

Project title: High-Resolution Electrical Capacitance Tomography

Electrical capacitance tomography (ECT) is an imaging technique based on the measurement of electrical capacitance between electrodes placed around the object under study. Unlike X-ray tomography, ECT does not use ionizing radiation, which makes it safe even for prolonged and repeated monitoring.

This technique finds application, among other things, in industry, where its greatest advantage is exceptional speed—modern systems can capture up to 1000 images per second, allowing for the tracking of highly dynamic processes. In medical applications, its potential lies in the ability to perform long-term, completely non-invasive measurements, such as monitoring lung function in patients in intensive care units.

Despite its many advantages, ECT has one critical limitation: very low image resolution. This is due to two main factors: the limited number of electrodes used (usually only 12 to 24) and the high computational cost associated with image reconstruction.

Increasing the number of electrodes is not easy, as it inherently involves reducing their surface area, which in turn leads to a decrease in the measured capacitance values. When the electrodes become too small, the electrical signal weakens to a level that is difficult to detect, even by very sensitive systems. However, in recent years, intensive research has been conducted into new measurement methods and acquisition sequences. One of the most promising approaches involves the synthesis of virtual electrodes—dynamically combining several adjacent electrodes into larger measurement units. This allows for a significant increase in the number of electrodes without physically adding new channels, thereby increasing the number of measurements without compromising signal quality.

At the same time, the rapid development of computational hardware and machine learning techniques in recent years has opened up entirely new possibilities for data processing. Computational problems that were recently considered intractable are now becoming solvable thanks to the use of specialized graphics processors and advanced algorithms.

The aim of this project is to investigate the potential for significantly increasing image resolution in ECT by applying modern measurement and numerical methods. The project will determine the actual limits of spatial resolution achievable with this imaging technique.

A new sensor consisting of 256 electrodes will be designed, in combination with a dedicated switching system and measurement sequences based on the concept of synthesized electrodes. In parallel, image reconstruction methods will be developed using the latest advances in deep learning, capable of processing models many times larger than those used in conventional electrical tomography. A key element will also be the creation of an advanced simulation environment that will enable the generation of large training datasets for network learning.

By combining precise hardware, intelligent measurement methods, and modern data processing approaches, we expect a major breakthrough in ECT image quality. The resulting images should allow for the distinction of much smaller structures than previously possible, which may lead to more accurate monitoring of industrial processes and better diagnosis and patient care in clinical practice. Importantly, all developed tools will be made available under open science principles, enabling further development and practical implementation in both research and industrial settings.