1st IPASC Meeting (04.11.2019): Discussion Notes

Roundtable discussion - Summary Data Acquisition and Management theme

04.11.2019

1. **Metadata Consensus Document**
    a. Mandatory parameters contain everything necessary to be able to reconstruct an image (will be included as a mandatory header):
        i. Detector position (x,y,z)
        ii. Sampling frequency
        iii. Wavelength
        iv. UID
    b. Remaining parameters are included as additional (optional) attributes
2. **Open Source Conversion tool**
    a. Open source API (having a BSD 3.0-like Licence)
        i. Initial prototype will be python-based, but should be later be callable from different programming languages
    b. IPASC will develop the API and will then forward it to the vendors. The vendors will implement the conversion respective to their proprietary file format. They then have the option to contribute their API implementation back to IPASC which will then make it publicly available.
    c. Risks:
        i. Loose vendors if implementation is too cumbersome
        ii. Maintenance work for IPASC
3. **Open source photoacoustic (PA) reference database**
    a. Data will be in the standardised IPASC format
    b. Data needs to already published (respective doi as mandatory parameter for the database entry)
    c. Main purpose: reproducibility studies and benchmarking of processing algorithms
    d. Decision on hosting strategy needs to be made (and on respective funding source if applicable)
4. **Next steps**
    a. Adjustment of Metadata Consensus Document according to suggested changes (J+L)
    b. Development of IPASC data format prototype and conversion tool (DAM task force)
    c. Decisions on remaining discussion points relating to the open source PA reference database (all DAM theme members)

Roundtable discussion - Summary Phantom Development theme

1. **Geometries and target inclusions**
    1. System specific phantom geometries have to be designed and developed.
    2. Target inclusions should enable one to assess various system parameters such as
        1. Spatial resolution
        2. Sensitivity with respect to depth
        3. Other key parameters
    3. Geometries and target inclusions have to be finalized with a detailed discussion with study design (SD) theme.
    4. Outcome – Use Wire/mono filaments made with nylon for macroscopy systems. The materials should be stable under high temperature conditions (>150°C). Diameters of the filaments should be ~100 um.

2. **Tunable vs static optical and acoustic properties**
    1. Static properties for benchmarking phantoms and tunable for application specific phantoms.
    2. Phantom needs to be tested at different operating/handling temperatures.
    3. Stability with respect to temperature needs to be assessed. Ship with a thermometer with a max/min temperature record whilst phantom handling. Discuss with SD theme.
    4. Acoustic scattering – Avoid for system benchmarking due to the complexities involved in the fabrication and testing.

3. **Multi-center studies**
    1. Multi-center fabrication of base material will be carried out initially- current study involves 12 participants
        1. Initial recipe is distributed- Aims to get familiarized with phantom fabrication procedure using mineral oil-polymer composite.
        2. Recipe for synthesizing tissue mimicking base material will be distributed once feedbacks from 3.a.i are received.
        3. Reproducibility of optical properties will be assessed from transmittance and reflectance measurements at Cambridge.
        4. Acoustic characterization will be primarily carried out by NPL and Leeds groups.
    2. Multi-center fabrication of image quality phantoms will be performed in 2020.
4. **Next steps**
    1. Obtain feedback from multi-center studies.
    2. Fabrication of tissue mimicking base material.
    3. Test the optical and acoustic properties of tissue mimicking base material.
    4. Present updates at SPIE photonics West 2020, BIOS meeting.

Roundtable discussion - Summary Study Design theme

Discussion questions:

1. Which image quality metrics do you think are valuable for PAI system characterization?
2. Which metrics do you use to evaluate or compare PAI and/or other imaging devices? How do you measure these metrics?
3. Are there other metrics or related challenges that should be considered?

1. Discussion of specific candidate metrics

a. Spatial resolution (axial, lateral, and elevational)
   i. Elevational or out-of-plane resolution is important
   ii. What inclusion types are appropriate? Planar dispersions of spheres, various filaments, etc. Need to talk to phantom design group re: practicality.

b. “Penetration depth”
   i. Penetration depth in ultrasound IEC standards is based on minimum detectable signal vs. electronic noise floor. In PAI what most people mean is “vessel detectability depth”, “useful imaging depth”, or similar. Something that means how deep you can see a vessel with endogenous and/or exogenous contrast depending on the application
   ii. Minimum detectable optical absorption coefficient (MDOAC) could be a useful metric for summarizing this aspect of image quality, separates from reporting detectable concentration of a chromophore
   iii. A relevant standard IQ metric is “low-contrast detectability”
   iv. How deep do targets need to be? E.g., 3 cm for ring-scanner PAT, but 2-3 mm for PA mesoscopy. Handheld, perhaps down to 2.5-3 cm. What phantom dimensions constitute a semi-infinite medium?

c. Spatial measurement accuracy (1D, 2D, and/or 3D)
   i. Distances are very important for ultrasound imaging (image calipers, depth measures, etc.)
   ii. Expected to be part of typical use of photoacoustic image information
   iii. How do you ground truth or tolerance position of inclusions? If sources have multimodal contrast, can you use ultrasound, micro-CT, other tools? Is using ultrasound of the PAI instrument a fair approach or not?

d. Uniformity

i. Several types of ‘uniformity’ identified: uniformity of background, uniformity of target inclusions (expected to be homogeneous PA sources), uniformity in signal amplitude over the field of view.
ii. How to quantify? Coefficient of variation is appealing (ROI std. deviation over ROI mean amplitude), see Joseph et al. JNM 2017

e. Property Measurement Accuracy
i. Quantitative imaging biomarkers such as hemoglobin concentration, blood oxygen saturation, contrast agent concentration
ii. All of these are based on chromophore concentration
iii. Consider tests suitable for assessing absolute measurements as well as trending/dynamic measurements

f. Linearity (signal vs. absorption coefficient)
i. Key consideration for quantitative biomarkers
ii. May need to be expressed as a function over field of view due to fluence variation
iii. Related to image uniformity, but may need separate metrics since several effects may induce nonlinearity.
iv. Use sparse distribution of targets over the field of view, similar to uniformity test

g. Artifacts
i. Difficult to quantify, but worth establishing categories/classes
ii. Could require binary reporting of image artifacts as present or absent during testing

2. **Discussion of how to measure and prescribe testing of IQ metrics**
a. We should ask people to produce best-case scenario images when possible under a pre-specified scope of allowable adjustments. Parameters can be modified at acquisition, but should not be tweaked/optimized in post-processing.
b. Phantom study protocols need to be very specific. If they’re open-ended, the participant isn’t at fault for doing something unexpected/detrimental to analysis/system comparison.
c. ROI size and shape should be pre-specified by the protocol. For example, circular ROIs matching inclusion size known *a priori*. Manual ROI drawing can have significant impact on contrast metrics.
d. Participants should disclose uncertainty in test results due to device parameters, measurement uncertainty, and possible human error.
e. Phantoms will need variable shape factors for each system (cuboid, cylinder, etc.), but a given test method design can be easily modified to be appropriate for each.

3. **Next steps**
    a. Identify consensus topics and design challenges overlapping between Study Design and Phantom Design working groups, engage with phantom group.
    b. Work with phantom group to consider ways to reduce dimensionality for phantoms intended for evaluating contrast-based image quality metrics. We don't want to embed and image a large number of targets with variable properties/position to cover all the proposed tests. What's the simplest phantom that achieves maximal image quality characterization utility?
    c. Review literature for expected total hemoglobin, hematocrit, and SO_2 values of blood vessels vs. size in vivo
    d. Review literature for image quality metrics used in standards for mature imaging modalities
    e. Survey IPASC membership at large to get initial ranking, prioritization of potential IQ metrics
    f. Develop draft study protocol for multi-center phantom imaging