EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-h16**
Version: 1.0

Title: Quantification of image quality in X-ray diagnostics

Abstract

Modern medical imaging techniques require sophisticated procedures for image quality assessment as classical measures, based on linear system theory, are no longer appropriate. Standardised image quality metrics are crucial for conformity testing, comparison of different devices, personalised dose management and for the underpinning of novel developments. Task-based image quality assessment using model observers is a promising approach, but new traceable methods are needed. Similarly, a complete metrological uncertainty characterisation and validation in clinically relevant applications, such as X-ray computed tomography (CT) and mammography, need to be undertaken.

Keywords

X-ray diagnostics, multiparametric data analysis, image quality, dose management, model observer, computed tomography, mammography, Bayesian statistics, Monte Carlo simulation, anthropomorphic phantoms, test phantoms

Background to the Metrological Challenges

Medical X-ray CT imaging and mammography are two of the main sources of human exposure to radiation and this needs to be reduced whilst maintaining sufficient image quality to meet the clinical objective.

Established methods of image quality assessment assume that the imaging systems are linear and shift-invariant. However, these methods are not relevant for modern clinical imaging systems, such as CT, as these apply nonlinear reconstruction algorithms which violate these assumptions. With mammography, the results of image quality parameters have thus far correlated sufficiently well with the observations made by radiologists, however image processing is becoming more advanced, including the use of non-linear methods and images based on new technologies are highly processed. Current methods are only suitable for use with unprocessed images, therefore new sophisticated multiparametric data analysis approaches need to be developed for use with the software-processed mammography images that are used in clinical diagnosis. Task-based image quality assessment using model observers is a promising approach for this purpose. Mathematical model observers based on physical aspects of the imaging system, like the Non-Prewhitening with Eye Filter model, have already been developed for image quality assessment. Another model observers approach currently being used is the channelised Hotelling observer, which is a binary classifier applied to a low-dimensional projection of the image, i.e. the channels. By using appropriately defined channels, this mathematical observer has been shown to have a behaviour related to that of a human observer. Both of these model observers approaches have been shown to have a high correlation with human observers for clinical tasks such as the detection and discrimination of lesions. Therefore, virtual image quality assessments need to be undertaken to compare the performance of these established task-based model observers with newly developed methods of image and data analysis, including machine-learning and Bayesian methods.

New high quality metrics are needed for the evaluation of processed/reconstructed images. Approaches that have already been investigated include task-specific and objective image quality assessment methods. Currently, model observers are being developed to solve a discrimination task on a large set of images. The performance of this classification is then used to calculate a figure of merit which quantifies the quality of the images. This approach needs to be further developed in order to provide traceability to the image quality metrics. To meaningfully compare different imaging devices, or to carry out conformity tests, these metrics need to be accompanied with a complete metrological uncertainty characterisation. A Bayesian uncertainty analysis has already been developed for the assessment of CT image quality. This resulted in a whole probability distribution for the figure of merit, providing a comprehensive uncertainty characterisation. However, thus far, a complete quantitative uncertainty characterisation has not been developed for the metrological estimation of task-specific image quality metrics beyond simplifying the distributional assumptions made for the binary classification task. Bayesian and other methods, including efficient Monte Carlo sampling procedures need to be developed.

Test phantoms and anthropomorphic phantoms, which are suitable for relevant clinical tasks such as the detection or discrimination of lesions, need to be developed and applied in the characterisation and optimisation of the novel image quality metrics.

Mathematical observers have previously been compared with human observers, in simplified conditions, demonstrating a significant correlation. Exact confidence intervals have also been developed for the figure of merit produced by the channelised Hotelling observer for a binary classification task under normality assumptions. However, novel image quality metrics also need to be successfully validated in clinically relevant applications, including several classes of lesions and acquisition techniques, via statistical comparison of the results with those obtained in human observer studies.

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 JRP shall focus on the traceable quantification of image quality in X-ray diagnostics.

The specific objectives are

1. To perform virtual image quality assessments for comparing the performance of established task-based model observers with newly developed methods of image and data analysis, including machine-learning and Bayesian methods.
2. To develop traceable image quality metrics based on model observers. In addition, a complete uncertainty characterisation should be undertaken for the metrological estimation of the image quality metrics. This should include the development of Bayesian and other methods, including efficient Monte Carlo sampling procedures.
3. To develop and apply test and anthropomorphic phantoms, which are suitable for relevant clinical tasks such as the detection or discrimination of lesions, in the characterisation and optimisation of the novel image quality metrics.
4. To validate the novel image quality metrics in clinically relevant applications, which should include several classes of lesions and acquisition techniques e.g. X-ray CT and mammography, via statistical comparison of the results with those obtained in human observer studies.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers), standards developing organisations (CEN, ISO and those associated with Directive 2013/59/Euratom on protection against ionising radiation) and end users (e.g. hospitals and health centres). This should include the establishment of a European network, including NMIs and stakeholders, to support the standardisation of the assessment of image quality.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes, and it is expected that multidisciplinary teams will be required. To enhance the impact of the research, the involvement of the appropriate user community such as medical practitioners, hospitals and industry 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.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

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

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 JRP 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,
- Transfer knowledge to the X-ray diagnostics 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 EMPIR 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

Time-scale

The project should be of up to 3 years duration.