New Developments of Multi-parametric MRI Techniques and Radiotherapy Applications

Jing Cai, PhD, DABR, FAAPM
Professor, Department of Health Technology and Informatics
The Hong Kong Polytechnic University

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

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.

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 SNP contrasts (F1, T0, F-1) are acquired in different RF cycles to ensure a short TR and thus to reduce the sensitivity to susceptibility.
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).

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.

Segmentation Using Multi-parametric MRI & AI

- Complete: edema
- Core: necrosis
- Enhancing tumor

Multi-parametric MRI Fusion

- 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 (5D-MRI)

- Compressed Sensing
- View-sharing
- Parallel imaging
- Physiological Tracking
- Watershed Decomposition
- Machine Learning
- Quantum Computing
- Data Segmentation
- MRI-based Planning
- Radiation
- Multi-parametric MRI
- Elasticity Mapping

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.

Complete: edema
Core: necrosis
Enhancing tumor
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 $256 \times 256$ U-Net and a $70 \times 70$ 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.

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.

Multi-parametric MRI Radiomics

Identifying Spatial Imaging Biomarkers of Glioblastoma Multiforme for Survival Group Prediction

- Pretreatment MRI scans of GBM 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.

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.
Acknowledgement

PolyU Team
Yuanpeng Zhang, PhD
Tian Li, MS
Ge Ren, MS
Edmond Lam, MS
Haiyan Ruan, MS
Jiechao Zhang, MS
Xiaoli Tang, MS
Andy Cheung, MS
Zongru Ma

PolyU Collaborators
Michael Ying, PhD
Harry Qin, PhD
Lawrence Chan, PhD

Other Collaborators
Fang-Feng Yin, PhD
Jackie Wu, PhD
Lei Ren, PhD
Spring Kong, MD, PhD
Victor Lee, MD
Amy Cheung, MD
Wen-Hsi Ho, MD
Francis Le, PhD
Koek-Hung Au, MD
Edward Hui, PhD
Charles Chang, PhD
Nam-Iuan Chen, PhD
G. Wilson Miller, PhD
Paul Rogers, PhD
Yaoqin Xie, PhD

Funding Support
NIH R01CA226899
GRF 151022/19M
GRF 151023/18M
HMRF 06173276
HMRF 07183266
ITS-080-19
Hong Kong Scholars Program

Other Collaborators
Fang-Fang Yin, PhD
Jackie Wu, PhD
Spring Kong, MD, PhD
Victor Lee, MD
Amy Cheung, MD
Wen-Hsi Ho, MD
Francis Le, PhD
Koek-Hung Au, MD
Edward Hui, PhD
Charles Chang, PhD
Nam-Iuan Chen, PhD
G. Wilson Miller, PhD
Paul Rogers, PhD
Yaoqin Xie, PhD

PolyU Collaborators
Michael Ying, PhD
Harry Qin, PhD
Lawrence Chan, PhD

Funding Support
NIH R01CA226899
GRF 151022/19M
GRF 151023/18M
HMRF 06173276
HMRF 07183266
ITS-080-19
Hong Kong Scholars Program