depth sensitivity. A 3D forward model and machine learning-based reconstruction are implemented using simulated datasets. Preliminary simulation results show improved depth discrimination compared to conventional two-dimensional (2D) EIT.

**Keywords:** Electrical impedance tomography, image reconstruction, 3D imaging, microelectrodes, machine learning

## Background, Motivation and Objective

EIT stands out as a cost-effective, non-invasive, and radiation-free imaging technique<sup>1,2,3</sup>. Recently, there have been efforts to push its resolution to the micro-scale for cell biology applications.<sup>4,5,6</sup> We have contributed to this push by developing a glass-based micro-EIT platform to achieve faithful reconstructions of zebrafish eggs and their larval development.<sup>7</sup> This was enabled by a custom convolutional neural network (CNN) reconstruction approach, which we benchmarked against standard methods (one-step Gauss-Newton and total variation).

Despite such advances, key limitations remain. Notably, most existing micro-EIT systems (including our own prior work) rely on planar electrode configurations and 2D reconstruction, which limits depth resolution and introduces ambiguity in volumetric interpretation. Extension to 3D remains a major challenge due to hardware limitations and inverse problem complexity.

This work aims to overcome these challenges by introducing a two-layer electrode architecture and a corresponding 3D reconstruction framework, enabling volumetric imaging and depth-resolved slice visualization.

## Description of the New Method and System

Our two-layer micro-EIT platform includes both a novel hardware architecture and a corresponding 3D reconstruction framework. The measurement system consists of two 16-electrode circular arrays 1 mm in diameter (0.125 mm electrode diameter), facing each other across a 0.5 mm deep microfluidic chamber. 3D-printed holders are used to keep the system together, consisting of the two microelectrode ring layers, as well as the polydimethylsiloxane (PDMS)-based microchannel intended to support future in situ biological sample culture (as shown in Fig. 1).

3D forward models are implemented using EIDORS with refined mesh resolution (element size  $\sim 0.05$ ), and datasets of simulated measurements (1024 voltage values per data) are generated. Based on these datasets, multiple 1D-CNN models implemented in PyTorch are trained under different parameter settings to learn to map measurement data to volumetric conductivity distributions.

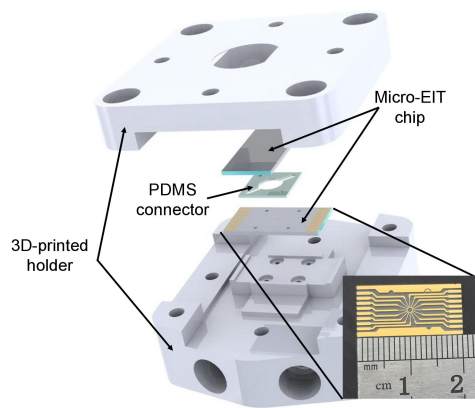


Fig. 1. Exploded view of the two-layer micro-EIT system, including a 3D-printed holder with fluidic connections, PDMS microfluidics for cell culture, and micro-EIT electrode chips (top and bottom). Ruler for chip scale.

## Results

Simulation datasets have been generated and used to train multiple CNN models, yielding 3D reconstruction results along with corresponding 2D slices (Fig. 2. a and b). The results indicate that our two-layer structure and reconstruction framework are feasible and enable initial volumetric imaging and slice-based visualization.

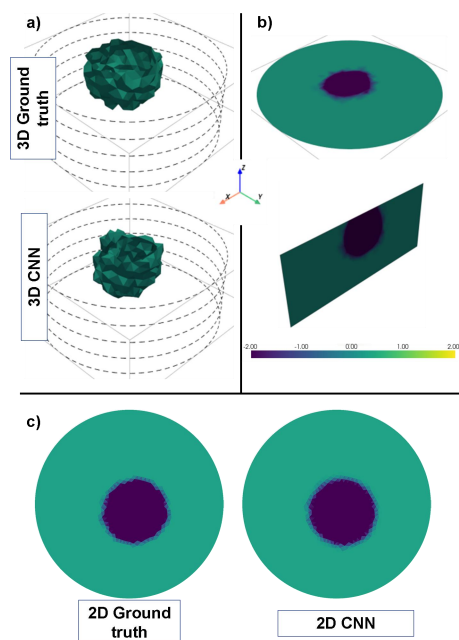


Fig. 2. micro-EIT reconstruction results: a) 3D simulated ground truth and CNN-based reconstructed image, b) corresponding 2D slice extracted at the central plane along the x and z-axis and c) 2D simulated ground truth and CNN-based reconstructed image. The results demonstrate the feasibility of volumetric reconstruction and slice-based visualization of our two-layer micro-electrode system.

Compared to conventional single-layer configurations, which provide limited depth information (as shown in Fig. 2. c), the two-layer design shows improved volumetric sensitivity, suggesting enhanced sensing capability.

Although quantitative evaluation and experimental validation are ongoing, these results demonstrate the potential of our approach for 3D micro-EIT imaging. Future work will focus on optimizing excitation patterns, improving reconstruction accuracy, and experimental validation.

## Conclusion

This work represents a step towards 3D micro-EIT imaging through the integration of two-layer system design and machine learning-based reconstruction.

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