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Harnessing Open Innovation for Integrated Retrospective Motion Correction

Digital Poster · 55 min | Artifact Correction Strategies in Brain and Body · Session: 1:40–2:35 PM · Digital Posters Row B · 12 **Keywords:** MOTION DETECTION AND CORRECTION OPEN INNOVATION

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Impact

We demonstrate the benefits of enabling Open Innovation interfaces for retrospective motion correction approaches.

Synopsis

Motivation: Motion artifacts remain a major hurdle in the clinical workflow, with different MRI vendor-specific partial solutions. Here we explore how to enable scalable rigid body motion correction solutions using Open Innovation APIs.

Goals: Make motion data accessible to third-party retrospective motion correction (RMC) algorithms within the scanner reconstruction pipeline.

Approach: A research interface for external motion detectors was extended by a logging mechanism to combine motion information and MR acquisition data. The data was used in an Open Recon RMC implementation.

Results: Initial simulations confirm accurate motion logging and synchronization, demonstrated by successful retrospective motion-corrected reconstructions of in-vivo scans with synthetic motion.

INTRODUCTION

While many different approaches have been suggested for mitigating the effect of motion (e.g. [1-4]), the associated artifacts remain one of the major issues constraining efficient clinical MRI workflows[5,6]. Challenges for such approaches include a) the distribution to a broad range of clinical applications, and b) supporting different technical innovations. For the first aspect in the context of head imaging, optical motion detection systems independent of the MR acquisition have proven their suitability, especially if markerless (e.g. Tracoline, TracInnovations A/S, Ballerup, Denmark[7]). For the second aspect, hardware independent open interfaces have been suggested, connecting external detectors to a vendor specific prospective motion correction framework[8].

In addition to these motion-related advancements, recently the concept of Open Innovation has raised significant interest[9], covering topics such as non-proprietary formats for cross-vendor descriptions of sequences (e.g. PulSeq[10], gammaStar[11]) or image reconstruction (e.g. Gadgetron[12]).

In this work, we aim at extending a previous implementation[8] such that the detected rigid body motion updates from an external detector can be used for retrospective motion correction in Open Recon, the Siemens environment for Open Innovation reconstructions.

METHODS

Providing an Open Innovation interface for retrospective Motion Correction

In this work we extend the previously introduced research Access-i-Moco interface for prospective correction[8] by a logging protocol, which stores motion information along with the k-space data. For unambiguous temporal alignment, the logged information contains a) the motion parameters from the external detector, including unique frame numbers and time stamps; b) the time stamps of the MR system upon reception and usage of the parameters; c) the acquisition and loop counters; d) additional information, such as whether prospective motion correction was performed.

A commercially available open reconstruction framework, Siemens Open Recon, was extended by a research module for enabling 3D reconstructions and for the interpretation and conversion of the logged data to ISMRMRD Physiological Waveforms[13], making the data available for vendor independent processing.

In addition to these framework aspects, a NuFT-based reconstruction using the new Motion Physiological Waveforms was implemented in Python. For each corrupted acquisition line, the nominal Cartesian k-space coordinates are corrected and a phase shift is applied to the k-space data. To enable the described research extensions, an adapted version of the research T1-Turbo-FLASH (MPRAGE) sequence from the previous work[5] was used. For reproducible experiments[14] an Access-i test client was developed for simulating the motion detector and injecting predefined motion trajectories.

In vivo experiments

Two datasets were acquired with the research MPRAGE with different injected trajectories (pure translation and a combination of translation and rotation) in a female volunteer (52y) on a 1.5T MAGNETOM Avanto fit (Siemens Healthineers, Forchheim, Germany). Imaging parameters: TR/TE/TI 1500/1.7/900 ms, field-of-view (FoV) 224x224x192 mm^3, R=1, isotropic resolution of 1mm³, TA=5:38min. The volunteer was instructed not to move during the experiments. The Access-i-Moco test client was used for purposely corrupting the acquired k-space data. Open Recon was configured to replace the Fourier transform by the described Python motion correction and still benefit from product processing, such as distortion and intensity correction (Open Recon product "raw to complex image" mode).

RESULTS and DISCUSSION

Fig. 1a shows the suggested data flow, from the external motion detector to the Open Recon framework; for this work, the motion detector was simulated using the described Access-i-Moco test client.

Fig. 2a shows the corrupted and the corrected images for the case of pure translation; the correction was performed using the logged motion information and the aforementioned Python implementation in Open Recon, confirming accurate motion logging and synchronization. Fig. 2b depicts the injected motion trajectory.

Fig. 3 shows the results and motion trajectory for the case of combined translations and rotations. As in Fig. 2a the correction can fully recover artifact free images, demonstrating that full motion correction is supported by the presented approach.

Future work will have to investigate whether the logging format, as suggested here, needs further extensions for 2D use cases in order to properly account for a combination of (potentially partial) prospective and retrospective correction.

CONCLUSION

We have demonstrated that Open Innovation can be extended to motion detection and correction. While here the motion was purposely controlled and injected using a test client, the setup is expected to work identically for real motion detection, to be shown by future work.
Furthermore, with this work we provide the basis for a discussion on a generic Open Innovation motion detection description that could potentially serve as an extension of the ISMRMRD format. This would enable a clear separation of the tasks of acquiring the MR data, determining the pose information and performing the motion-aware reconstruction.

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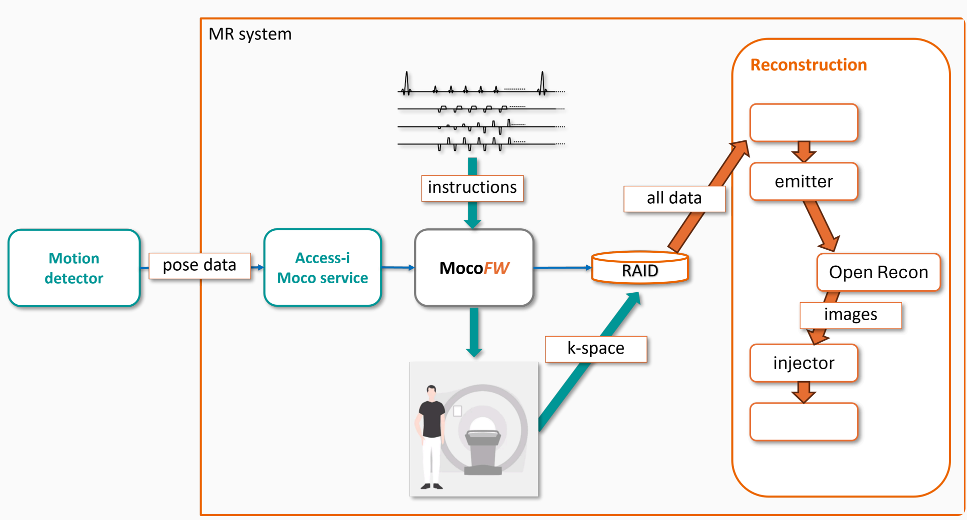
Figures and Tables



Scan for high-resolution version

Figure 1: *Figure 1: The data flow of motion information through the MR system to the OpenRecon pipeline. Both k-space and pose information are available for a motion aware reconstruction. The MocoFW can be used for optional prospective correction; here it was used for purposely corrupting the acquisition. In this work, the motion detector was simulated using a test client capable of sending in predefined pose information.*

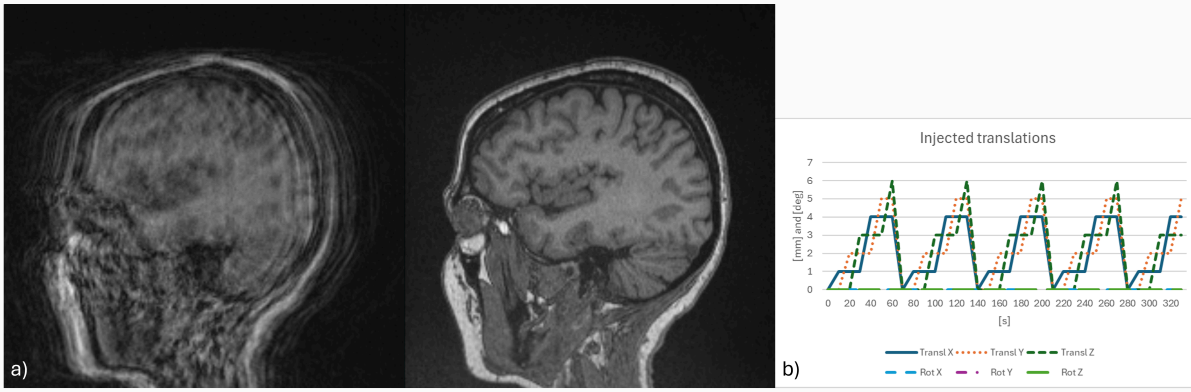


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Figure 2: *Figure 2: a) The case with injected pure translation before (left) and after (right) motion correction. b) The injected motion information. This case demonstrates that k-space and motion information are well synchronized*

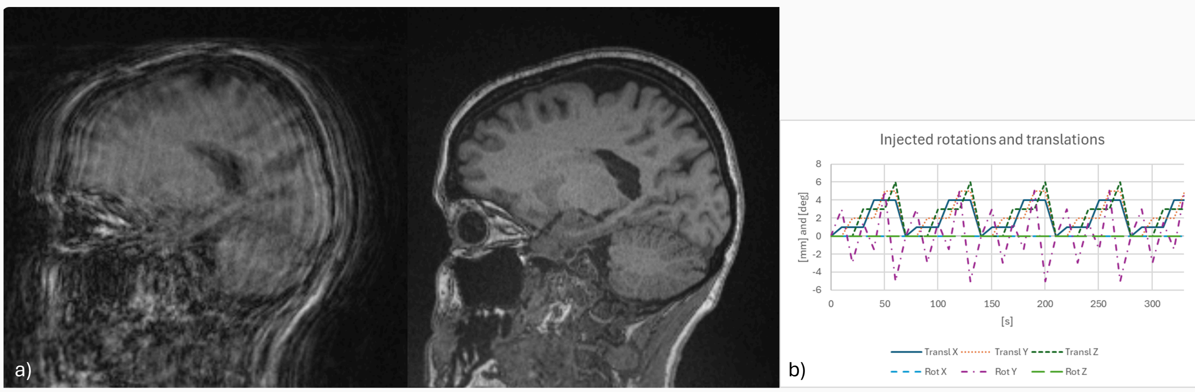

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Figure 3: *Figure 3: a) Reconstructions of the volunteer acquisition with injected combined translations and rotations, before (left) and after (right) motion correction. b) The injected motion information (translations and rotation). This example demonstrates that the suggested approach is suited for complete rigid body motion correction use cases.*