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ImageJ detectability index plugin update

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Previous work

- In 2019 I wrote a set of ImageJ plugins [1]
  - The formula is based on equation 2 in Solomon et al [2]:

$$d'^2 = \frac{\left[\int\int |W(u,v)|^2 .TTF^2(u,v).E^2(u,v)dudv\right]^2}{\int\int |W(u,v)|^2 .TTF^2(u,v).NPS(u,v).E^4(u,v)dudv}$$

  - I replaced the double integrals with single integrals over radial spatial frequency:

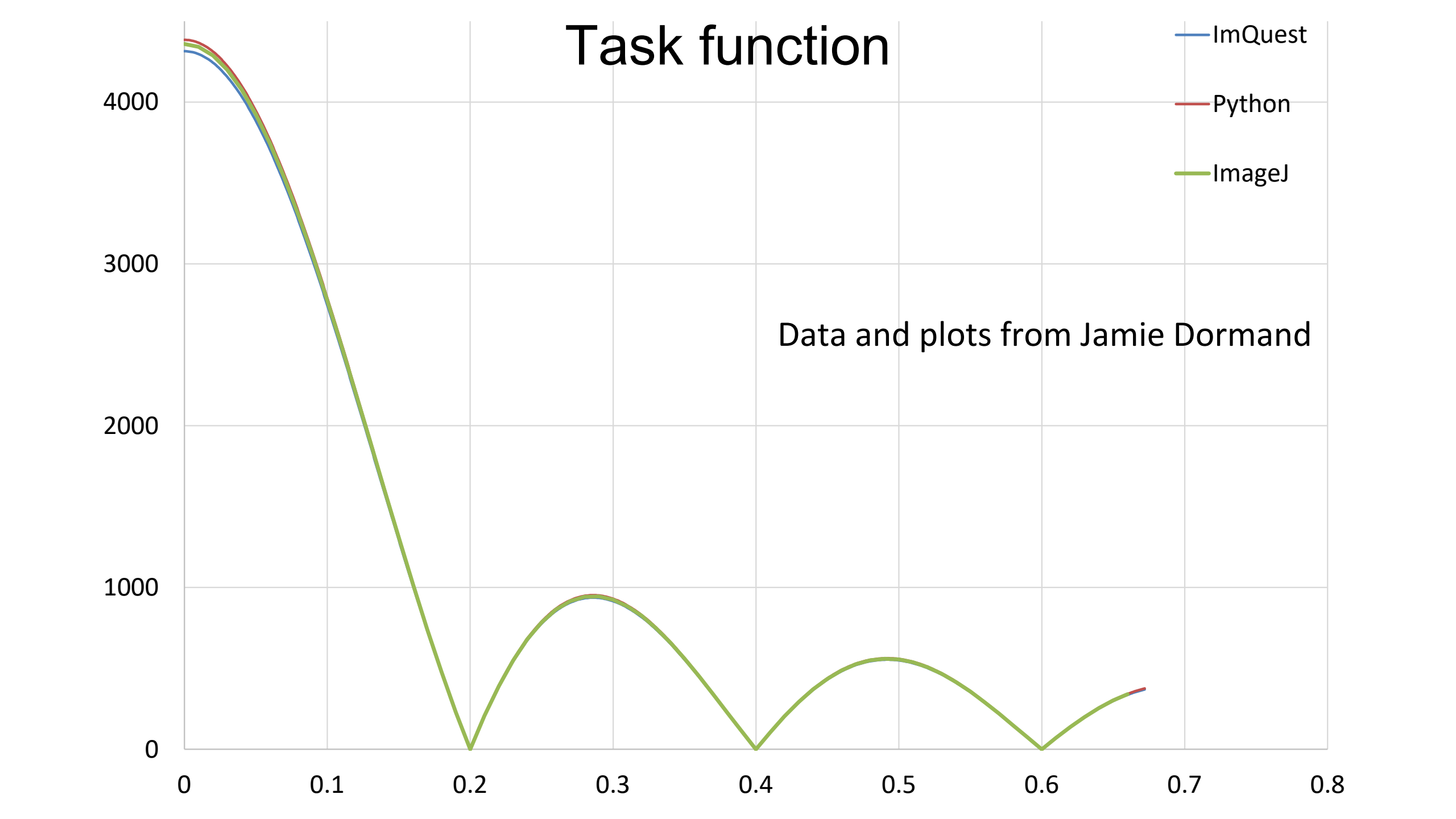
$$d'^2 = \frac{\left[\int_0^{f_N} |W(f)|^2 .TTF^2(f).E^2(f)df\right]^2}{\int_0^{f_N} |W(f)|^2 .TTF^2(f).NPS(f).E^4(f)df}$$

Recent events

- Jamie Dormand has been writing detectability index code in Python
  - d’ values agree with my plugin, but not with ImQuest
    - 1D TTF, NPS and task function results very similar for ImageJ, Python, and ImQuest
    - Jamie’s plots shown on the next slide
  - Jamie discussed with me, and then with Justin Solomon (who wrote ImQuest)

- The d’ formula from my ImageJ plugins is not mathematically equivalent to the formula used in Solomon et al [2] or ImQuest

- Collapsing the 2D integrals to radial integrals in the d’ formula mathematically under-represents higher frequency components


Task function
ImQuest
Python
ImageJ
Data and plots from Jamie Dormand
4000
3000
2000
1000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Modifications to the formula

- Adding a 2.π.f term to the integrals makes the radial spatial frequency formula mathematically equivalent to the 2D integrals

Original: $$d'^2 = \frac{\left[\int_0^{f_N} |W(f)|^2 .TTF^2(f).E^2(f)df\right]^2}{\int_0^{f_N} |W(f)|^2 .TTF^2(f).NPS(f).E^4(f)df}$$

Corrected: $$d'^2 = \frac{\left[2\pi \int_0^{f_N} |W(f)|^2 .TTF^2(f).E^2(f).f\,df\right]^2}{2\pi \int_0^{f_N} |W(f)|^2 .TTF^2(f).NPS(f).E^4(f).f\,df}$$

Simplified: $$d'^2 = 2\pi \frac{\left[\int_0^{f_N} |W(f)|^2 .TTF^2(f).E^2(f).f\,df\right]^2}{\int_0^{f_N} |W(f)|^2 .TTF^2(f).NPS(f).E^4(f).f\,df}$$

Modifications to the formula

- Square rooting both sides:

$$d' = \sqrt{2\pi}\frac{\int_0^{f_N} |W(f)|^2 . TTF^2(f) . E^2(f) . f df}{\left[\int_0^{f_N} |W(f)|^2 . TTF^2(f) . NPS(f) . E^4(f) . f df\right]^{0.5}}$$

- ImQuest d' values remain different. They are larger than values calculated using the above equation
  - An issue remains with the task function. It should be based on a jinc rather than sinc function to correctly reflect the radial profile of the Fourier transform of a 2d circular lesion

Other things to consider

- Task function
  - From conversations with Angus Fraser, and a literature review on his part, a Gaussian task function is more representative of a clinical task than a simple top hat function [3]

- Frequency response of the eye (E)
  - The code in ImQuest changed in 2023

- The choice of task function and eye response affects d’ values

Planned changes to the ImageJ plugin

- d’ formula
  - I will be adding the 2.π.f term to the formula
  - This will change the calculated d’ values

- Task function (W)
  - Currently uses a top-hat function
  - I will be adding a Gaussian option and a jinc-based option
  - Use of these will change the calculated d’ values

- Frequency response of the human eye (E)
  - I will be adding an option to use equation 4 from Eckstein et al 2003 [4]
  - Similar to equation 3 in Solomon et al 2015 [2], but no normalisation or squared term
  - Use of this will change the calculated d’ values

Acknowledgements

- Many thanks to Jamie Dormand, Angus Fraser, and Justin Solomon for their useful discussions, time, and willingness to share

References

1. https://bitbucket.org/dplatten/imagej-plugins/
2. Solomon, J., Wilson, J. and Samei, E. (2015) Characteristic image quality of a third generation dual-source MDCT scanner: Noise, resolution, and detectability. *Medical Physics* [online]. 42 (8), pp. 4941–4953. https://dx.doi.org/4941–4953. 10.1118/1.4923172
3. Maruyama, S. (2025) Gaussian Function Model for Task-Specific Evaluation in Medical Imaging: A Theoretical Investigation. *Journal of Imaging Informatics in Medicine* [online]. 39 (1), pp. 794–804, https://dx.doi.org/10.1007/s10278-025-01511-9
4. Eckstein, M., Bartroff, J., Abbey, C., Whiting, J. and Bochud, F. (2003) Automated computer evaluation and optimization of image compression of x-ray coronary angiograms for signal known exactly detection tasks. Optics Express [online]. 11 (5), p. 460, https://dx.doi.org/10.1364/OE.11.000460
5. Pimenta, E.B. and Costa, P.R. (2025) Model observers and detectability index in x-ray imaging: historical review, applications and future trends. *Physics in Medicine & Biology* [online]. 70 (7), p. 07TR02, https://dx.doi.org/10.1088/1361-6560/adc070

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Any questions?

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