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MERIT.jl

MicrowavE Radar-based Imaging Toolbox: Julia's Version

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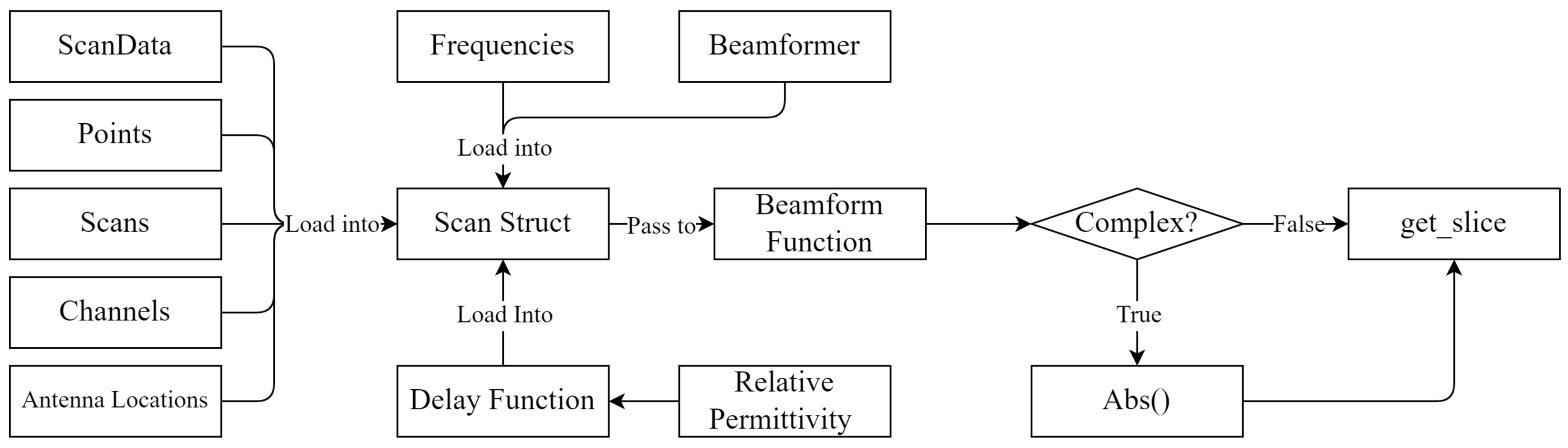
Abstract

MERIT aims to provide a software framework that is robust, easy to use and performant. It would implement a variety of microwave imaging algorithms, while leveraging powerful features available in Julia. This allows users to purely focus on developing new algorithms without having to worry about building the external scaffolding of functions required to produce an image.



Introduction

The use of such OS frameworks has seen much success in other fields such as PsychoPy and PsyToolkit in the psychological sciences, and Maxima in mathematical computing. The groundwork was laid by D. O'Loughlin, M. A. Elahi, E. Porter, et al in their paper entitled "Open-source Software for Microwave Radar-based Image Reconstruction". Here they implemented a series of classic beamformers such as "Delay-and-Sum", "Modified-DAS" and "Multiply-DAS". The MATLAB library also provides a series of utility functions that can be called to generate the imaging domain, or to generate an image slice from the beamformed data, for example.

The main drawback of MATLAB is that the language is far from performant, running about 2.24x slower than an equivalent Julia script [1]. Julia implements the "Multiple Dispatch" programming paradigm, which allows for powerful extensibility and an intuitive interface.

Method

Microwave imaging borrows heavily from the field of radar. One of the algorithms borrowed is the Delay-and-Sum beamformer. In DAS beamforming, we have an antenna array that can receive transmitted signals. Then for each channel (composed of a transmitting and receiving antenna), we calculate the path delay through every point using an estimation of the relative permittivity of the medium. To image a point, we time-align all the received signals using the calculated delays and calculate the squared sum. In the frequency domain this can be represented as:

$$I(r) = \left[\int_\Omega \int_{\mathcal{A}} \int_{\mathcal{A}'} S_{a,a'}(\omega) e^{j\omega\tau_{a,a'}(r,\omega)}\, da\, da'\, d\omega\right]^2$$

Where Ω is the transmitted frequency, $\mathcal{A}$ is the transmitting antenna and $\mathcal{A}'$ is the receiving antenna. We assume that the relative permittivity is the same across every path. One can then arrive at a discretised and parametrized version of the DAS beamformer.

$$I_{\epsilon_i}(r) = \left[\sum_{\Omega} \sum_{\mathcal{A}} \sum_{\mathcal{A}'} S_{a,a'}[\omega] e^{j\omega\tau_{\epsilon_i,a,a'}(r)}\right]^2$$

$$\tau_{\epsilon_i,a,a'}(r) = \frac{\sqrt{\epsilon_i}}{c_0}\left[\|r-a\| + \|r-a'\|\right]$$

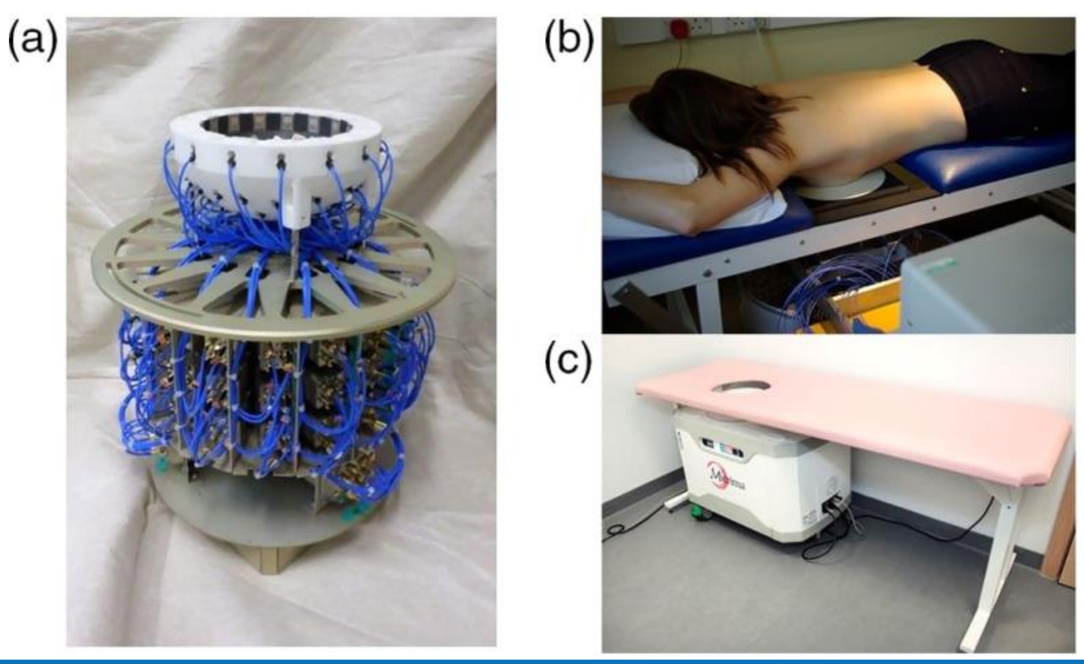


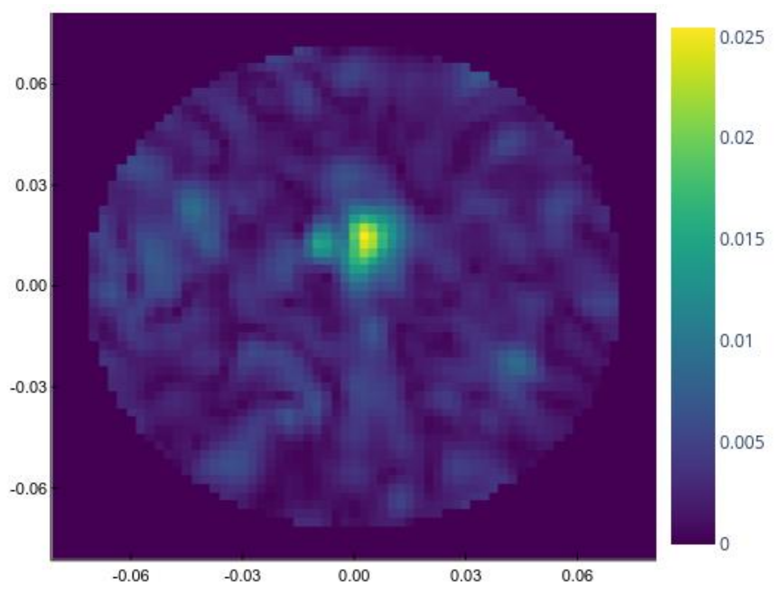
Image of the MARIA M4 System [2]

Julia Features

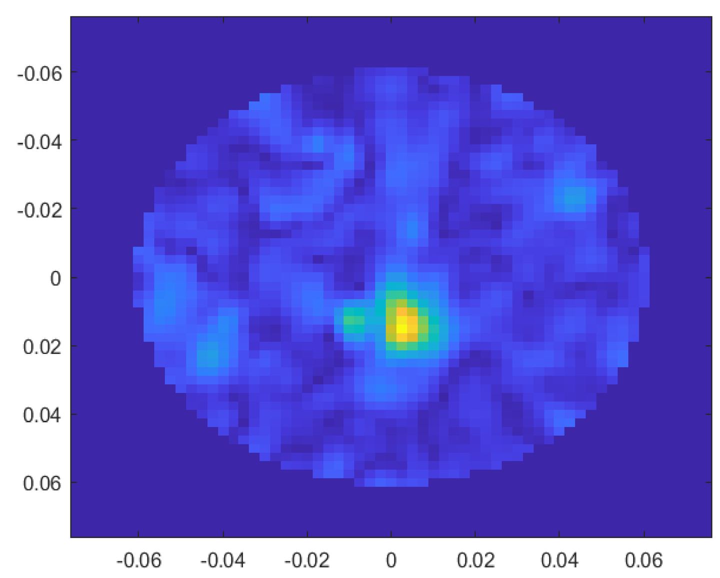
Julia as a programming language offers many powerful features that sets it apart from other languages. These features were the deciding factor when considering which language to port the MERIT library to. They include:

- Multiple Dispatch
- Memory Safety (with the option to turn it off)
- Easily broadcastable function definitions
- High level syntax code, compiled at runtime

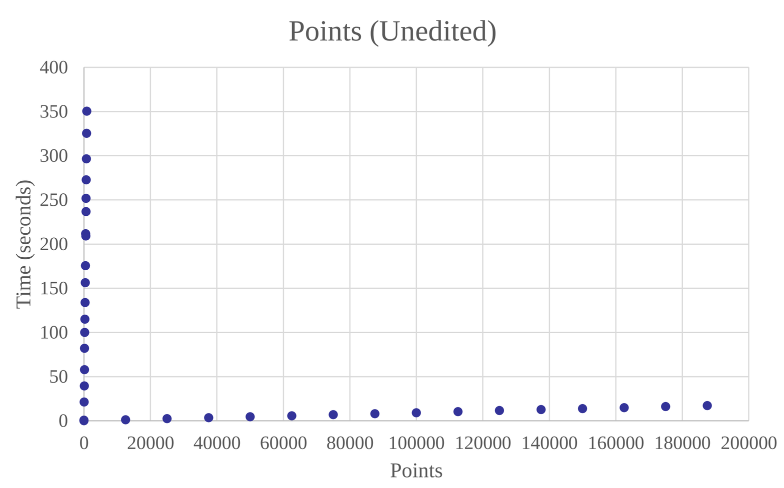
Results

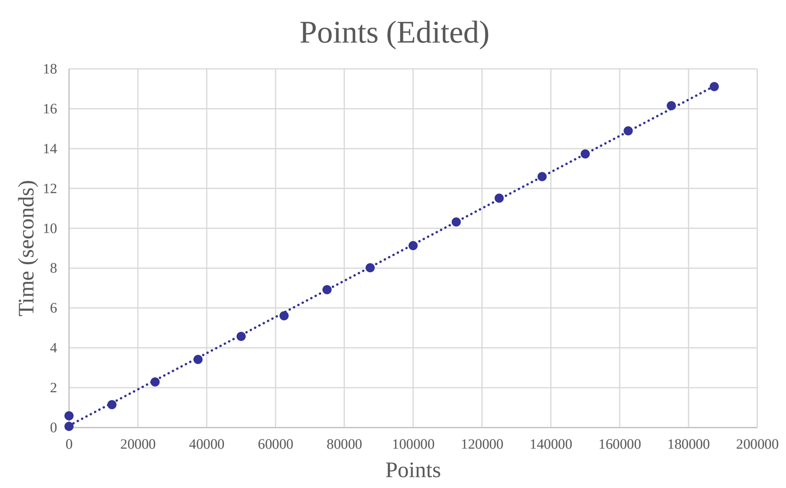


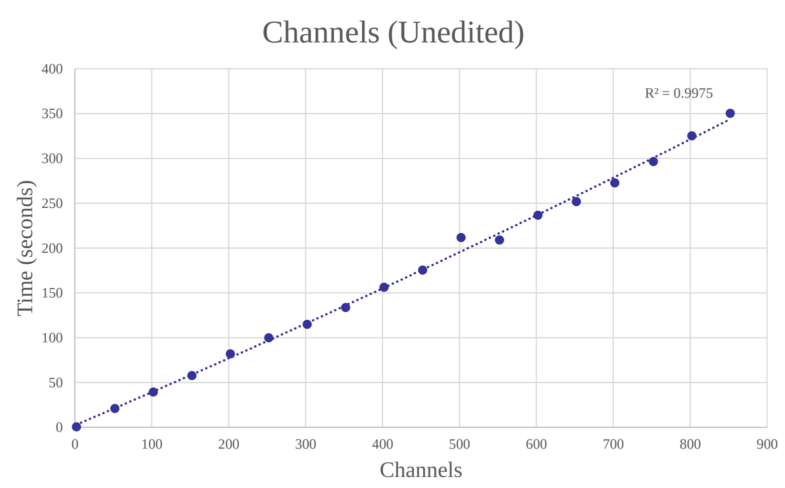
Julia Output

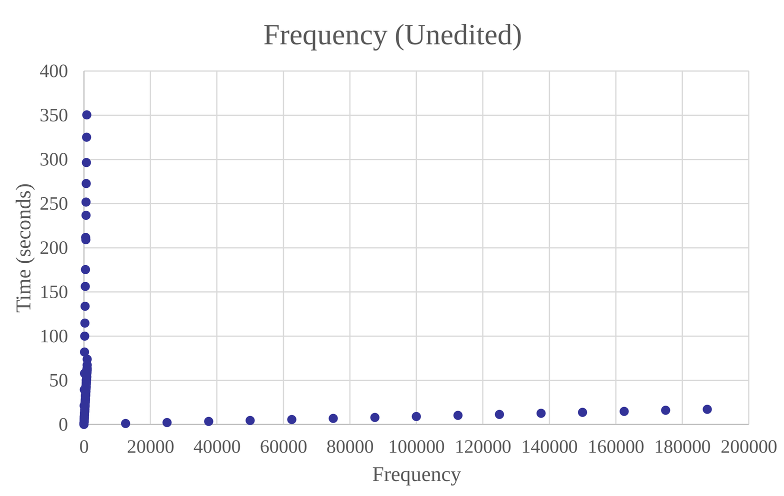


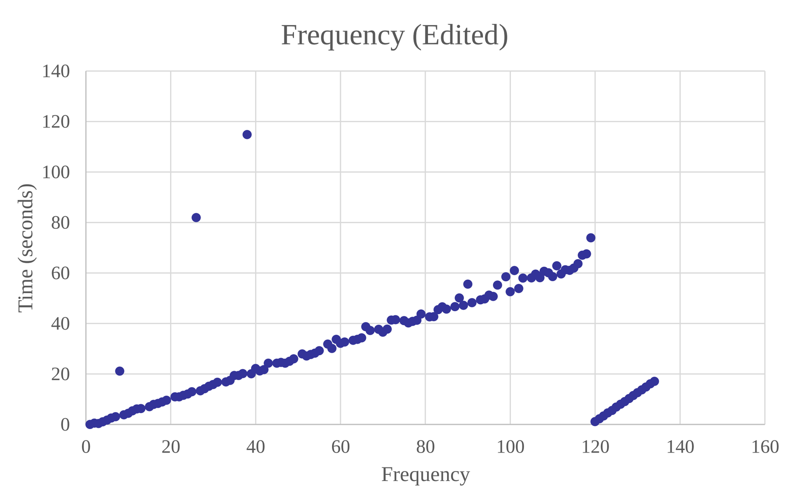
MATLAB Output











References

[1] J. Aruoba, S. Boragan; Fernandez-Villaverde, "A comparison of programming languages in economics:An update," p. 4, 2018

[2] Preece AW, Craddock I, Shere M, Jones L, Winton HL, "MARIA M4: clinical evaluation of a prototype ultrawideband radar scanner for breast cancer detection", 2016