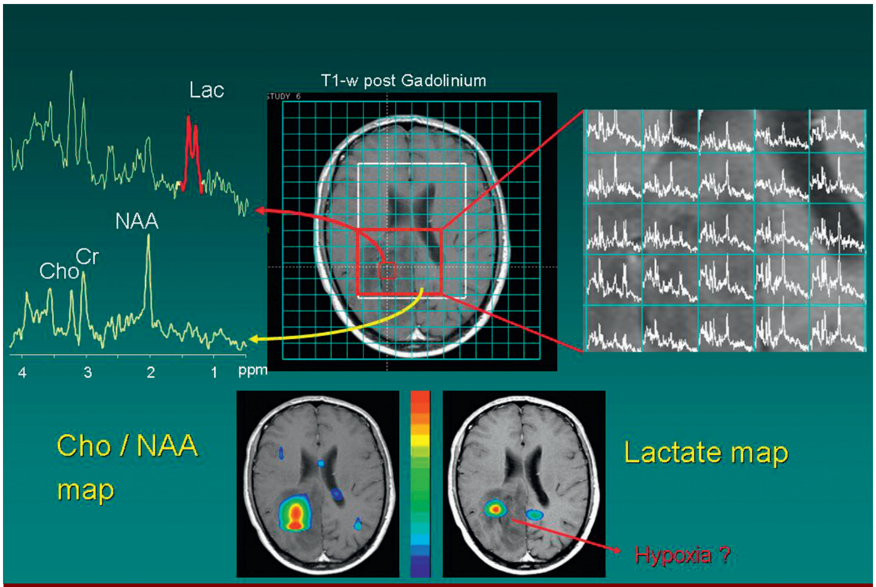
The on-going development of MRI technology is crucial to improving the treatment of major diseases. **Dr Danielle Graveron-Demilly** explains how the FAST project is moving Magnetic Resonance Spectroscopy (MRS) research towards the non-invasive, in-vivo assessment of metabolic content

Magnetic Resonance Spectroscopic Imaging

Although a relatively new technique, Magnetic Resonance Imaging (MRI) has rapidly grown in importance since the first image was published in 1973, to a point where it is now a central element in radiology and a widely used technique in hospitals and medical centres across the world. MRI scans allow medical professionals to visualise anatomy in living tissue by using the signal of water while weighting the image with physical processes provides a view of phenomena like brain activity, etc. Whilst these benefits enable many important advances, biochemical processes need to be monitored too. This is where MRS comes in. Unlike MRI, MRS can detect biochemistry, which makes it unique. MRI detects only water – ubiquitous in living tissue – and fat. MRS imaging (MRSI) combines MRS and MRI. Thus, MRSI scans provide an image of biochemistry in living tissue by using signals from organic molecules; not only does this allow the direct reporting of events at molecular level, but it also enables the non-invasive in-vivo-detection and imaging of disease biomarkers – also known as metabolites. As such, European researchers are working to develop the next generation of medical imaging techniques in line with modern health priorities, work in which the FAST project (Advanced Signal Processing for Ultra-Fast Magnetic Resonance, and Training), a Marie Curie-funded initiative coordinated at the University of Lyon in France, is playing a key role.

Working in the emerging field of Magnetic Resonance Spectroscopic Imaging (MRSI), the project brings together academic and industrial partners from across Europe with the overall goal of paving the way to real-time MRSI scans, something which will bring significant benefits to medical professionals. It is now widely acknowledged that MRSI has great potential in terms of improving the diagnosis of major diseases such as cancer, Alzheimer's and diabetes, as well as in monitoring therapy and drug follow-up. Nevertheless, much work remains to be done before it is established as a routine clinical tool, largely because the concentration of metabolites in living tissue is at least several thousand times lower than the concentration of water in living tissue.



MRSI of a low grade oligodendroglioma © Nijmegen

The potential of MRSI

The low concentration of metabolites is an issue that represents a significant obstacle to MRSI's prospects of eventually establishing itself as integral part of modern radiology. The immediate consequence is that the signal-to-noise ratio of metabolite signals is low, which in turn means that the time it takes to acquire an MRSI scan is correspondingly long – about ten minutes. Nor is this the only important consideration for the FAST project, as the fact that the resulting metabolic images have low spatial resolution (typically 20 x 20 voxels) also needs to be addressed. Well aware of the far-reaching implications of its work, the FAST project has thus developed a comprehensive approach designed to address all of the major issues surrounding MRSI, and to ensure it responds to the needs of modern medicine by providing doctors with the kind of comprehensive, accurate and effective imaging they need to advance medical treatment – preferably in real-time.

The FAST approach

FAST includes both using and developing the kind of advanced techniques that can lead to major breakthroughs. Magnetic field strengths as high as 14T for pre-clinical (animals) and 7T for clinical (humans) studies, enable FAST's researchers to establish new detection limits for in-vivo spectroscopy, not only in terms of spatial resolution and speed, but also with respect to the detection of new biomarkers. With field strengths as high as 14T for in-vivo imaging, this is research that could revolutionise the study of transgenic models of disease. Some FAST partners were the first to score in this field. Similarly, the ability to map neurochemistry at a spatial resolution equivalent to that achievable by positron emission tomography – or even exceeding it – opens up new perspectives in the phenotyping of many genetic models. A preponderant topic covered by FAST is free software for cutting-edge semi-parametric estimation of metabolite concentrations and corresponding metabolite images. Currently called jMRUI (Java-based Magnetic Resonance User Interface), the software package assures that the algorithms FAST devises, can be used in Clinics and Research Laboratories with minimal effort in an Information System. To this end, the algorithms are packaged in an innovative, collaborative, graphical user-interface. Furthermore, it is based on plug-ins enabling future integration of European software packages. Over thousand packages have already been distributed worldwide. The jMRUI will gradually evolve into eMRUI (exploitation of the internet). In addition, j(e)MRUI is a training element designed to both provide a solid grounding for young students in all aspects of MRSI, as well as help experts boost their knowledge even further.

Working in a complex, technically demanding area like spectroscopic imaging, the project's work involves research across a wide range of areas, including some which may surprise those unfamiliar with imaging. At first glance FAST's work to develop a Virtual Scanner might seem to fall into this category, yet closer inspection reveals it to be an integral part of the project's work, and one which reflects its broader philosophy. FAST's work in developing a Virtual Scanner enables quantum-mechanical simulation of in-vivo MRSI signals from spin Hamiltonian parameters for diverse, user-adaptable, measurement protocols. The spin Hamiltonian parameters can, in turn, be derived from high-resolution MRS or from quantum chemistry calculations. The simulated MRSI-signals serve as metabolite reference signal database.

The project partners hold expertise in a number of fields, ranging from medicine right through to theoretical physics, including biochemistry, physics and informatics, leaving FAST well-placed to equip students with the skills and knowledge they will need to cope with the challenges of the future

With the project's work incorporating research into a number of cutting-edge areas, all of which require great technical expertise, this is no easy task. FAST develops rapid and robust 3D MRSI acquisition techniques and magnetic hyper-polarisation at the forefront of MR-methodology, both of which present a daunting research challenge.

Nevertheless, by using both advanced interactive web-based materials and traditional methods, those within FAST are confident they can provide innovative, effective, broad-based training to both young researchers and experts. Indeed, the inter-disciplinary, inter-sectorial composition of the FAST project lends itself well to providing training and transferring knowledge in all aspects of MRSI. The project partners hold expertise in a number of fields, ranging from medicine right through to theoretical physics, including biochemistry, physics and informatics, leaving FAST well-placed to equip students with the skills and knowledge they will need to cope with the challenges of the future. ★

At a glance

Full Project Title

Advanced Signal-Processing for Ultra-Fast Magnetic Resonance Spectroscopic Imaging, and Training (FAST)

Project Partners

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Dr Danielle Graveron-Demilly is the Vice-Director of the Laboratory CREATIS-LRMN, Université Lyon 1. She is an expert in Signal Processing for Magnetic Resonance Spectroscopy and leads the successful development of the jMRUI software package for medical applications.

MARIE CURIE ACTIONS

FAST