Biomedical Imaging Based on Electrical Capacitance Volume Tomography
Company Profile

Total Staffs: 130 person
Total R&D Staffs: 30 persons (25%)
PhD and Ms = 30% of total R&D staffs;
Internship students: 25 (PhD 3, MS 8, BS 15)
R&D Budget: 20-30% of turnover

R&D Divisions

- Basic Research Divisions
  - Electronic Science and Technology
  - High Performance Computing and Software Engineering
  - Sensors Technology (Ultrasound, Electromagnetic Wave, Capacitance, Impedance)
  - Biophysics and Bio-molecular
- Applied Research Divisions
  - Non Destructive Testing
  - Industrial Process Imaging
  - Medical Physics and Biomedical Imaging
  - Cancer Clinical Research
1. Center for Electronics Science and Technology
   Analog Sensor Circuits; Signal Conditioning; Data Acquisition System; Mechatronics and Automation

2. Center for High Performance Computing
   Signal and Image Processing; Image Reconstruction; Acoustic Field Computation; Electromagnetic Field Computation; Sensor Design; Software Analysis and Development

3. Center for NDT and Process Imaging
   Magnetic Induction Tomography; Acoustic Imaging; Neutron Tomography; ECVT; Computational Fluid Dynamics (CFD); CFD—ECVT

4. Center for Medical Physics and Cancer Research
   Bio-Physics Laboratory; Bio-Medical Imaging Laboratory; Computational Medical Physics; Cancer Research

5. Cancer Research Clinic
   Clinical research of medical devices for diagnostics and therapy in collaboration with Indonesian Institute of Health

1.2tflops computer machine for 4D brain chaos imaging analysis and other high performance computing applications
What Is Tomography?

Tomography is a technique used to produce a 'slicing' image of cross-sections of an object through image reconstruction from signal data of numerous sensors located on the surface of the object at different angles.

Hospitals need different types of tomography imaging system to differentiate illness from healthy tissues for diagnostic purposes. There are various numbers of tomography modalities based on the sensor used ranging from electromagnetic emission, ultrasound to electrical properties measurement. Examples of tomography techniques are the well-known CT-Scan, magnetic resonance imaging (MRI) and positron emission tomography (PET).

PET—CT: Image fusion readily localized tumor location in the spleen (arrow) in this patient with lymphoma (green arrowheads indicate normal physiologic activity in the bowel and kidney).

RIGHT: PET image to visualize physiological function of human body; LOWER: MRI Image of human brain

MRI machine using 3 Tesla of magnetic field
Principles of ECVT

Electrical Capacitance Volume-Tomography (ECVT) is a volumetric tomography technique based on electrical capacitance measurement. This new system, developed by Warsito et al, (IEEE Sensors Journal, 2007) has revolutionized and replaced the classical two-dimensional ‘slicing’ technique of tomography imaging. For the first time, ECVT has enabled real time, 3-dimensional imaging of a moving object and real time volume imaging (4-dimensional). This unprecedented advancement has allowed for total integration of complete volumes within the sensing domain.

ECVT for biomedical imaging are using very low electrical field of less than 15V of voltage source transmitted from the transmitter electrodes, which is highly safe to human body and environmentally friendly. The high speed capability requires only seconds to fully scan the whole objects.

ECVT system consists of sensor system, data acquisition system and computer system for control, image reconstruction and display.

ECVT Principle

STEP 1: Capacitance measurement between pair of electrodes arranged in arbitrary 3D orientation utilizing soft-field nature of fringing electrical field. The measurement is performed between two electrodes where the capacitance varies with the distance between them.

STEP 2: Reconstructing 3D permittivity distribution within sensor domain from capacitance data using soft-computing algorithm. The algorithm calculates the inverse of the capacitance matrix to obtain the permittivity distribution.

\[ C = \oint \frac{\varepsilon \cdot \hat{n}}{\Delta V} d\Gamma \]

\[ \varepsilon \leftarrow F^{-1}[C'] \]
ECVT Brain Scanner offers a low-cost, radiation-free, instantaneous detection of physiological abnormalities in the brain caused by tumors, epilepsy, Alzheimer's Disease and other brain dysfunctions. The technology opens new possibilities for neuroscience researches and other applications.
ECVT Image of Brain Activity

RIGHT: ECVT image of normal brain activity showing high electrical activity on the whole cortical surface of the brain; LOWER RIGHT: ECVT image of abnormal brain activity of a patient suffered from brain tumor indicated by the MRI image (LOWER LEFT); the ECVT image is showing low electrical activities of the brain on both the left (especially) and right frontal regions of the brain that are mainly related to visual functions, and both right (especially) and left cerebellum that are related to motoric functions.
4D ECVT Brain Activity Scanner

Electrical Capacitance Volume Tomography (ECVT) has been applied, for the first time, to image the activity of human brain during different stimulations. Electrical signals measured from capacitance electrodes showed significant differences when the brain is in rest and in high task. The ECVT generates real time and volumetric image of the human brain during the activity, that helps study of human brain function and possibly detect abnormalities in the brain.

**METHOD**

**STEP 1:** Capacitance Measurement

\[
\nabla \cdot \varepsilon \mathbf{E} = \rho (\mathbf{r}, t); \\
\varepsilon_{\text{eff}} (\mathbf{r}, t) = \varepsilon_0 (\mathbf{r}) + \varepsilon_1 (\mathbf{r}, t) \\
\varepsilon_0 = \text{brain permittivity} \\
\varepsilon_1 = \text{brain electricity} \\
C = \oint_{\Gamma} \frac{\varepsilon \mathbf{E} \cdot \mathbf{n}}{\Delta V} d\Gamma \\
\]

**STEP 2:** 3D Image Reconstruction

\[
C \Rightarrow \varepsilon \quad (\text{Inverse Problem}) \\
\]

Sensor Design

Electrical signal monitoring of human brain during different stimulations

Image Courtesy: Prof. Tariq Durrani (IEEE Presidency Candidate)

Map courtesy: FMOE 3.36055E-001

LEFT: Normal brain activity map; ABOVE: MRI Image of the brain

ABOVE: Extracted images of human brain activity during moving right and left hands; BOTTOM: Brain activity image of patient with brain tumor with corresponding MRI image
ECVT Brain Scanner: Detecting Tumors

The images of MRI (left) & ECVT (right) for Ependymoma case: showing mass in left frontal lobe (MRI) and low brain activity in left frontal lobe and occipital lobe and cerebelum (ECVT).

The images of MRI (left) & ECVT (right) for Oligodendrogliaoma case: Showing mass in left temporal lobe (MRI) and low brain activity in left frontal and temporal lobes (ECVT).

The images of MRI (left) & ECVT (right) for Craniopharyngioma case: showing mass at the position of optic chiasum (MRI) and low activity of both left and right frontal lobes and occipital lobe (ECVT).

The image of MRI (left) & ECVT (right) for Cerebellopontine angle tumor case: Showing in cerebelum (MRI) and low brain activity in occipital lobe and cerebelum (ECVT).
WORLD’S FIRST

ECVT Breast

4D BREAST CANCER SCANNER

ECVT requires only seconds, radiation free, to scan whole breast to find abnormalities within the breast caused by malignant cancers, benign tumors or simple cysts without performing biopsy.
The ECVT differentiates malignant breast cancers from benign tumors and simple cysts based on differences in the permittivity value of the reconstructed images. The study shows a demarcation value of maximum normalized permittivity which is regarded as Cell Electrical Activity Index (CEAI) or MALIGNANCY INDEX of 0.3 to classify the malignant cancers from benign tumors and simple cysts. The ECVT is more sensitive to detect malignant cancer than simple cysts or benign tumors.
Mammography and USG are used as golden standards for breast cancer examination in clinical practices, ECVT provides 3D images of the breast in great conformity with the golden standards.
ECVT images of breast tumors show physiological abnormality of the electrical activity generated by the tumor, in conformity with FDG activity in the image of PET—CT. RIGHT: Images of malignant breast cancer and benign tumor obtained using mammography and ECVT.
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WE have strong networking with universities, research institutions, scientific societies and industrial consortium world wide. The network is an effective media for marketing and accessing the most frontier and state-of-the-art advancement of the technology and products. Participations in international conferences, publication in international journals and joining with international communities are thus very important factors to succeed the goals of the research center.
Beyond C++

Capacitive & Computation Technologies

To C (‘See’), Cure & Care

Cancer & beyond

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