European Partnership on Metrology
Call 2024 –Digital Transformation, Green Deal,
Normative and Research Potential

Selected Research Topic number: **SRT-d04**
Version: 1.0

Title: Trustworthy and quality-assured quantitative magnetic resonance imaging

Abstract

Quantitative magnetic resonance imaging techniques aspire to play the role of virtual biopsies, through the non-invasive measurement of tissue parameters of clinical interest. A dedicated metrological framework is therefore needed to produce pixel-wise maps of uncertainties, to make tomographic results trustworthy and objectively comparable. This will generate an enormous opportunity for medical imaging, with the potential to transform the whole healthcare landscape and boost personalised medicine.

Keywords

Medical imaging, Quantitative Magnetic Resonance Imaging (qMRI), Pixel-wise uncertainty, Personalized medicine, Artificial intelligence in healthcare, Electric Properties Tomography (EPT), Magnetic Resonance Fingerprinting (MRF).

Background to the Metrological Challenges

Digital transformation is significantly impacting the healthcare sector, particularly in the realm of medical imaging. Parallel to this, another transformation is occurring: the transition from traditional, qualitative, imaging techniques to measurement instruments able to provide quantitative maps of specific physical parameters. This change of paradigm is motivated by the strong potential of quantitative imaging for diagnostic purposes and subject-specific treatment planning and monitoring (e.g., for radiotherapy).

Magnetic Resonance Imaging (MRI) has emerged as one of the most important tomographic tools over the years due to its unmatched soft tissue contrast and the absence of ionising radiation. Currently, the number of MRI scans exceeds 30 million in EURAMET countries and, in some of them, the use of MRI more than doubled in the last 15 years. Alongside to this, quantitative MRI (qMRI) approaches, aimed at producing objective and comparable results, are on the rise. To support this development, the International Society for Magnetic Resonance in Medicine (ISMRM) set up specific study groups on quantitative MRI and on electro-magnetic tissue properties (EMTP). Despite progress, for qMRI techniques to transition into clinical practice, they must undertake important steps, mainly concerning their trustworthiness, which can be significantly accelerated through digitisation. In the field of qMRI, the aim is to become virtual biopsies, where each pixel carries the measurement of a biomarker, each with its own level of accuracy and precision that may vary significantly from point to point. A map of trustworthiness, which corroborates the quantitative image and allows its correct interpretation, is therefore required. This in turn requires an uncertainty evaluation carried out at the level of each single pixel. Uncertainty evaluation is challenging in qMRI, because of the extreme complexity of the measurement pipeline and the limited possibility to average multiple measurements performed on the same patient. These factors underscore the need for comprehensive metrological framework integrated into the image reconstruction process, enabling automated pixel-wise uncertainty estimates without requiring multiple measurements.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the

overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on metrology research necessary to support digital transformation in quantitative Magnetic Resonance Imaging (qMRI).

The specific objectives are:

1. To create a benchmark for the evaluation of uncertainty propagation in the selected most suitable qMRI implementations. To create an open access dataset of reference input data, composed of repeated and reproduced synthetic and experimental data, suitable for the purpose, and to make the dataset and relevant metadata publicly available.

2. To develop strategies that create, for any image produced through the selected most suitable qMRI implementations, a corresponding uncertainty map, which quantifies the pixel-wise reliability of the image itself. The strategies must facilitate generalisability (covering different approaches to qMRI, including regression, Bayesian, and data-driven approaches), be efficient (i.e., applicable to large-scale inverse problems), and be suitable for automation and incorporation in the reconstruction techniques.

3. To perform a validation of the developed strategies by involving multiple, short-term, intra-subject in quality assured vivo measurements.

4. To maximise the diagnostic effectiveness of the selected most suitable qMRI implementations by optimising the acquisition protocols for their input. To check the uncertainty obtained under different potentially influential conditions and compare it to the intrinsic variability exhibited by the measurands. To provide a comprehensive report (that incorporates surveys and data analysis) by including inter-subject and inter-protocol assessments, as well as longitudinal intra-subject observations, in which physiological variability may take place.

5. To facilitate the take up of the technology (digital tools) and measurement infrastructure developed in the project (such as software and datasets) by standards developing organisations and end users (MRI manufacturers, clinical community). This includes, where applicable, quality assurance and attributes of the tools, software, and datasets, such as usability, efficiency, compatibility, maintainability, and transferability, as recommended by ISO/IEC 25010, 25023, 25059 and associations that work to standardise quantitative MRI.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies, and other European Partnerships is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.4 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:
- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,

- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the clinical sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:
- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.