Computational Magnetic Resonance Imaging

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Die CovPassCheck-App

MRI in the 1970/1980s

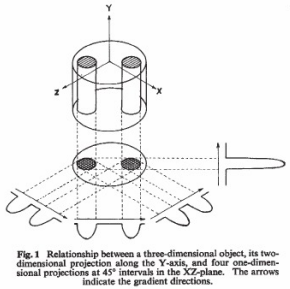
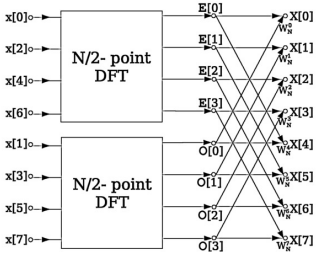
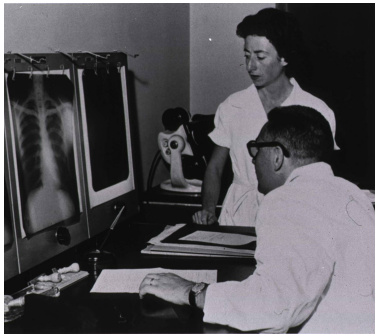


Fig. 1 Relationship between a three-dimensional object, its two-dimensional projection along the Y-axis, and four one-dimensional projections at 45° intervals in the XZ-plane. The arrows indicate the gradient directions.





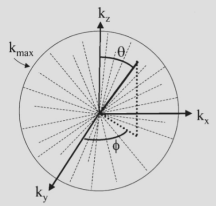
Cooley, Tukey 1965

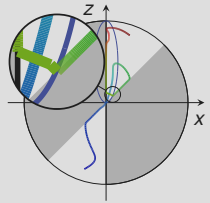
Lauterbur 1973

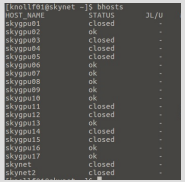
MRI today

Lustig 2007
Johnson 2008
Asslaender 2019

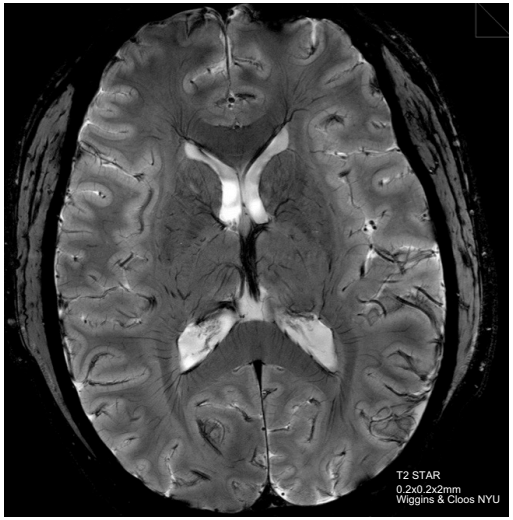
Computational Imaging







$$\min_u \frac{\lambda}{2}||Au - f||_2^2 + \mathcal{R}(u)$$



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First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole

The Event Horizon Telescope Collaboration
(See the end matter for the full list of authors.)

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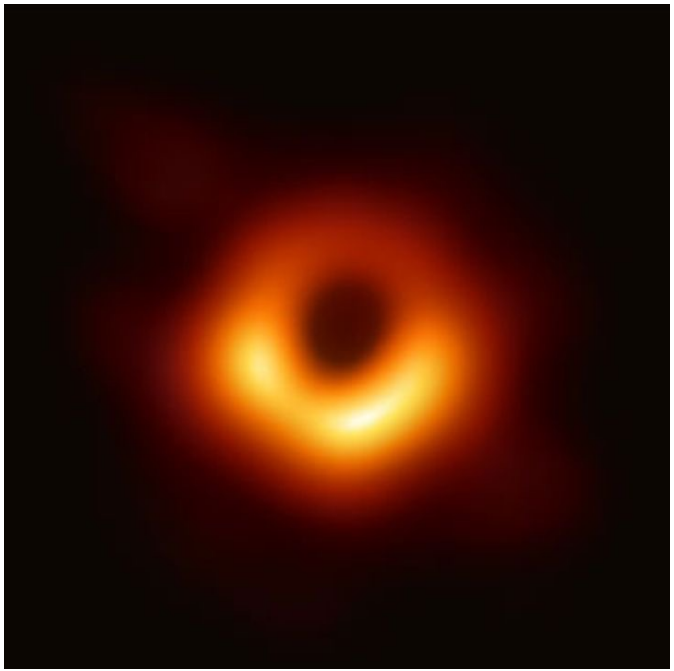
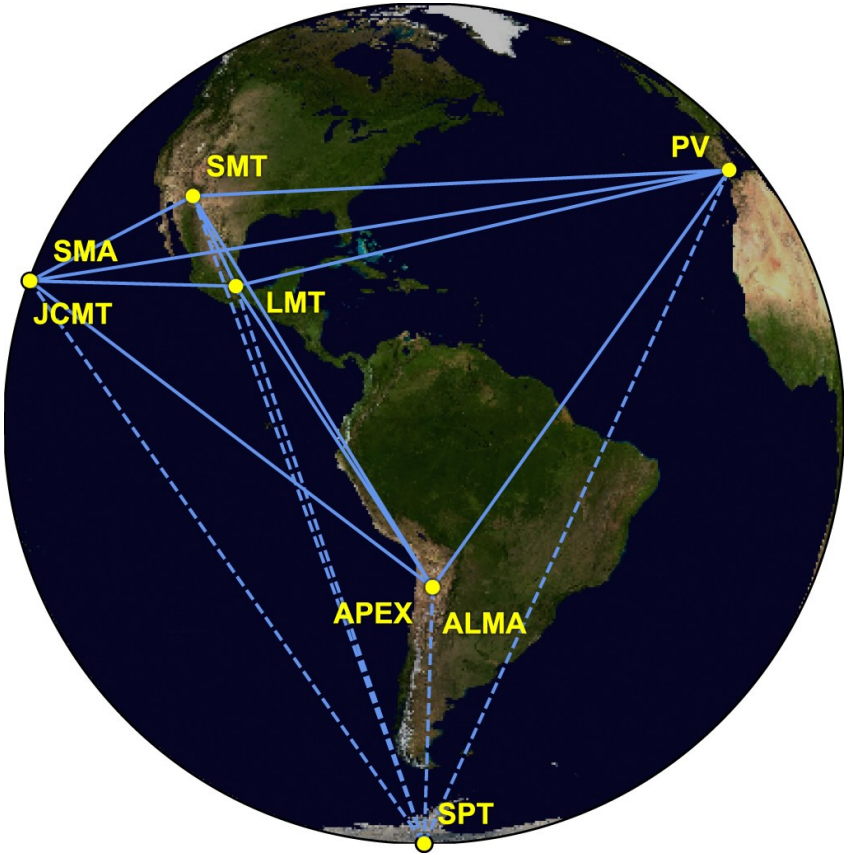


EHT


SMT
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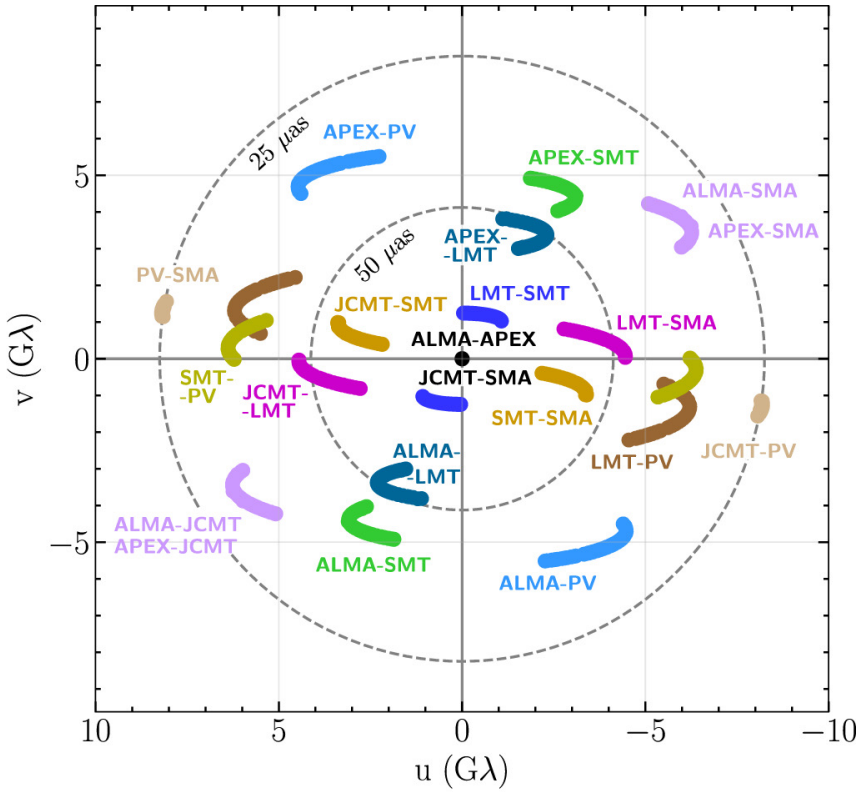
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APEX-JCMT
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ALMA-PV
v (Gλ)
u (Gλ)
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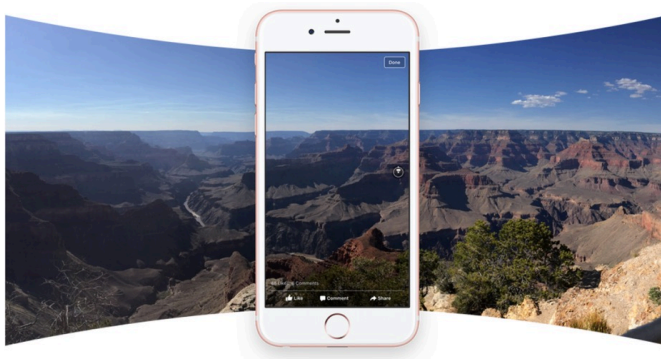
5
0
−5
−10

HDR (high dynamic range)

Google Pixel 3 night vision

Portrait mode

Panorama



apple.com

MR data acquisition: Fourier (k-) space

$$f_k(k_x, ky) = \int\int c_k(x, y) e^{-i(k_x x + k_y y)} u(x, y) dxdy$$

$$f_k(k_x, ky) = \sum\sum c_k(x, y) e^{-i(k_x x + k_y y)} u(x, y)$$

$$f = Au$$

Image reconstruction

$$f = Au$$

Forward problem

$$u = A^{-1}f$$

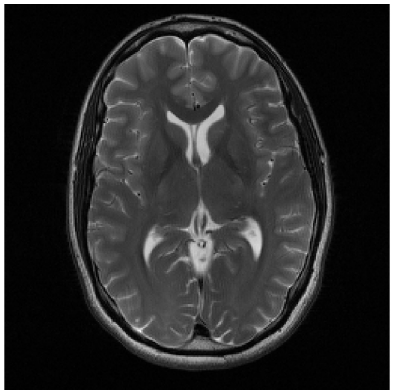
Inverse problem

$$\min_u \|Au - f\|_2^2$$

Numerical optimization

$u = A^{-1}f$ →

← $f = Au$



Course structure

Lecture:

MO 10:00 to 11:30, room 01.030 – Seminarraum

No lecture November 1st: Holiday

Exercise:

MO 10:00 to 11:30, room 01.030 – Seminarraum

No exercise November 18th: Departmental retreat

Modules and Instructors

1. Fundamentals of MRI
2. Fourier image reconstruction basics
3. Partial Fourier imaging
4. Non-cartesian image reconstruction
5. Image space parallel imaging
6. k-Space based parallel imaging
7. Non-cartesian parallel imaging and iterative reconstruction
8. Compressed sensing
9. Machine learning in MRI and neural network design
10. Training neural networks with backpropagation
11. Machine learning for MR image reconstruction

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Prerequisites

Courses:

Medical Engineering 2 (Prof. Dr. Andreas Maier)

Magnetic Resonance Imaging 1 (Prof. Dr. Frederik Laun)

General:

Programming: Preferable Matlab and/or Python

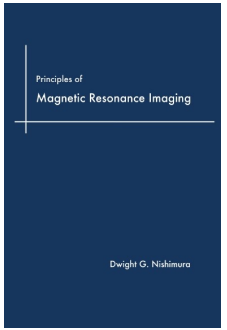
Linear algebra

Signal processing (Fourier transform)

Literature

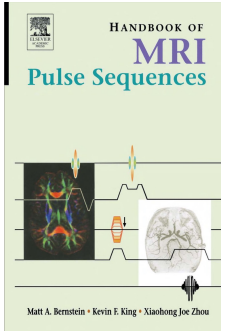
Z.P. Liang. Constrained Reconstruction Methods in MR Imaging. http://mri.beckman.illinois.edu/resources/liang_1992_constrained_imaging_review.pdf

D. Nishimura. Principles of Magnetic Resonance Imaging. https://www.lulu.com/en/us/shop/dwight-nishimura/principles-of-magnetic-resonance-imaging/paperback/product-1nqdq4j2.html?page=1&pageSize=4



M. Bernstein. Handbook of MRI Pulse Sequences.

https://www.amazon.com/Handbook-Pulse-Sequences-Matt-Bernstein/dp/0120928612



Misc. Papers

Exam/Grading

30min oral exam at the end of the course, one week between last lecture week

Jan 31st, Feb 3rd, Feb 7th, Feb 10th (slots first come first serve)

Two topics each, first you can choose yourself: 0-25 points per question

Grade scale:
1: 95%+
2: 85%-94%
3: 75%-84%
4: 60%-74%
5: 0%-59%

Labs

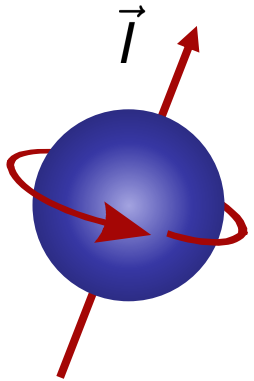
Programming and some analytical exercises. Matlab or Python suggested

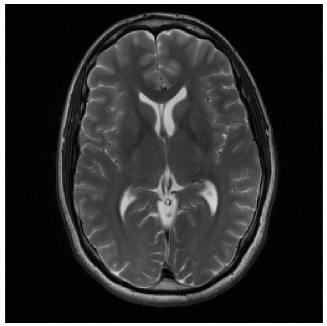
Bonus points for grade: 5 points per lab (55 points in total)

Lab reports due one week after lab session, on Wednesday 23:59

Maximum number of points decreases by one for each 24 hours after the deadline

Next week





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