OBJECTIVE IMAGE QUALITY ASSESSMENT SIMPLIFIED WITH GAUSSIAN MIXTURE MODELS

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SUMMARY

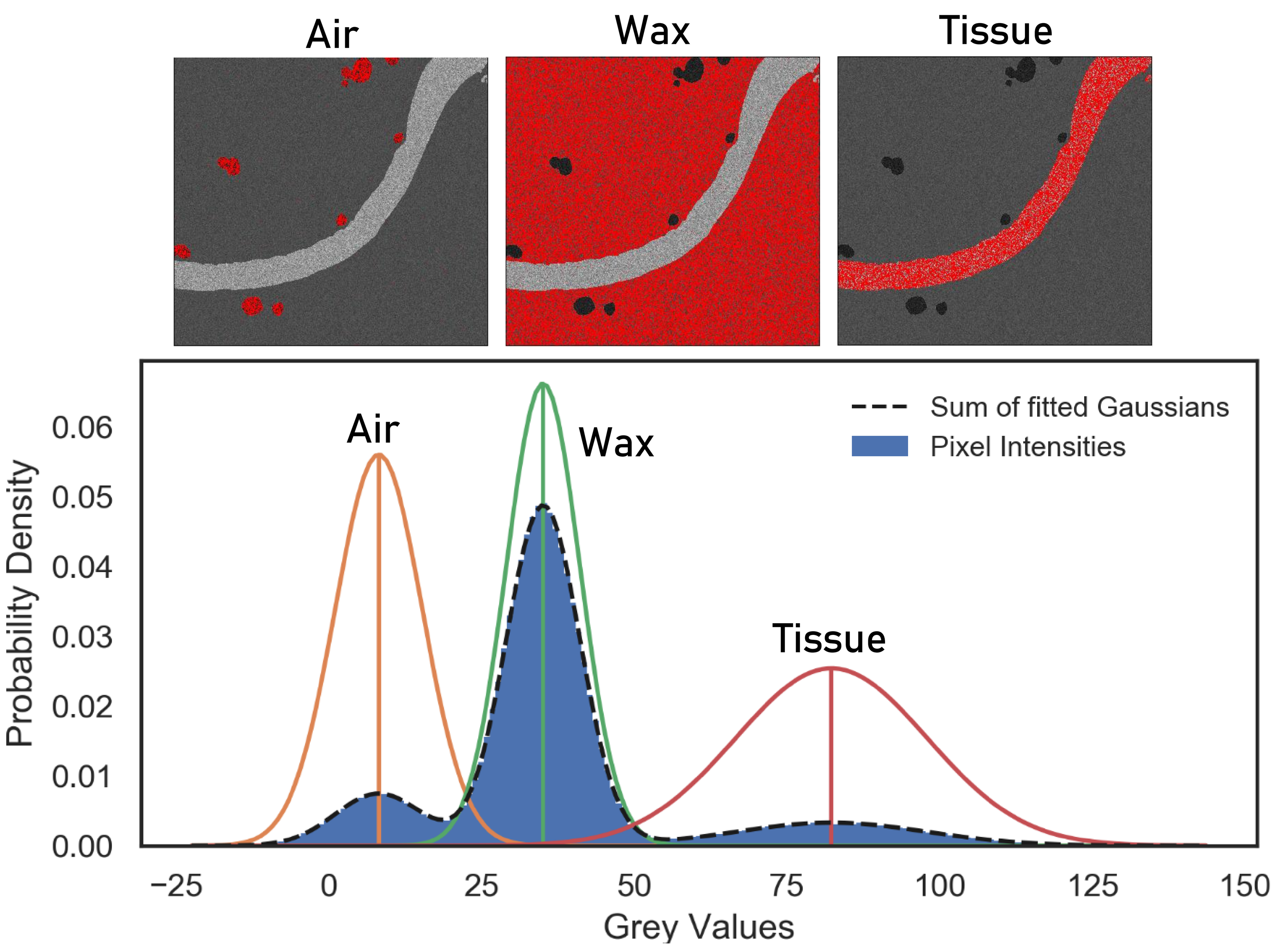
Quantifying image quality for X-ray micro-computed tomography (μCT) enables objective optimisation of imaging protocols [1].

Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) measure clarity of features in relation to the image noise. Conventional SNR and CNR measurement is performed by user selection of regions for each material, which is not repeatable and impractical for large numbers of 3D datasets [2].

Here, Gaussian mixture models (GMMs) have been used to calculate SNR and CNR of μCT datasets without user interaction. This GMM method is **semi-automated**, **objective**, and **repeatable**. Furthermore, estimated Gaussian properties of segmented materials can be used for applications such as quality control of imaging setups and optimisation of μCT imaging protocols.

IMAGE QUALITY ASSESSMENT

The grey value distribution of a micro-computed tomography (μCT) image is the sum of Gaussian distributions for each material in the specimen.



Gaussian mixture models (GMMs) estimate the mean (μ), standard deviation (σ) and the relative contribution of a user-specified number of Gaussian components, according to the number of materials in the specimen.

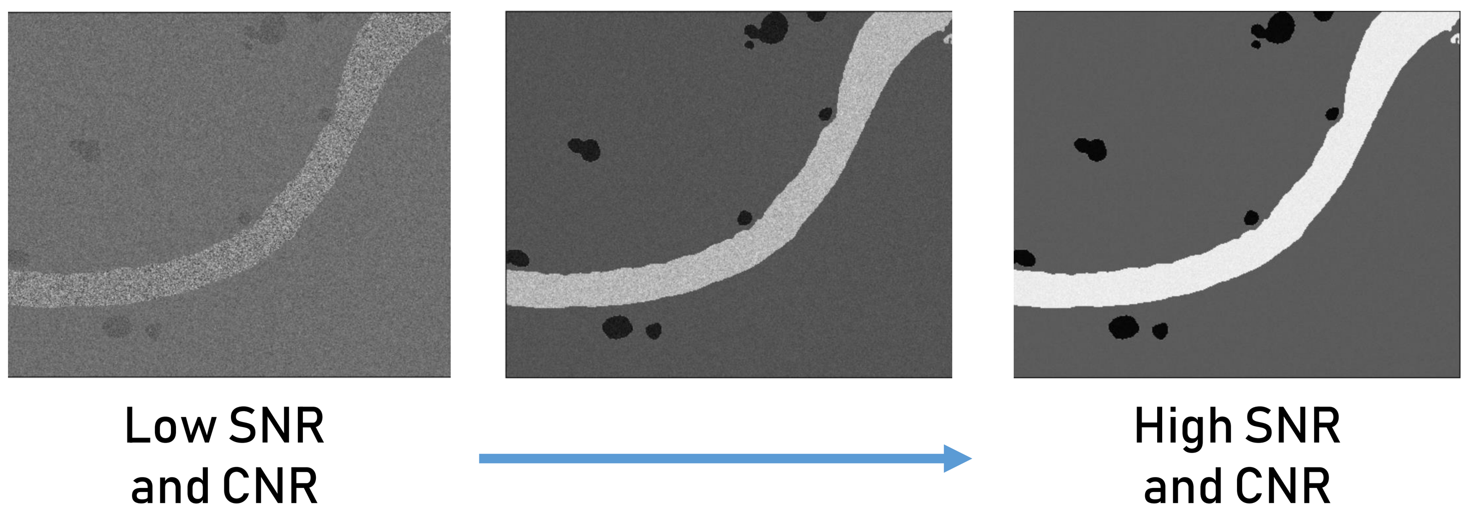
The estimated μ and σ was used to calculate signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) between all combinations of materials [3]. $\mu_{A,B}$ and $\sigma_{A,B}$ are the mean and standard deviation of grey values for materials A and B respectively.

$$\mathrm{SNR} = \frac{\mu_A}{\sigma_B} \qquad \mathrm{CNR} = \frac{|\mu_A - \mu_B|}{\sqrt{\sigma_A^2 + \sigma_B^2}}$$

A user-friendly tool to use GMMs for calculation of SNR and CNR was created using open-source Python libraries [4 – 8] and Fiji/ImageJ [9]. This tool was validated by comparing conventional and GMM calculation of SNR and CNR for phantom images with known SNR and CNR values.

BENCHMARKING TEST

Phantom images with known SNR & CNR (Ground Truth)
- ➢ Replaced grey values of each material with random values from Gaussian distributions with known μ and σ.

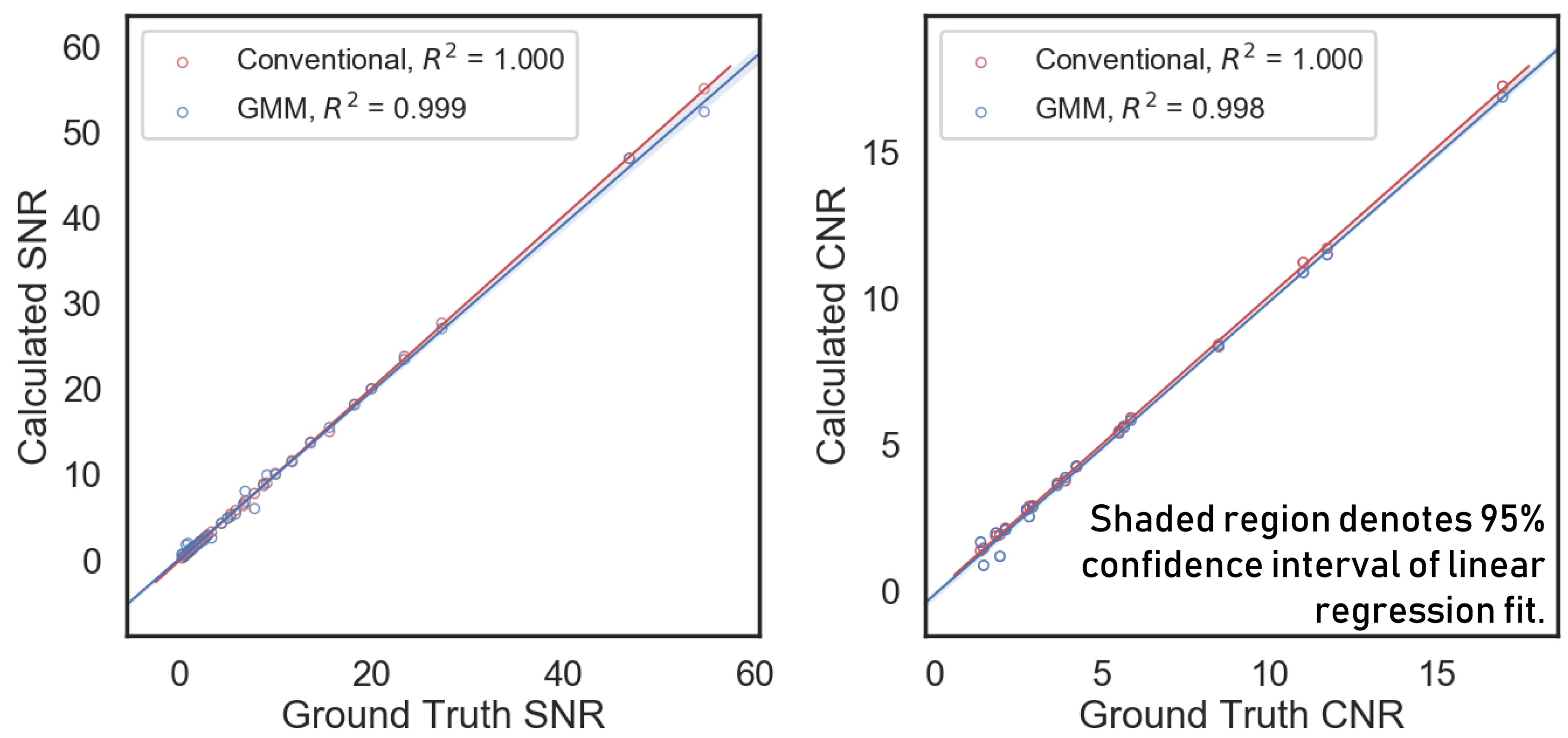


Calculation of SNR and CNR

Conventional
- ➢ 5 equal sized user-defined regions in each material on random slices (~5 x 10^3 pixels considered altogether)
- ➢ ~ 1 min/image with a custom user interface

GMM
- ➢ 15% of stack was used (~6 x 10^5 pixels considered altogether)
- ➢ ~ 1 s/image, no user interaction after setting initial parameters

SNR and CNR calculated with both methods were comparable to the ground truth values (R^2 > 0.99 in all cases).



CONCLUSION

Image quality assessment with Gaussian mixture models:
- ✓ Yields **comparable results to conventional** calculation.
- ✓ Is **more representative of entire image** as more pixels in the image are considered for calculation.
- ✓ Is **60x faster** than conventional calculation.
- ✓ Requires **no user interaction** after initial setup – objective and repeatable.

POTENTIAL APPLICATIONS

- ➢ Quality control for imaging setups
- ➢ Objective image acquisition protocol optimisation
- ➢ Aid selection of good quality specimens for further analysis, e.g. eliminating specimens with large components of unwanted materials

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This tool is available with a graphical user interface for Fiji/ImageJ and importable Python libraries at https://github.com/elainehoml/GMM_Image_Quality