Bakk::Mas Day 2024

Martin Uecker
Institute of Biomedical Imaging

Forschungsschwerpunkte des Instituts

Methodische Weiterentwicklung Magnetresonanztomographie

Schwerpunkte:

- Schnelle Bildgebung (Echtzeit-MRT, etc.)
- Quantitative Bildgebung (Relaxometrie, Flussmessungen, etc.)
- Hardware (Niedrigfeld-MRT)

MRI LAB Graz , 3T MRT-Scanner

Forschungsschwerpunkte des Instituts

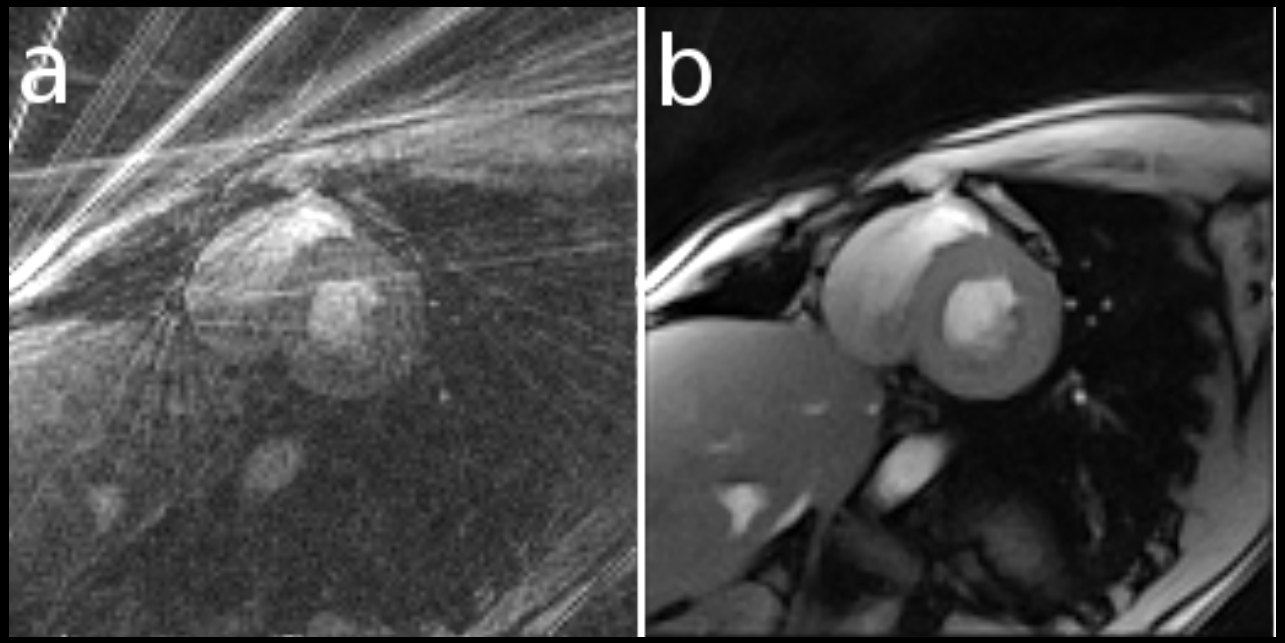
Methodische Weiterentwicklung Magnetresonanztomographie

Schwerpunkte:

- Schnelle Bildgebung (Echtzeit-MRT, etc.)
- Quantitative Bildgebung (Relaxometrie, Flussmessungen, etc.)
- Hardware (Niedrigfeld-MRT)

MRI LAB Graz , 3T MRT-Scanner

MRT Neue Rekonstruktionsmethoden



Konventionelle vs. iterative Bildrekonstruktion

Bildrekonstruktion als Inverses Problem

Generisches mathematisches / konzeptionelles Framework

Modellierung des Problems (Bild $\Rightarrow$ Daten)

$$y = Fx + n$$

Messdaten y, Vorwärtsmodell F, Bild x, Daten n

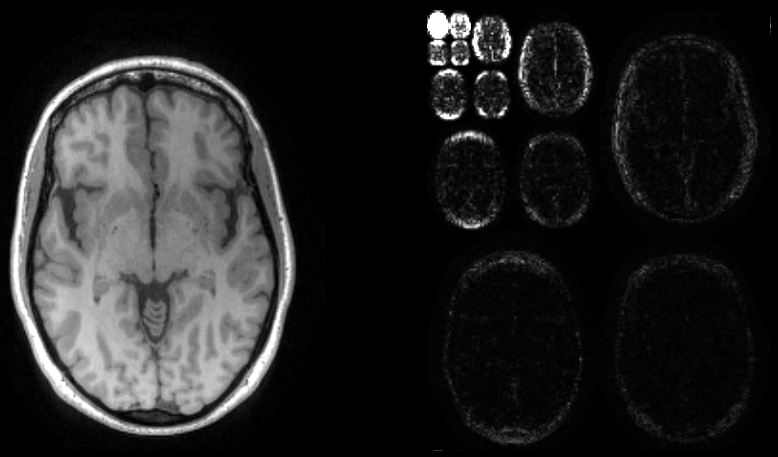
Regularisierte Lösung (Daten $\Rightarrow$ Bild)

$$x^\star = \operatorname{argmin}_x \quad \underbrace{D(Fx, y)}_{\text{Datenkonsistenz}} \quad + \quad \underbrace{\alpha R(x)}_{\text{Regularisierung}}$$

Vorteile:

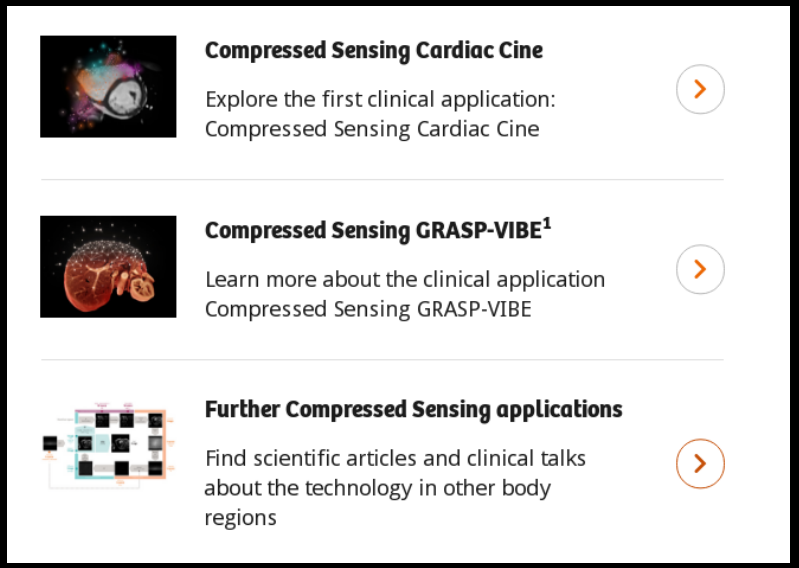
- Berücksichtigung von allen relevanten physikalischen Effekten (Modell F)
- Vorwissen mit Regularisierungstermen (R)

Compressed Sensing



Bildkompression mit Wavelets
(z.B.: JPEG 2000)

- **Ziel:** schnellere Scans
- Vorwissen:
  Komprimierbarkeit der Bilder
- Inkohärentes Abtasten
  der Daten



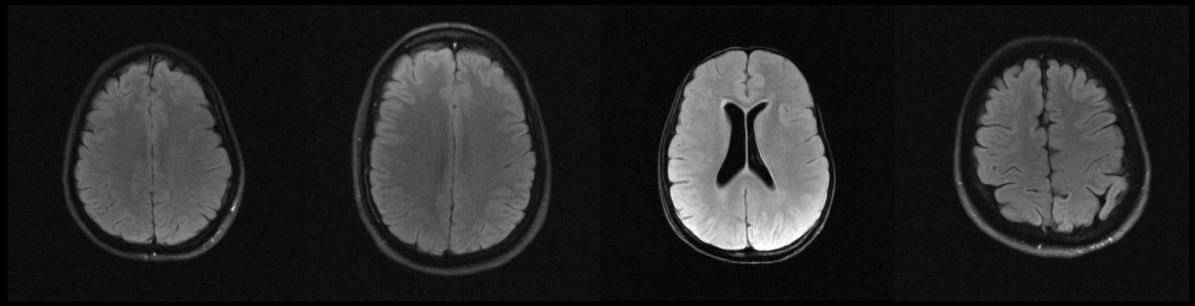
Erste Produkte in 2017

1. Block, Uecker, Frahm. Magn Reson Med 57:1086–1098 (2007)
2. Lustig, Donoho, Pauly. Magn Reson Med 58:1182–1195 (2007)

Bildrekonstruktion mit Deep Learning

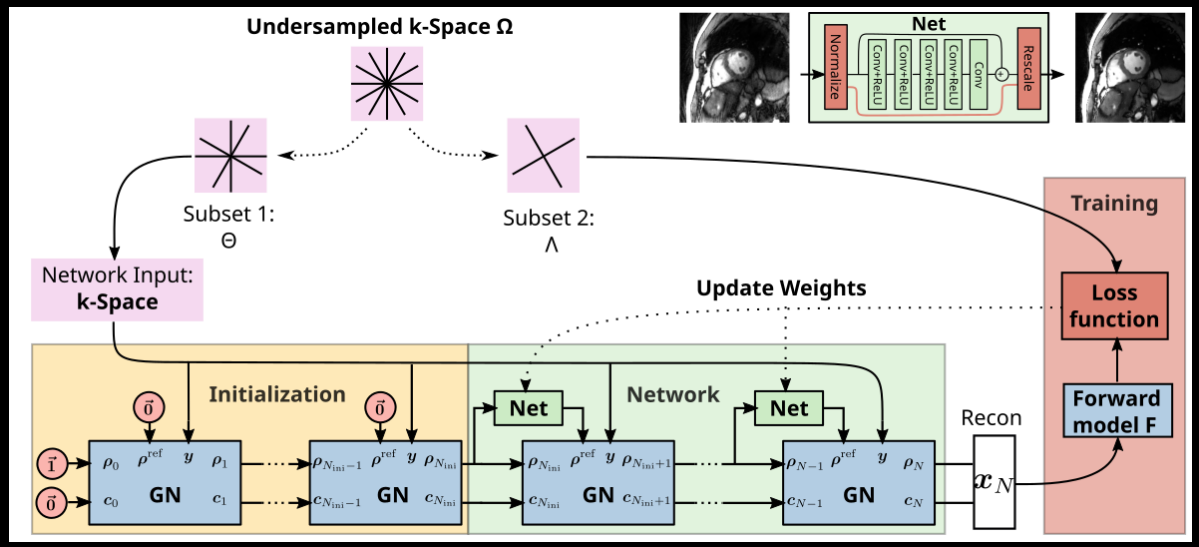
Zwei Forschungsrichtungen:

- Generative Modelle als Vorwissen



Künstliche MRT-Bilder aus generativem AI-Modell.

- Selbstüberwachtes Lernen (Echtzeit-MRT, Quantitative MRT)



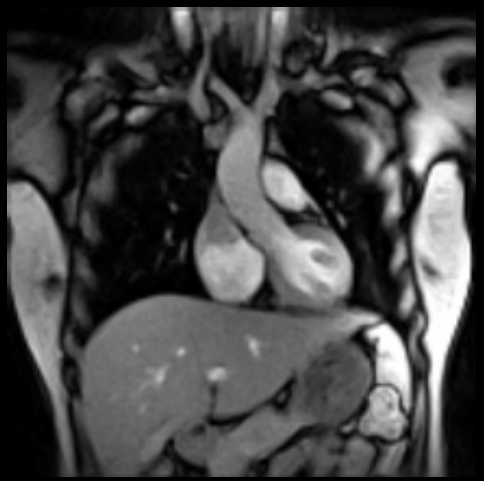
Prinzip selbstüberwachtes Lernen für Echtzeit-MRT

Echtzeit-MRT

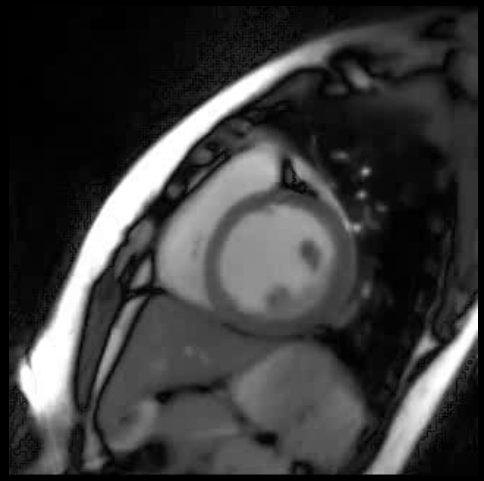
- Effiziente radiale Messsequenzen
- Vorwissen über zeitliche Redundanz

$\Rightarrow$ **2D Echtzeit-Bildgebung (20 - 100 Hz)**

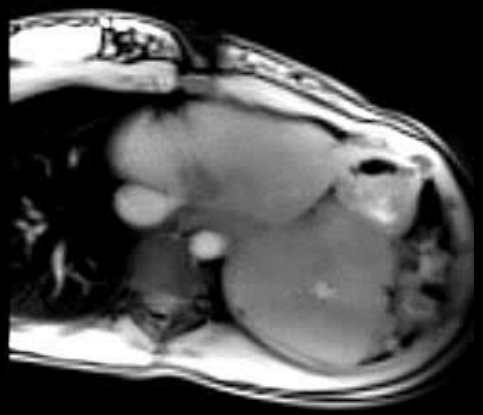
GPU Rekonstruktion



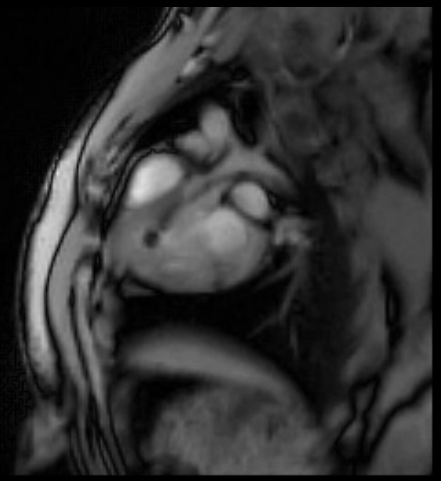
freie Atmung



Arrhythmien

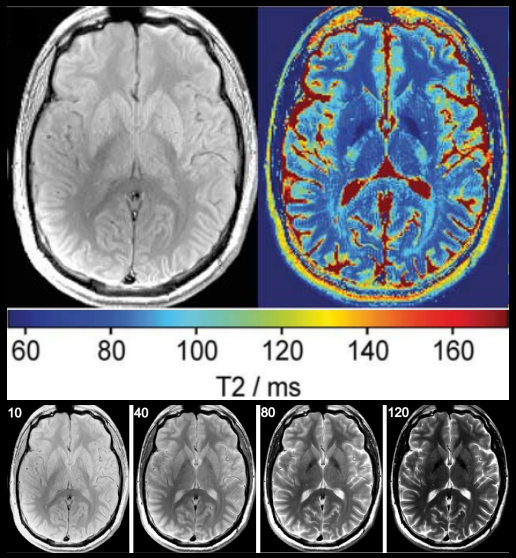


Schlucken

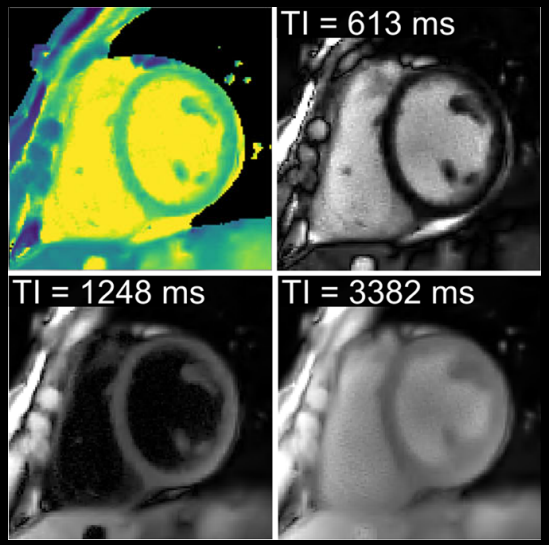


Myokard-Biopsie[3]

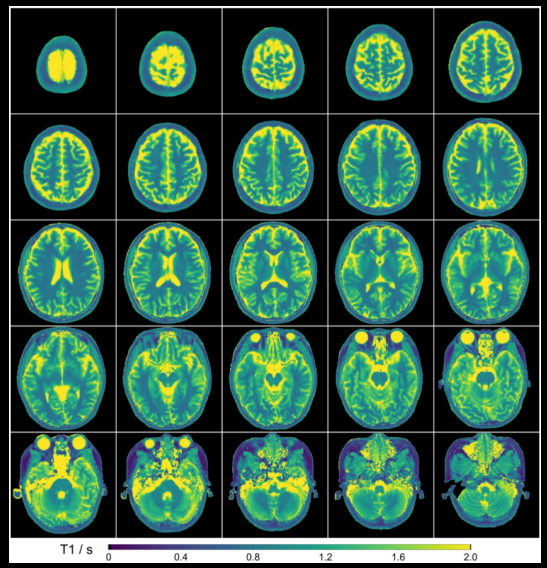
Quantitative MRT



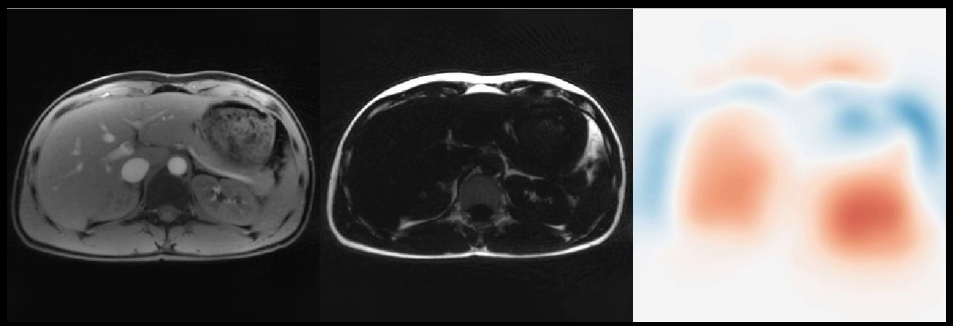
PD and T2 map of the brain and synthetic images (ME-SE, TA = 96s)[1]



T1 of the myocardium and synthetic images (radial IR-FLASH, TA = 4s)[2]



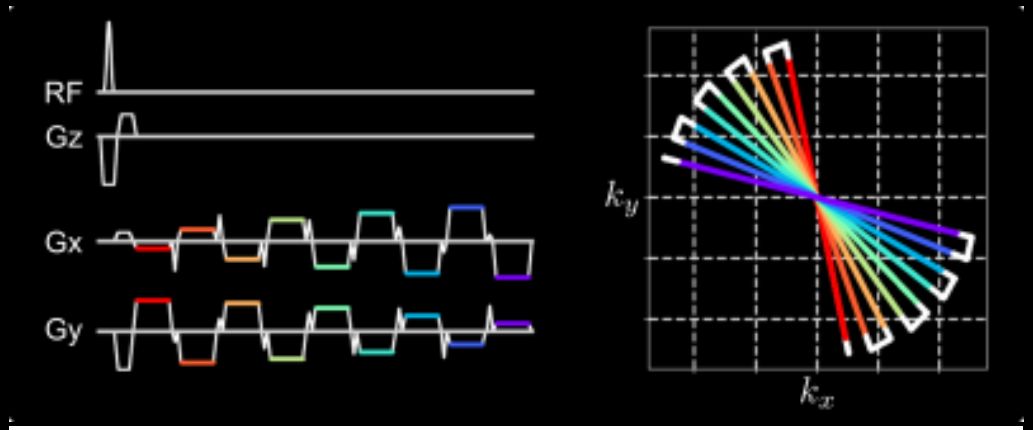
25 T1 of the brain (5x radial 5-SMS IR-FLASH, TA = 60s)[3]

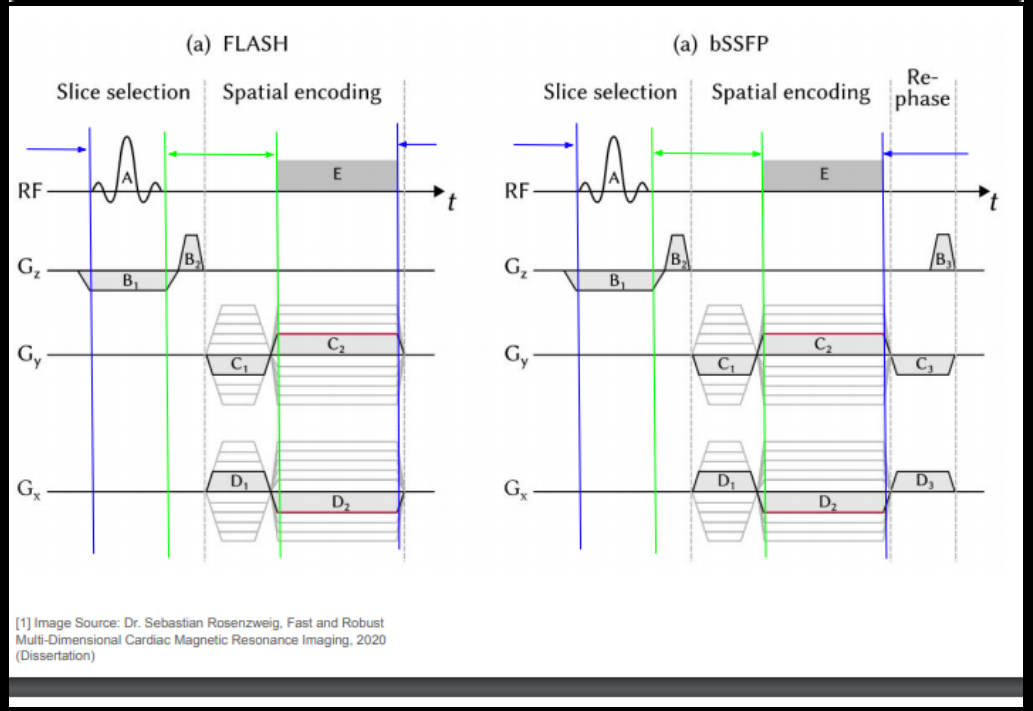


Water, fat, and B0 field (radial ME-FLASH, TA = 0.158 s)[4]

1. Sumpf et al. J Magn Reson Imaging 34:420-428 (2011)
2. Wang et al. J Cardiovasc Magn Reson 21:60 (2019)
3. Wang et al. Magn Reson Med. 85:1258-1271 (2021)
4. Tan et al. Magn Reson Med 82:1000-1011 (2019)

Messsequenzen

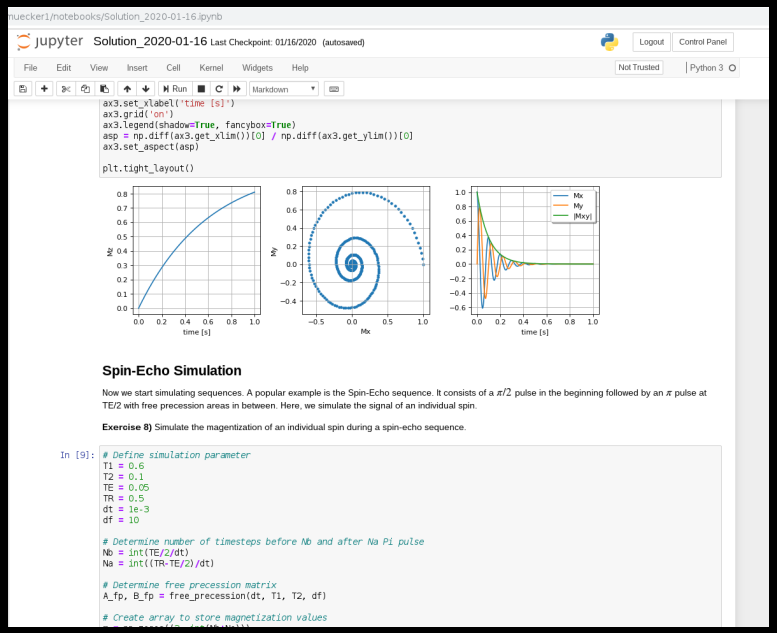


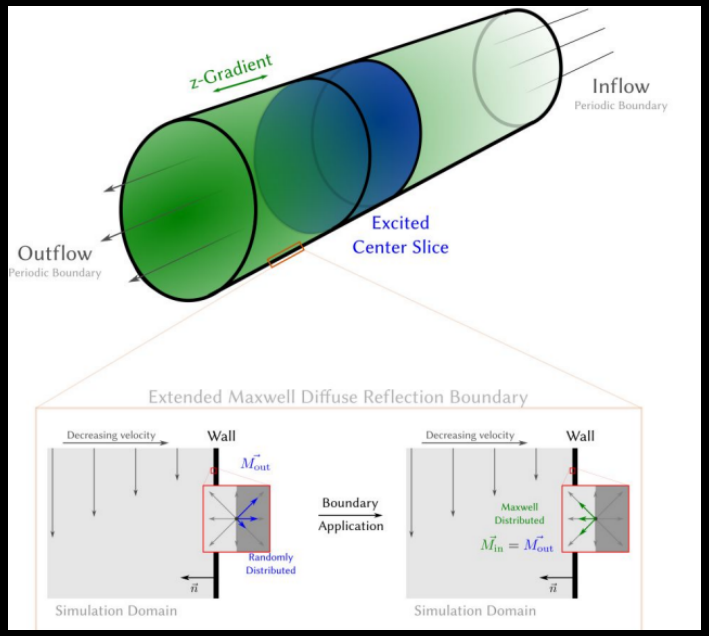


[1] Image Source: Dr. Sebastian Rosenzweig, Fast and Robust Multi-Dimensional Cardiac Magnetic Resonance Imaging, 2020 (Dissertation)

Simulationen

- Verständnis und Optimierung von Effekten in der MRT
- z.B. Optimierung der Radiofrequenzpulse, Verständnis von Artefakten, Flussphänomenen

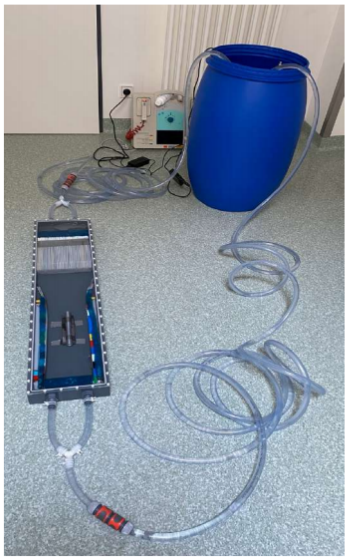




MRT-Phantome

Flussphantom, 3D-Druck, etc.

Methods and Materials: Experimental Setup



Water Pump

- Pipe flow model
- Tubing system
- Barrel filled with water

- Siemens Magnetom Skyra 3T
- Body Coil

BART: Software Toolbox for Computational MRI

- **Goals:** rapid prototyping, reproducible research, clinical translation

- Collaboration: UC Berkeley, UT Austin
- BSD Lizenz
- `https://mrirecon.github.io/bart/`

BART image viewer

Funding:
NIH Grant U24EB029240, Grant R41RR09784 and Grant R01EB009690, DFG Grant UE 189/1-1, DZHK (German Centre for Cardiovascular Research), American Heart Association Grant 12BGIA9660006, UC Discovery Grant 193037, Sloan Research Fellowship, GE Healthcare, and a personal donation from David Donoho's Shaw Prize

BART

UNIVERSITÄTSMEDIZIN GÖTTINGEN : UMG

NIH National Institute of Biomedical Imaging and Bioengineering
Creating Biomedical Technologies to Improve Health

Themenbereiche

- Bildrekonstruktion und Nachverarbeitung
- Programmierung von Pulssequenzen
- Maschinelles Lernen
- MRT-Physik, Simulationen
- Software Defined Radios, (RF-)Elektronik
- Echtzeit-MRT und interventionelle MRT
- Quantitative MRT (Fluss, Relaxometrie)
- Phantombau (3D-Druck, Flussphantome)
- Hardware: Low-Field MRT, Tabletop MRT

Siehe: `https://www.tugraz.at/institute/ibi/`

Danke für Ihre Aufmerksamkeit!