Real-Time MRI Technology

Jennifer Anne Steeden[1]

[1]Centre for Cardiovascular Imaging, University College London, London, United Kingdom

Synopsis

Real-time MRI is the ability to continually acquire high temporal resolution data. Technological advances which have enabled high temporal and spatial resolution real-time MRI, include; i) hardware improvements; ii) efficient acquisition strategies (non-Cartesian trajectories and data undersampling); iii) reconstruction algorithms (parallel imaging, temporal encoding, Compressed Sensing), iv) rapid reconstruction (data reduction and parallelization on GPUs).

Highlights

- Hardware improvements; gradient systems and coils

- Acquisition strategy; Non-Cartesian trajectories and data undersampling

- Reconstruction techniques; Parallel imaging, Temporal encoding, and Compressed Sensing

- Reconstruction speed-ups; Data reduction and Graphics Processing Units- Real-time processing

Target audience

Participants interested in how real-time MR can be achieved;

- How we can speed up imaging

- Reconstruction algorithms

- Speeding up of reconstructions

- Real-time processing

Outcome/Objectives

- Understand how fast imaging can be achieved; efficient trajectories and data undersampling

- Understand reconstruction algorithms available; parallel imaging and compressed sensing

- Understood how fast visualization can be achieved; data reduction and GPUs

- Understand how real-time processing can be achieved and used

Real-time MRI Technology

MRI is inherently slow, making imaging of moving structures challenging.

Real-time MRI is the ability to continually acquire high temporal resolution data. Advances which have enabled high temporal and spatial resolution real-time MRI, include;

- Hardware improvements; gradient systems and coils
- Acquisition strategy; Non-Cartesian trajectories and data undersampling
- Reconstruction techniques; Parallel imaging, temporal encoding and Compressed Sensing

As well as fast acquisition, real-time imaging should ideally have:

- Rapid reconstruction and display of the resulting images
- Possible operator control to interact with the acquisition parameters

Real-time MRI is most commonly used for:

- Cardiovascular imaging (1)
- Speech imaging (2)
- Image guidance for interventional procedures (3)
- Joint movement (4)

Hardware improvements;

- Advanced in Gradients; decreased time to traverse k-space
- Advances in Coils; Maximising SNR and allowing maximum acceleration

Acquisition strategy;

Cartesian acquisitions are slow as only a small amount of k-space if covered after each excitation. Alternative, efficient trajectories include;

- Echo Planar Imaging (EPI, figure 1a) (5); single shot or as a multi-shot acquisition
- Radials (figure 1b) (6); robust to undersampling
- Spirals (figure 1c) (7); efficient readout

Undersampling

Reducing the amount of k-space data collected results in spatial aliasing; (figure 1c-e).

Reconstruction techniques;

Reconstruction techniques that allows us to recover images from the undersampled k-space data, include;

* Parallel imaging; uses spatially independent information from multiple coils

- SENSE (Sensitivity Encoding) (8); works in image domain. Non-Cartesian SENSE requires use of iterative conjugate gradient algorithm (9)
- GRAPPA (10); works in k-space. Non-Cartesian GRAPPA uses independent kernels for different segments of space (11)

* Temporal encoding; alternating the missing lines in k-space in subsequent frames

- Keyhole imaging (12)
- TGRAPPA; temporal information used to calibrate weights (13)
- TSENSE; temporal information used to calculate coil sensitivity maps (14)
- Further exploited to improve the reconstruction, and enable higher accelerating to be achieved; k-t GRAPPA (15) and k-t SENSE (16)

* Compressed Sensing (17); exploits data sparseness and compressibility

- Temporal finite difference; real-time speech (18)
- Spatio-temporal sparsity (k-t SPARSE-SENSE); real-time cardiac cine (19)

Reconstruction Speed-ups;

Fast reconstruction is challenging due to the large data sets, and complexity of reconstruction algorithms.

*Data reduction; to reduce reconstruction times;

- Selection of most suitable coil subset (20)
- Array compression to combine channels (21)

*Graphics Processing Units (GPUs); massively parallel architecture to speed up algorithms (compared to CPUs; central processing units) that can be parallelized (22)

- Non-uniform FFT (23); up to x85
- Cartesian SENSE (24); up to ~x36
- Spiral SENSE (25); up to ~x15
- Compressed sensing (26); up to ~x27

Post-processing;

*Slice tracking;

- Exercise
- Intervention

*Segmentation;

- Vocal tract analysis (27)
- Flow calculation; Aortic segmentation (28)
- 3D kinematics of the knee (29)

Acknowledgements

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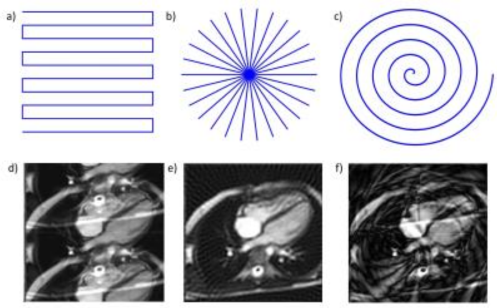
Figures



Efficient k-space trajectories; a) EPI, b) Radial, c) Spiral.

Data under sampling by a factor of 2 in; d) Cartesian imaging (folder artefact), e) Radial imaging (streaking artefact), f) Spiral imaging (ringing artefact)

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