UNIVERSITY OF EASTERN FINLAND

Computational physics and inverse problems research

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Finnish Centre of Excellence in Inverse Modelling and Imaging 2018-2025

COMPUTATIONAL PHYSICS AND INVERSE PROBLEMS (33)

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2018-2025

CENTRES OF EXCELLENCE IN RESEARCH

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FINNISH METEOROLOGICAL INSTITUTE

Aalto University

WHAT ARE INVERSE PROBLEMS

Inverse problems:

The aim is to calculate estimates for parameters that cannot be directly observed, e.g., mercury-in-glass thermometer

Forward problem:

CAUSE → EFFECT, $m = A(\theta; I) + n$

- Well-posed, easy to solve

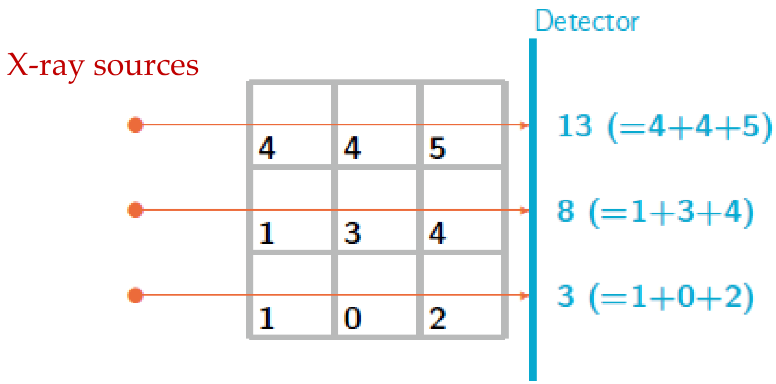
Inverse problem:

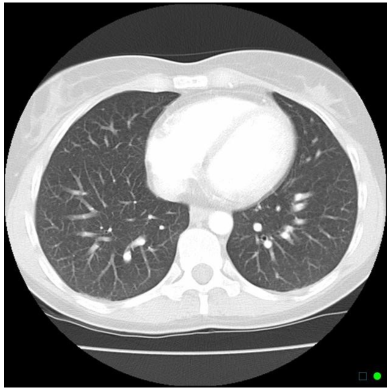
EFFECT → CAUSE, $\theta \approx A^{-1}(I; m)$

- Ill-posed, difficult to solve

Aim in our research:
To develop mathematical models and computational methods for solving inverse problems arising from challenging real-world applications

Tomographic imaging, X-ray CT

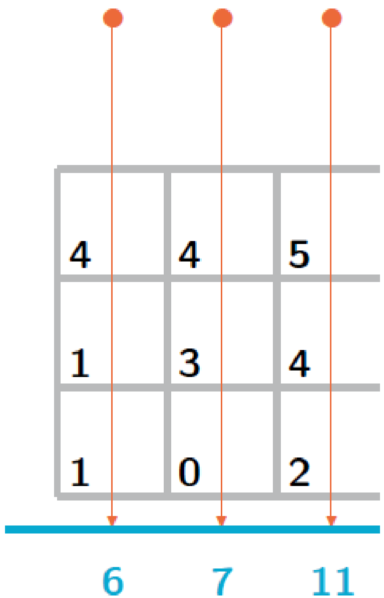


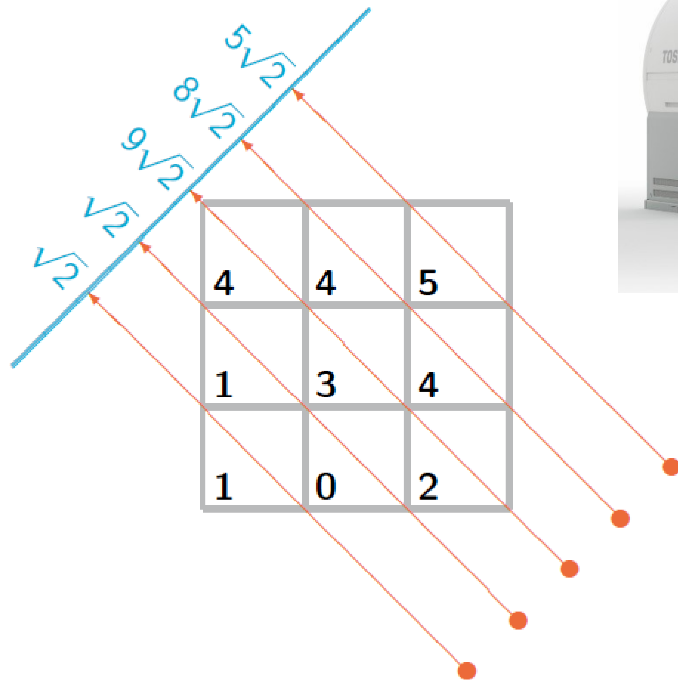


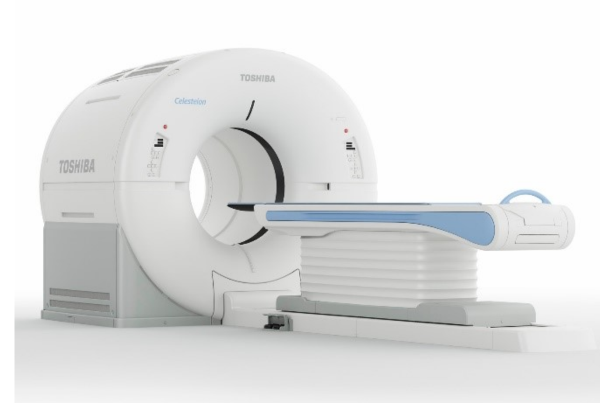
X-ray CT image

Projection image (X-ray image)

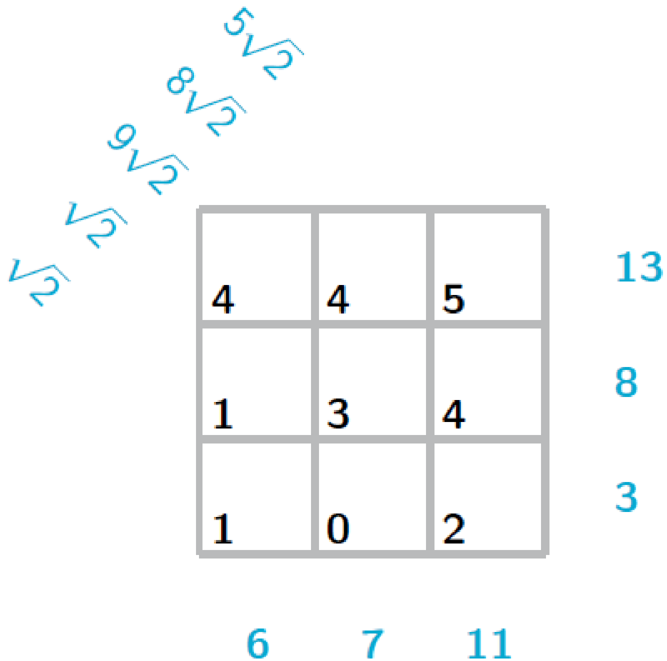
Several projections are needed for tomographic image

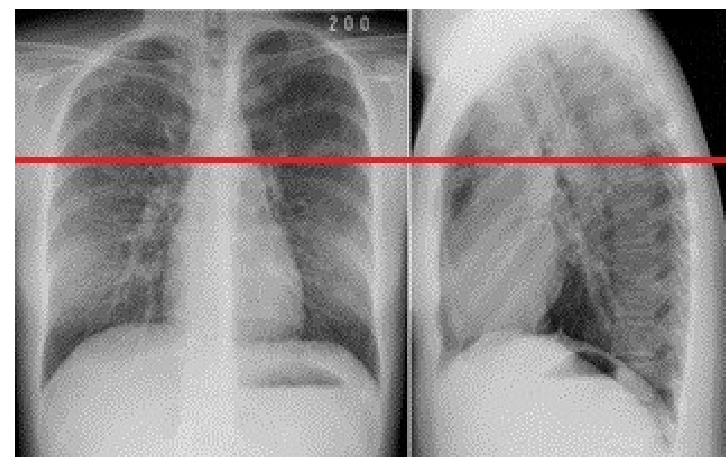




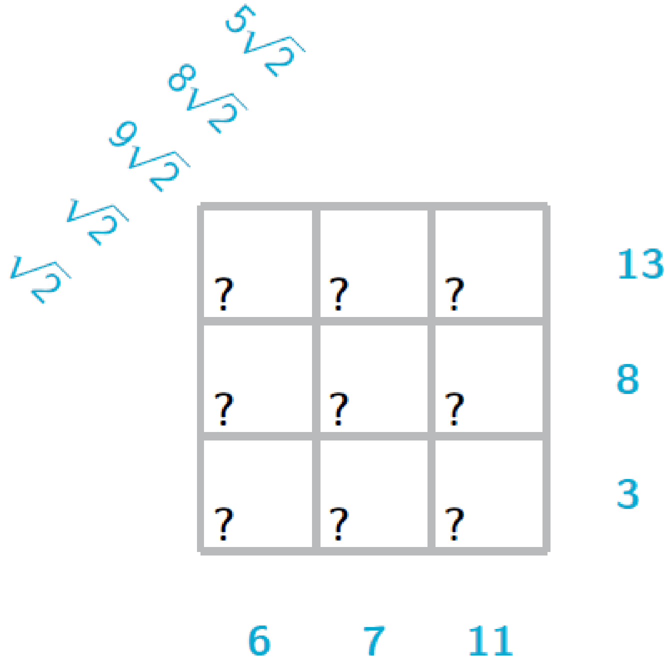


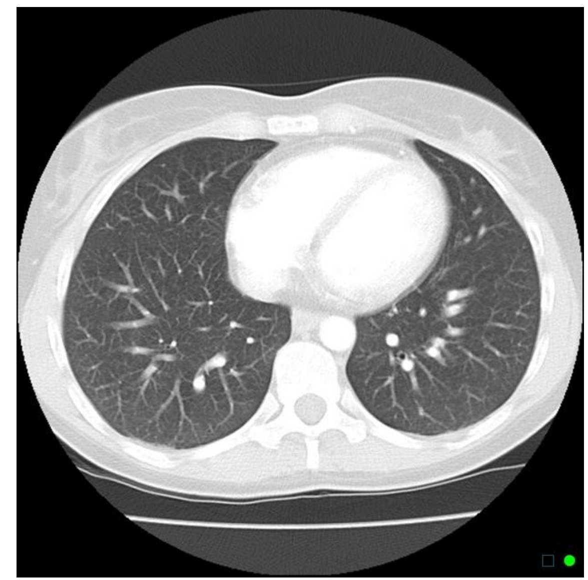
Forward problem: Compute the projection images when the X-ray source and the internal attenuation cofficients are known





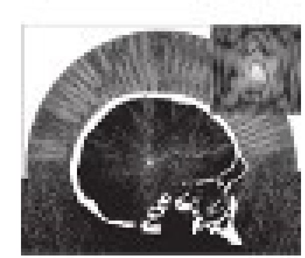
Inverse problem: Projection images (transmitted X-rays) are measured, estimate the attenuation coefficients





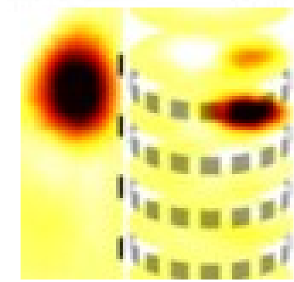
APPLICATIONS

Biomedical inverse problems



- CT, MRI, PET, SPECT, hybrid medical imaging, optical imaging, imaging using coupled physics, biomedical electrical impedance tomography, ultrasound tomography and therapy

Industrial inverse problems



- Process tomography (EIT, ECT, MWT, EMFT), non-destructive testing, thermal tomography, ultrasound tomography

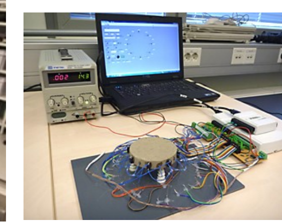
Inverse problems in geosciences and in atmospheric sciences

- Seismic imaging, remote sensing
- Atmospheric inverse problems

Miscellaneous distributed parameter estimation problems

- Acoustics and electromagnetic modelling

INFRASTRUCTURE



Tomographic imaging laboratory

- Process tomography, non-destructive testing, medical imaging
- Eight EIT/ECT imaging systems
- Electromagnetic flow tomography system
- Prototype thermal tomography setup

Optical and acoustic instrumentation

- Prototype instrumentation for photoacoustic and acousto-optic tomography

Other infrastructure available through collaborators (KUH, AIVI, international collab.)

Flow loop in test; water-air flow imaging

Electromagnetic flow tomography (EMFT)

- In EMFT, two pairs of coils and 16 electrodes are used.
- The aim is to reconstruct the velocity field based on the boundary voltage measurements created with applied ***B***-fields and the flowing conductive fluid.

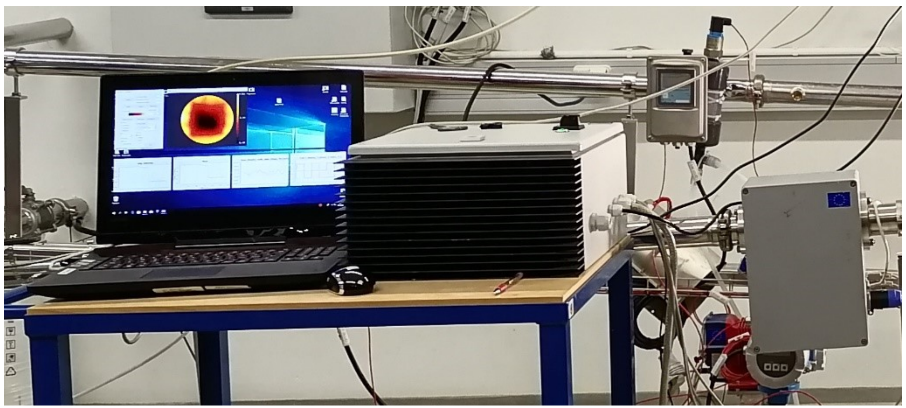


Fig 1. (a) The EMFT device.

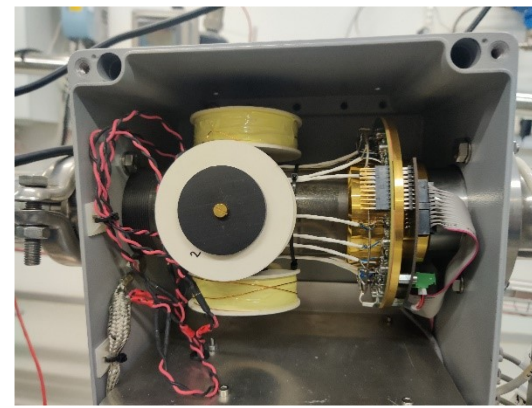


Fig 1. (b) EMFT sensors.

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Results, symmetric single-phase flows…

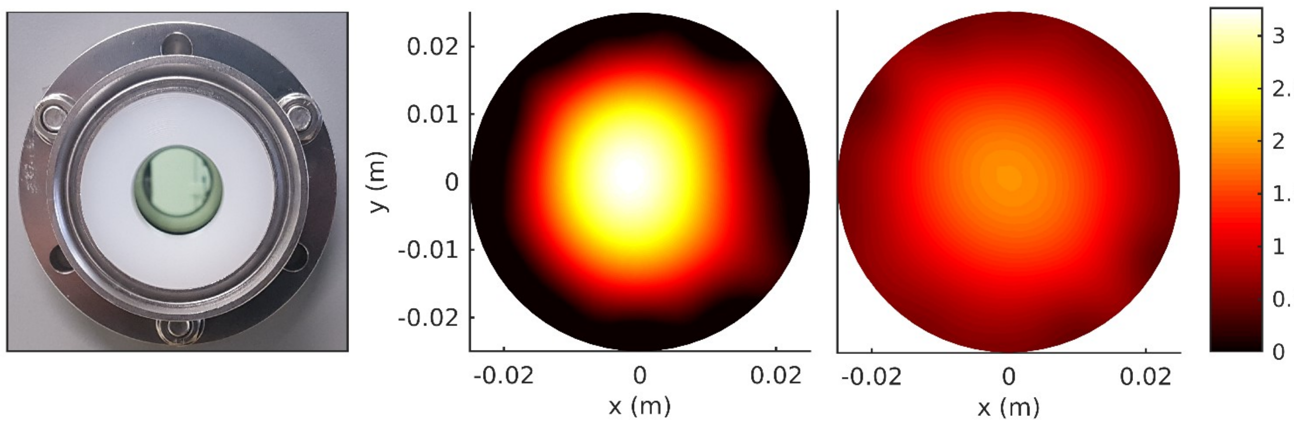


Figure 2. The pipe with a hollow cylinder. Middle: The flow field reconstruction with the block inside the pipe. Right: The flow field reconstruction without the blockage.

…and asymmetric single phase flow

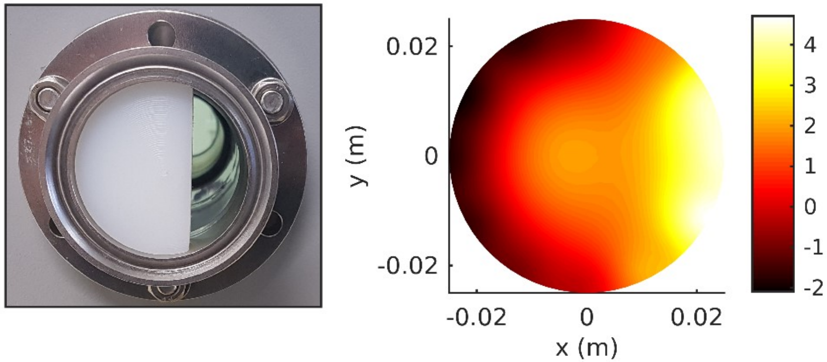


Figure 3. The pipe with a piece of plastic blocking 2/3 of the pipe diameter. Right: The flow field reconstruction with the blockage.

Electrical Tomography (ET)

- ET has two rows of sensors with 16 equally spaced stainless steel electrodes on each row.
- The aim is to reconstruct first the conductivity distribution and from that the phase fraction distribution of the two-phase flow.

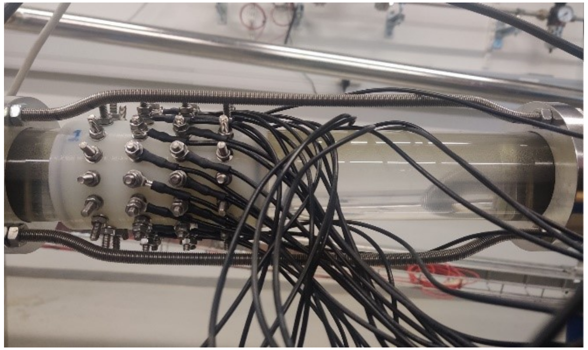


Fig 3. (a) ET sensors.

Fig 3. (b) ET device.

Experimental validation

Visualization planes of the estimates

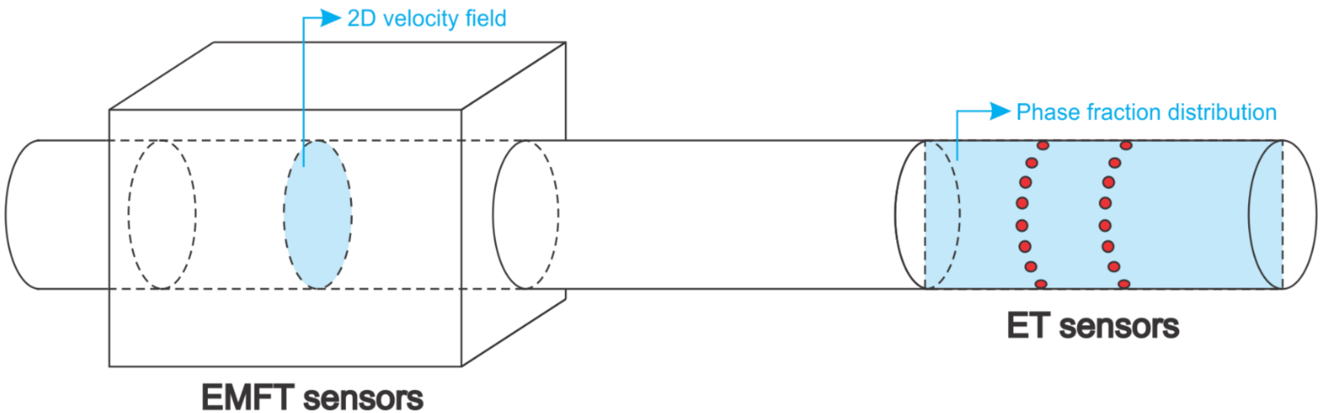


Fig 15. Visualization planes of the phase fraction distribution and velocity field.

Experimental validation

The flow loop facilities: the Electrical Tomography Laboratory at UEF

a) Camera 1
b) Ultrasound flow meter device (UFM)
c) UFM sensors
d) Laptop for EMFT
e) Electronics of EMFT
f) EMFT sensors
g) ET sensors
h) Back-light
i) Camera 2
j) Laptop for ET
k) Electronics of ET
l) Vertical pipe segment

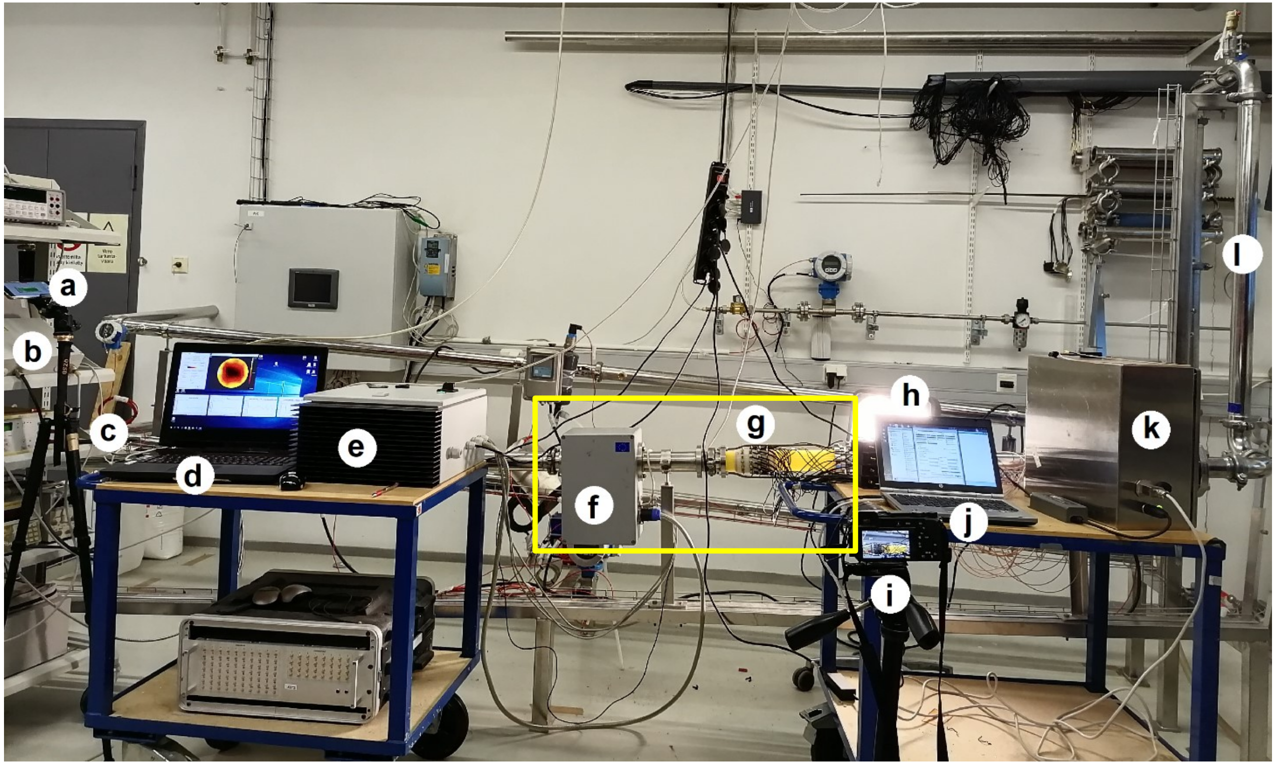


Fig 14. The flow loop facilities.

Results (Experimental validation)

Case 1: 10% oil fraction with all stationary average velocity.

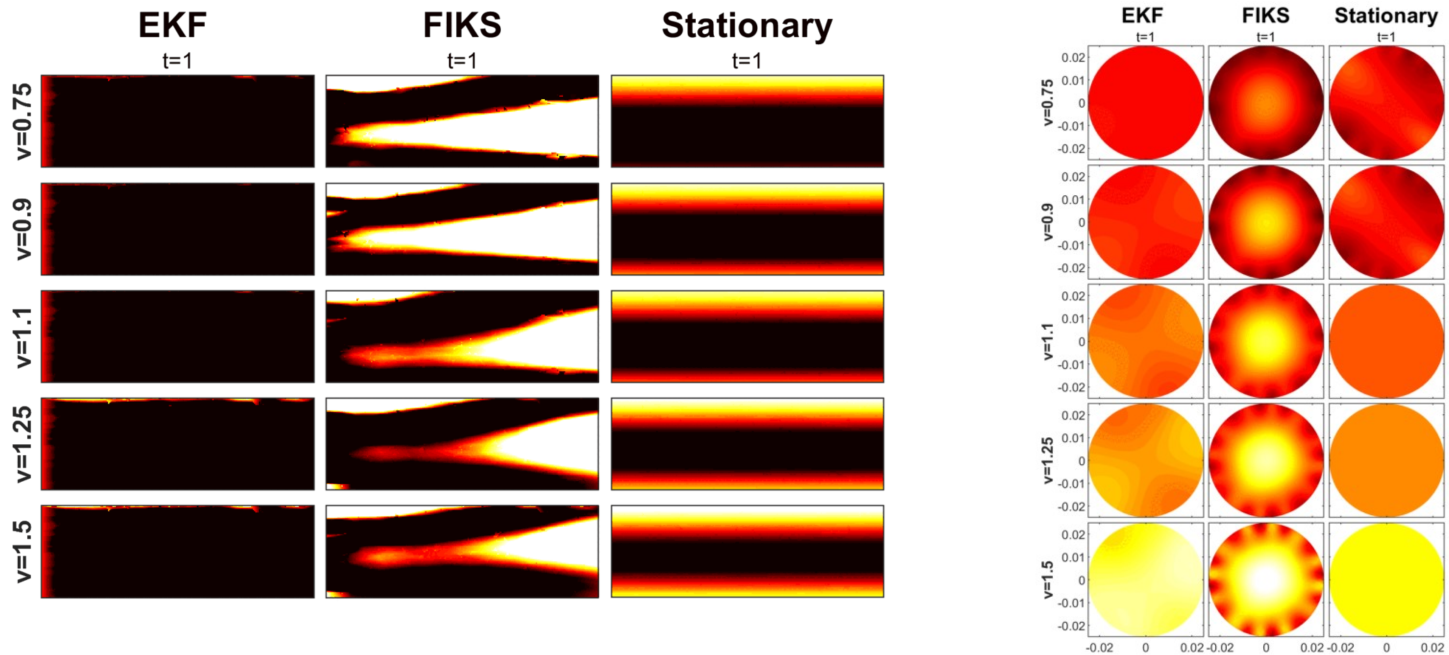
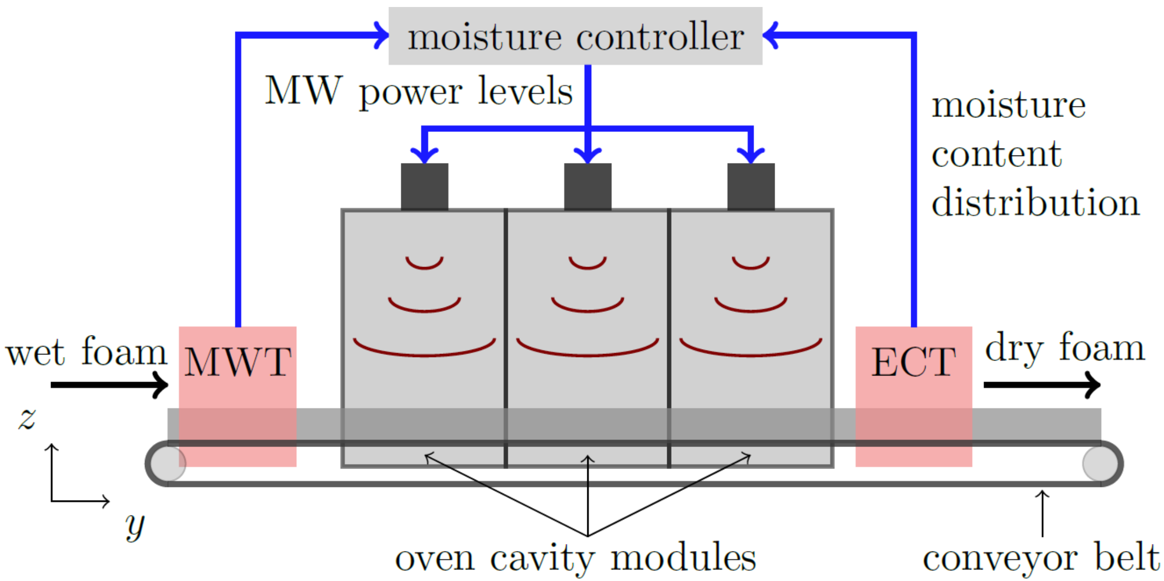


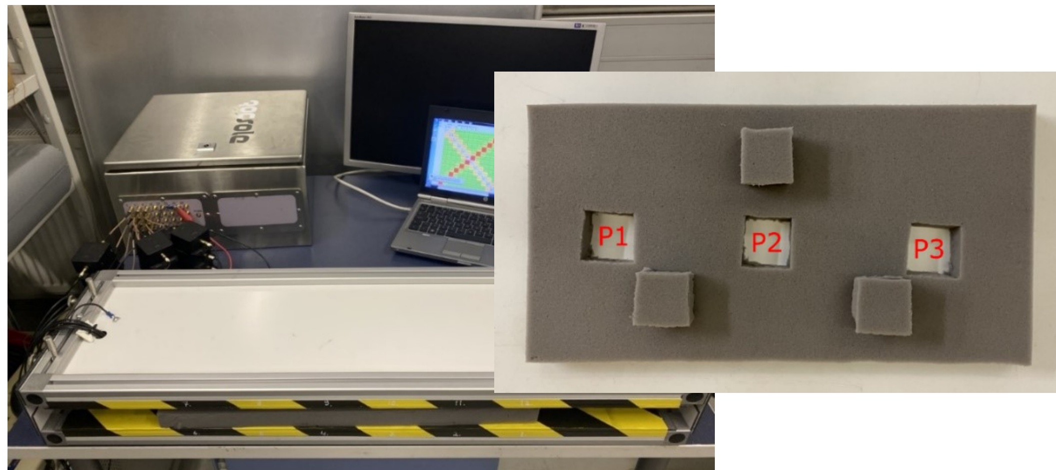
Fig 16. Temporal evolution of 10% oil fraction distribution with all stationary average velocity (left) and velocity field (right) of all approaches.

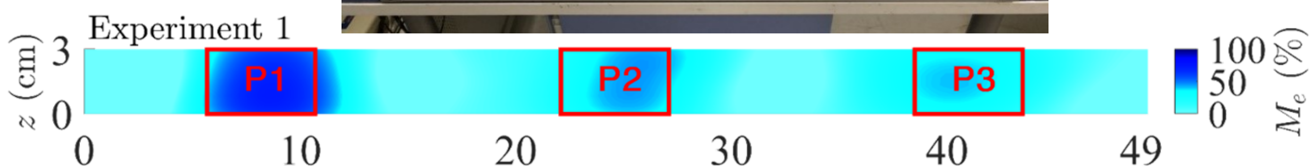
Mikroaaltokuivatuksen säätö käyttämällä tomografista kuvantamista (ECT ja/tai MWT)



Kapasitanssitomografialla ja/tai mikroaaltotomografialla mitataan kuivatettavan kappaleen (vaahtomuovi) kosteusjakauma ja tätä tietoa hyödynnetään säädettäessä kuivatuksen tehoa. Ulostulevan kappaleen kosteusjakauma saadaan halutunlaiseksi.

ECT-sensori vaahtomuovin kosteusjakauman mittausta varten





ECT-rekonstruktio epätasaisesta kosteusjakaumasta, jossa kappaleen P1 kosteus on kaksinkertainen verrattuna kappaleisiin P2 ja P3.

Esimerkki PI-säätäjästä

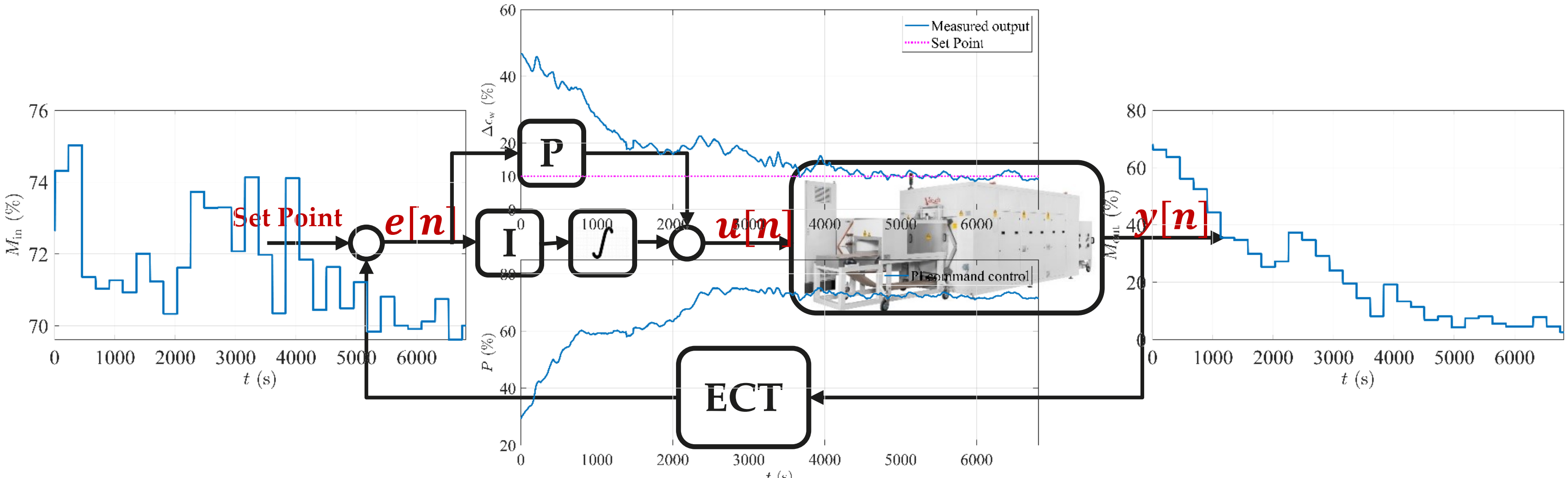
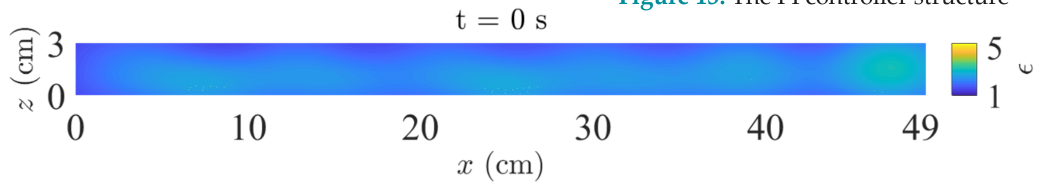


Figure 13: The PI controller structure



Thank you!

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