New Developments of Multi-parametric MRI Techniques and Radiotherapy Applications

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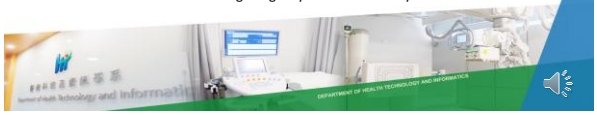
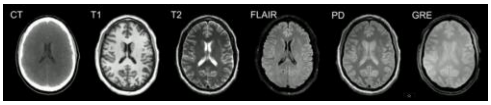
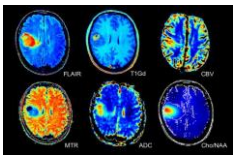


Outline

- Introduction
- New developments in technology
  - Simultaneous multi-parametric MRI
  - Deep learning assisted reconstruction
  - Synthesized contrast imaging
  - Sequence optimization
- Applications in radiation oncology
  - Segmentation
  - Synthetic CT
  - 4D-MRI
  - Radiomics

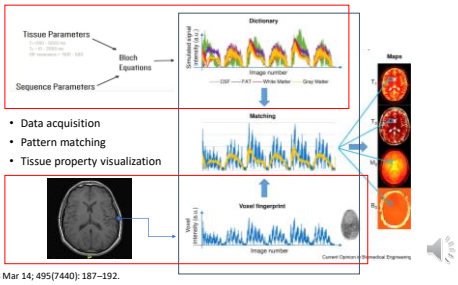
Multi-parametric MRI





- Multi-parametric MRI of a brain tumor (glioblastoma).
- FLAIR, gadolinium-enhanced MRI, cerebral blood volume (CBV, perfusion imaging), MTR, apparent diffusion coefficient (ADC, diffusion imaging) and Cho/NAA ratio (metabolic imaging by MRS).

MR Fingerprinting (MRF)

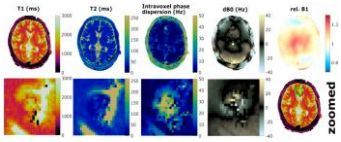


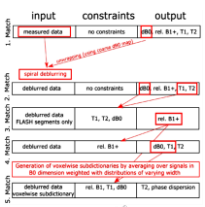
- Data acquisition
- Pattern matching
- Tissue property visualization

Ma et al, Nature. 2013 Mar 14; 495(7440): 187–192.

Magnetic Resonance Field Fingerprinting (MRFF)

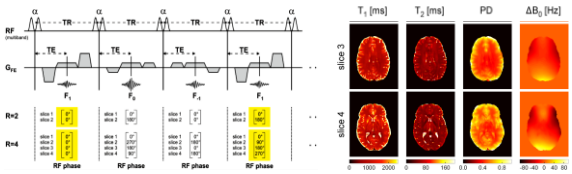
- Simultaneously estimates T1, T2, intravoxel phase dispersion, dB0, and relative B1 maps.
- For each matching step, the input data, the constraints (partially or totally fixed parameters in the matching step), and the output are shown. Nonpattern match steps are shown in red





G. Korzdorer, *et. al.* 2018

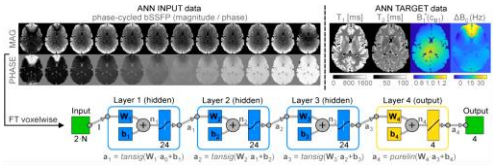
Simultaneous Multi-slice Triple-echo Steady-state (SMS-TESS)



- Rapid simultaneous T1, T2, PD, and delta-B0 mapping of human brain tissues.
- Multiband RF pulses are used to excite multiple slices simultaneously.
- The three SSFP contrasts (F1, F0, F-1) are acquired in different RF cycles to ensure a short TR and thus to reduce the sensitivity to susceptibility.

R. Heule, *et. al.* 2018

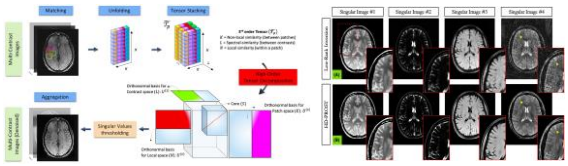
Artificial Neural Network (ANN) Fitting for Simultaneous Extraction of Multi-parametric MRI



- Quantification using phase-cycled balanced steady-state free precession (bSSFP)
- The feedforward ANN training scheme including input/target data (first row) and the optimized network architecture (second row).

R. Heule, *et. al.* 2020

High-Dimensionality Undersampled Patch-based Reconstruction (HD-PROST) for Multi-contrast MRI

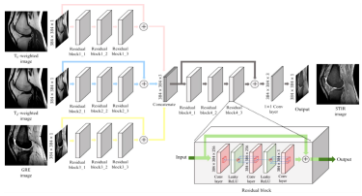


- Enables multi-contrast MR images in a short acquisition time without compromising image quality, increasing the potential of conventional parameter mapping.

A. Bustin, *et. al.* 2018

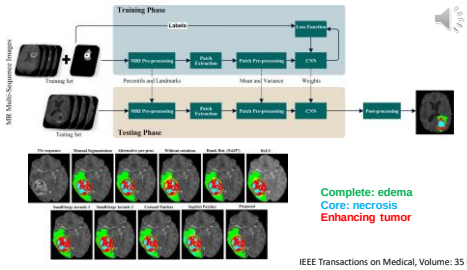
Synthesized Contrast with Multi-parametric MRI

- Generate STIR images from three multi-contrast MR images, without additional scanning, using a deep neural network.
- A potential alternative to the STIR pulse sequence when additional scanning is limited or STIR artifacts are severe.



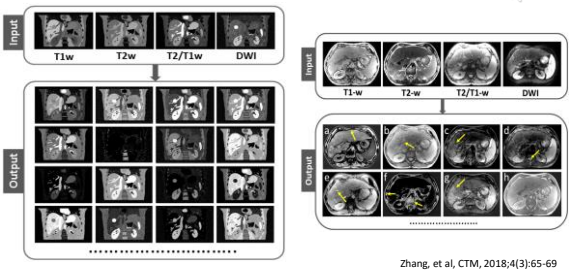
S. Kim, *et. al.* 2020

Segmentation Using Multi-parametric MRI & AI



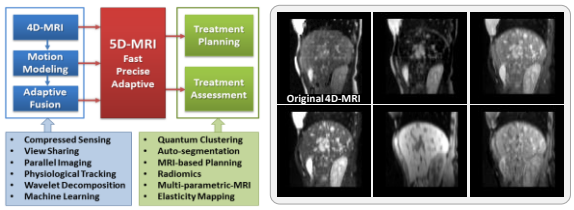
IEEE Transactions on Medical, Volume: 35 Issue: 5

Multi-parametric MRI Fusion



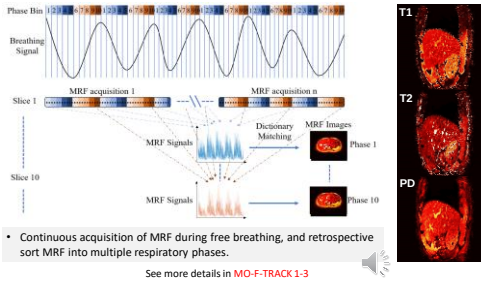
Zhang, et al, CTM, 2018;4(3):65-69

Multi-parametric 4D-MRI (5D-MRI)



- Combining 4D-MRI and multi-parametric MRI to synthesize multi-parametric 4D-MRI
- More effective for tumor motion management applications in RT

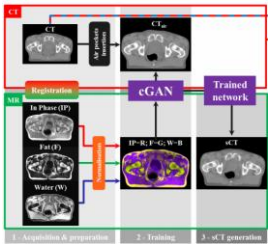
Multi-parametric 4D-MRI using MRF



- Continuous acquisition of MRF during free breathing, and retrospective sort MRF into multiple respiratory phases.

See more details in MO-F-TRACK 1-3

2D cGAN for Synthetic CT

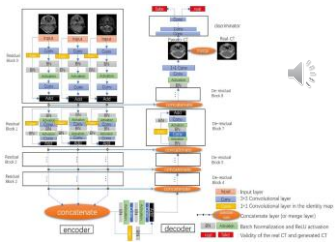


- A 2D Conditional Generative Adversarial Nets (cGAN) comprised of a 256 × 256 U-Net and a 70 × 70 patch discriminator.
- Dixon reconstructed water, fat and in-phase images obtained from a conventional dual GRE sequence were used as the multi-channel input to generate sCT images.

Maspero, et al. Phys Med Biol, vol. 63, no. 18, pp. 185001, Sep 10, 2018.

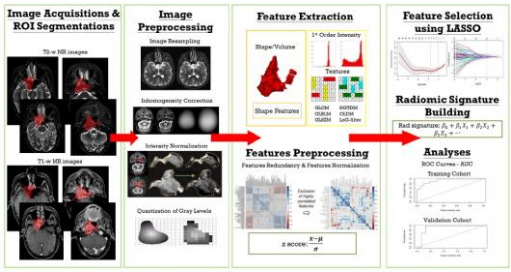
Multi-parametric MRI for Synthetic CT

- MCMP-cGAN model, consisting of multi-channel Residual U-Net as the generator and 5-layer CNN as the discriminator.
- The input layer has multiple MR datasets from different MR sequences.
- The MCMP-GAN model performs better than UNet-GAN and SCSP-GAN.

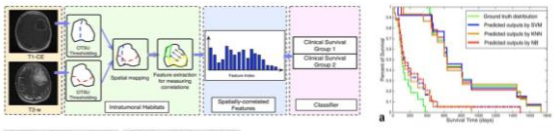


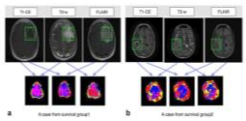
Tie et al, Med Phys. 2020 Apr;47(4):1750-1762.

Multi-parametric MRI Radiomics



Identifying Spatial Imaging Biomarkers of Glioblastoma Multiforme for Survival Group Prediction





- Pretreatment MRI scans of GBMs to identify tumor subregions and quantify their image-based spatial characteristics that are associated with survival time.
- spatially correlated features effective for predicting survival groups

J Magn Reson Imaging. 2017 Jul;46(1):115-123

Summary

- Multi-parametric MRI provides unique advantages over CT and therefore opportunities for improving cancer RT treatment through more precise targeting, planning, and assessment.
- Multi-parametric MRI technology is advancing fast. Being mindful about the advances is important to best utilize the MRI tool for RT applications.

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