PHILIPS

Clinical research

Accelerating quantitative MRI research

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Quantitative MRI techniques can allow accurate objective analysis of tissue changes and functional impairment, and are starting to be specified as clinical trial end-points. Acceleration of MRI scans for clinical trials is very important; not only to save expensive imaging time (~£350-500/hr in the UK), but also to improve the value of the research, since image quality often depends on patient motivation and engagement which is hampered by long scan times.

At Newcastle University, Dr Kieren Hollingsworth's clinical research includes two patient populations that particularly benefit from scan acceleration. Quantitative fat fraction measurements are used to improve the assessment of progressing disease in muscular dystrophy, as well as assessment of the liver in type 2 diabetes. Measurement of fat fraction by MRI indicates replacement of healthy tissue with fat, which occurs in both of these patient populations.

The patients with muscular dystrophy – a muscle-wasting disease, variants of which affect boys as young as 4-5 years old – find it particularly challenging to keep still in the scanner. In the patients with type 2 diabetes, liver fat fraction measurements require a lengthy breath hold during imaging, which is challenging for most patients and impossible for some. Acceleration of the measurement in both of these patient populations is highly beneficial.

Dr Kieren Hollingsworth is a Reader in Magnetic Resonance Physics at the University of Newcastle. His research concentrates on creating and clinically validating methods of accelerating quantitative MRI to (i) reduce costs of clinical trials and (ii) and to improve the patient experience. He has published extensively on new ways to quantify early functional impairment and tissue change in diseases.

Dr David Higgins is a Senior Scientist at Philips, part of the UK&I MR Clinical Science team and the wider global network of Philips Clinical Scientists. They provide: MR physics support; advanced teaching on the functions of the MR system; prototype pulse sequence deployment and monitoring; novel pulse sequence development advice; guidance for image reconstruction and analysis projects; advice for interfacing novel hardware.

Compressed sensing **research**

There are numerous ways to accelerate MRI scans, which involve either (i) acquiring data faster, or (ii) missing out some of the conventionally-acquired data (undersampling; for example, parallel imaging methods), and then removing or mitigating the problems which occur in reconstructed images as a result. An exciting new undersampling method was brought from the field of general signal processing to the attention of the MRI physics community in 2007, called compressed sensing.[1]

Dr Hollingsworth recalls, "I had seen the early theoretical work on compressed sensing using retrospective downsampling of fully sampled data, and I realised that it would be an exciting advance for our clinical research. But only if the shortened data acquisition could be played out on the scanner, and only if we could prove it made no difference to our quantitative measurements across a cohort of subjects. I was determined to apply it to the benefit of our participants!"[2]

As part of the research collaboration with Philips MR Clinical Science, the scanner was modified by Dr Higgins to implement the compressed sensing data acquisition. Dr Hollingsworth combined this work with his research on the optimal 3D Poisson disk k-space sampling schemes required for his patient population, to allow the implementation of these schemes on the scanner. He remembers: "We assessed the method for accelerating muscle fat fraction measurement in muscular dystrophy, and showed that compressed sensing combined with parallel imaging achieved substantially greater fidelity of fat fraction than parallel imaging alone, and fivefold acceleration was possible with preservation of fine anatomical features required for analysis. We also showed that, for certain pre-defined protocols, that optimal choice of wavelet weighting parameter was the same between study subjects."[3] This was important information to generalise compressed sensing methods for potential clinical routine use.

Further clinical research was performed using the combined compressed sensing and parallel imaging method, reported in two high-impact Radiology papers. The first showed that volumetric muscle fat fraction measurements with R2* modelling can be significantly accelerated with the method, reducing imaging cost and patient burden in muscular dystrophy clinical trials.[4] The second demonstrated how liver fat fraction measurements can be obtained with significantly shorter breath holds (4.7 seconds vs 17.7 seconds), potentially allowing a greater number of patients to be successfully examined with good image quality.[5]

Compressed SENSE – **The Product**

Recognising the significant impact that these modern acceleration methods could have in the clinic, Philips had embarked on bringing this method to the global clinical market. There are many challenges to be met in moving research functionality into clinical routine and this application was no different. A commercial product needed to address many significant barriers to adoption:

- **Universal – a combined compressed sensing and SENSE parallel imaging method needed to be applicable to all body areas and contrasts;**
- **Ease of use – allowing complete scan parameter flexibility (allowing k-space to change in 2D, 3D, static and dynamic, 4D);**
- **Fast – clinical image reconstruction times needed to fit with hospital workflow on existing scanner hardware.**

All these challenges were met with Philips' innovations in the production option "Compressed SENSE"[6], which can be used to accelerate MRI scans for all contrasts in all anatomies. As part of this development, research prototypes of Compressed SENSE were evaluated at selected sites, and Dr Hollingsworth was able to test it extensively and provided valuable feedback to Philips, in particular regarding challenging imaging situations on realistic patient groups. Dr Hollingsworth confirmed that the noise presentation of the method was "visually recognisable as 'speckled noise' and without 'cartooning' as found in many research implementations" of compressed sensing. This is important for radiologists reading the scans; "it permits the recognition of noise levels in a way familiar from conventional MR imaging".

As an indicator of the success of Compressed SENSE in the clinical routine, Compressed SENSE is the most successful MR software introduction Philips has ever had. By working with partners such as Dr Hollingsworth in the development of research methods and for evaluation of Philips prototypes, technical innovations can make an impact in routine healthcare more quickly.

At Newcastle University, the research continues. "With the academic work of establishing and proving the two applications completed, we are now using compressed sensing to accelerate our clinical research work. In Duchenne muscular dystrophy, we are using fivefold acceleration to ease the measurement of fat fraction and contractile surface area changes during testosterone therapy. In our studies of interventions for type 2 diabetes, we are using accelerated measurements of liver and visceral fat to make breath holding easier."

Future **perspective**

Newcastle University continues its successful collaborations with Philips MR Clinical Science in a wide range of research areas, such as fluorine-19 lung ventilation imaging, lithium-7 imaging of the brain during the treatment of bipolar disorder, and advanced cardiac imaging and spectroscopy.

Co-creation of MR imaging solutions with imaging experts is a priority for the worldwide Philips MR Clinical Science group, enabling collaborations that serve this common goal: improving patients' lives.

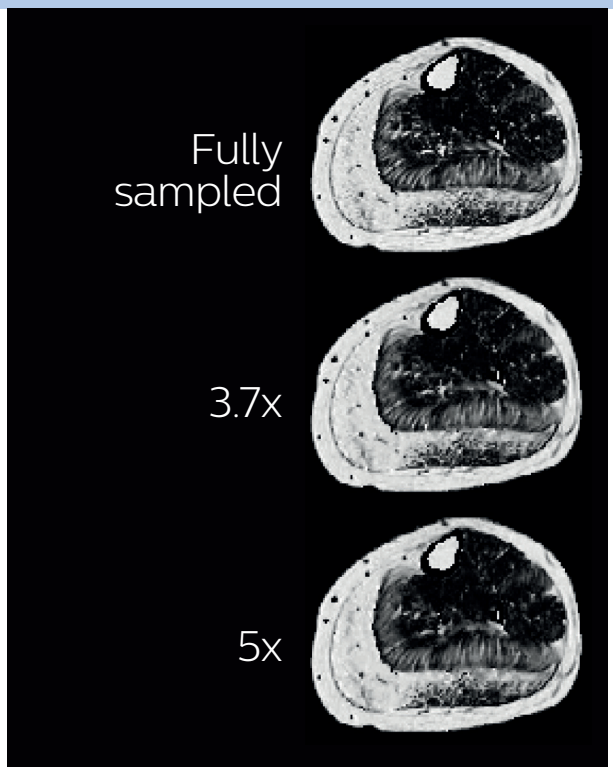

Figure 1: Fat fraction map (0%-100% scale) of a calf cross-section in a subject with Becker Muscular Dystrophy, showing significant fat replacement of the gastrocnemius and soleus muscle groups. Top: fully sampled image, Middle : prospective 3.7x acceleration, Bottom: prospective 5 x acceleration.

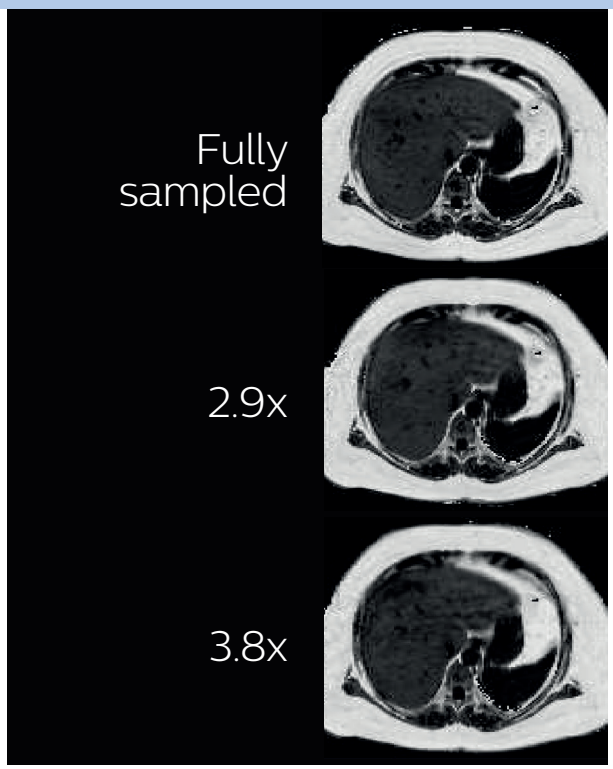

Figure 2 : Fat fraction map (0-100% scale) of a liver cross-section in a subject with Type 2 Diabetes and hepatic steatosis (19% fat). Top: fully sampled image, Middle: prospective 2.9 x acceleration, Bottom: prospective 3.8x acceleration

Explore the Philips MR image quality in the Body Map at

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