SIGNET State of the Art (SotA) Analysis

This document explains the clinical SotA related to SIGNET and identifies several enabling technologies where breakthroughs are expected to disrupt image guided therapy and interventions, as well as regular diagnostic imaging.

Development of MRI guidance for interventional procedures has been pursued by several academic groups and enterprises over the past decades. The challenges that need to be overcome are the strong electromagnetic interactions of (conductive) catheters, which can cause serious local heating and patient burns, and accurate localization and visualization of the catheter. MRI imaging the local magnetic field as encoded in the frequency of the MR signal into spatial information. Any deviation from the nominal encoding field due to magnetic fields related to the catheter results in erroneous localization and/or signal loss.

Cardiac imaging constitutes the most challenging MRI use case for speed and artifact free imaging. Currently, in clinics this is addressed by motion-freezing techniques such as cardiac triggering in combination with breath holds allowing 4D imaging over the cardiac cycle relying on regular periodic heart cycle and repeatable breath hold positions. This significantly compromises patient comfort, and leads to long, unpredictable examination times.

Academic research has shown that sparse MR sampling techniques may replace these motion-freezing techniques by free-breathing examinations[[1]](#footnote-1). The related compressed signal models leverage sparsity of the encoded signal and low-rank matrix inversion but require massive computational resources and complex iterative algorithms to reconstruct high quality images (current latencies in the order of hours or days). These innovations have essentially shifted the complexity from the acquisition (breath hold, triggering) to the reconstruction component of the image formation. UMCU has recently shown fast MRI using a highly compressed representation of moving anatomy (MR-MOTUS[[2]](#footnote-2)) for liver imaging. Expansion to free-breathing cardiac MRI requires further improvements in data sampling, advances in breathing and cardiac motion detection (e.g. contact-free sensing by Philips’ VitalEye[[3]](#footnote-3)), AI (Deep Learning) reconstruction, and a breakthrough approach towards efficiency and patient compliance by visual guidance of patients to a relaxed, regular breathing rhythm.

Deep Learning can also provide a breakthrough in 3D Cine imaging[[4]](#footnote-4) at high temporal and spatial resolution, necessary for motion-adaptive treatment planning (e.g. robotic biopsies) and delivery. MRgRT motion-tracking algorithms and basic architecture have been developed in STARLIT public private partnership project.

*Table 1* provides an overview of similar projects on which SIGNET plans to build further.

Table 1: Similar Public Private Partnership research projects related to SIGNET.

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| Project name | Collaborative programme | Time period (approx.) | Technical focus | Relationship |
| SoRTS | ITEA3 | 2014-2016 | System of Systems Architecture for integration of treatment and imaging systems | First version of MRI guided motion detection and treatment control |
| STARLIT | ITEA3 | 2018-2020 | Radiation Therapy with real-time tracking of the target and beam steering based on MRI image stream | Reference implementation of the architecture for MR guided therapy control, with focus on MRLinac |
| DeNeCor | ENIAC(FP7-JTI) | 2013-2016 | MR compatibility of implanted and therapeutic devices | Initial demonstrator (TRL2) of TMS in MRI |
| MIGRATE | NHF CAVARIS (Dutch Heart Foundation) | 2014-2018 | Algorithms for improved cardiac function assessment, MRI compatible catheter and novel image guided treatment planning strategy. | MRI-guided catheter treatment in the heart utilizing MR tissue characterization to target and MR Roadmaps and MR fluoroscopy to navigate |
| IMPACT | ITEA3 | 2017-2020 | Data analysis and AI supporting minimal invasive workflows | Apply the workflow solutions also in MRI guided interventions |
| COSMO@HOME | EIT Health | 2019-2021 | Digital solution to prepare paediatric patients at home for their upcoming MRI examination | Insight in factors influencing patient experience and compliance during MRI |

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