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MERIT.jl: Julia's Version

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of the requirements for the degree of
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Abstract

MERIT aims to provide a software framework that is robust, easy to use and performant. It implements a variety of microwave imaging algorithms and a myriad of helper functions, all while leveraging the powerful features available in Julia. MERIT.jl also implements a "Scan" abstract datatype which allows users to subtype their own specialized datatype. Organizing the datatypes in this way means that MERIT.jl plays very well with Julia's own type hierarchy and also the other language features that depend on this. To encourage type safety, MERIT.jl implements a lightweight Points class which allows for efficient processing of coordinate points. In this way, collections of points won't simply be a matrix of Floats or Ints instead, they would be a Vector of the Points type. In this way, the Julia compiler will throw an error when Points aren't passed in the right argument, instead of providing a wrong output.

Acknowledgements

Thanks, Everyone!

Contents

Introduction

MERIT.jl was motivated by a need to streamline the development process for new imaging algorithms. Currently, any researcher who wants to code a novel microwave imaging algorithm not only has to code the algorithm itself but also has to code all the helper functions required to produce an image. All this time fixing bugs subtracts from the time that could be spent fine-tuning the algorithm and choosing an optimal parameter set. The use of such open-source software has seen widespread use in a myriad of fields. PsychoPy and PsyToolkit are two such frameworks that revolutionized the field of psychological sciences. By implementing commonly used functions and scripts, they have allowed researchers to design and run experiments in a matter of hours. It has also allowed researchers who have little to no programming experience to get up and running with automated data processing, thereby allowing them to focus more on the quality of their experiment. [1]

The use of microwaves in imaging has started to gain interest amongst the medical community as an alternative and safer form of imaging when compared to more traditional methods such as X-rays. Clinical trials such as the "MARIA M4" system has proven that such microwave-based methods are more comfortable and are a viable alternative to current mammograms [2]. Mammography is not the only area where this imaging modality is being trailed. It is seeing use in areas such as traumatic brain injury detection, bone degradation and tumor detection [?]. While the hardware has proved effective, the software leaves a lot to be desired.

That is where this project comes in. MERIT.jl aims to be an easy-to-use, extensible and featureful library. The goal being that anyone, regardless of coding experience, would be able to quickly create a script that allows them to process and visualize the scan data they have collected. The following sections will contain:

- A literature review on the existing microwave imaging systems
- A look into existing microwave imaging frameworks
- A discussion about the design choices and Julia features that are included
- An examination of the results and possible future work

Background

1.1 Literature Review

In order to understand the design requirements of the library, a literature review needed to be performed. The scope was narrowed down to 3 systems that showed promise and were broadly representative of the antenna configuration that future systems would adopt. Most systems will adopt one of the following setups

1. Monostatic
2. Leveled Multistatic
3. Fully Multistatic

These terms relate to the position of antennas around the breast tissue and how the resulting scan data would be structured.

1.1.1 MARIA M4

The first system we will look at is the MARIA M4 system developed by Preece et al within the Electrical and Engineering Department of the University of Bristol [2]. This is the 4th iteration in a series of MARIA systems that evolved from a system of 16 UWB antennas to 60 antennas in the current system. These all operate in a multistatic configuration, meaning that any antenna in the array can listen to any other antenna in the array, an example of which can be seen in Figure 1.2. This figure shows a top-down view, however, one can imagine this being generalized to a hemisphere of antennas around the breast.

As stated before, the MARIA M4 systems makes use of the UWB spectrum over a frequency range of 3 to 8 GHz. A VNA was used to step through the frequencies and collect the scans from the antenna. The system exploits the inherent symmetry in the antenna reciprocity to halve the number of channels (made of a transmitting and receiving antenna) collected, thereby speeding up the scan time. For the MARIA M4 system, this equates to a 1770 reduction in the number of channels collected. Figure **??**, shows the antenna array used in the M4 system (a), as well as the M5 system (c) which is an integrated package.

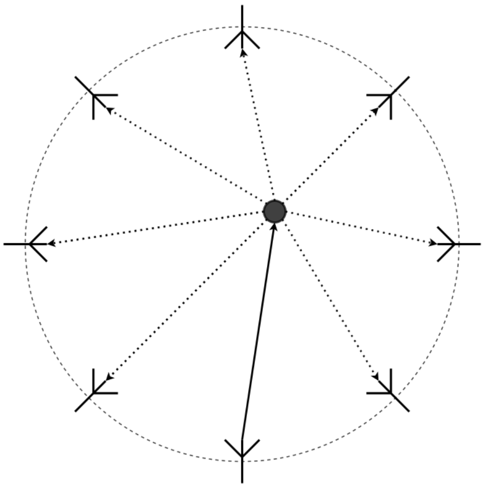

Figure 1.1: Example of a Fully Multistatic Configuration (Top-Down)

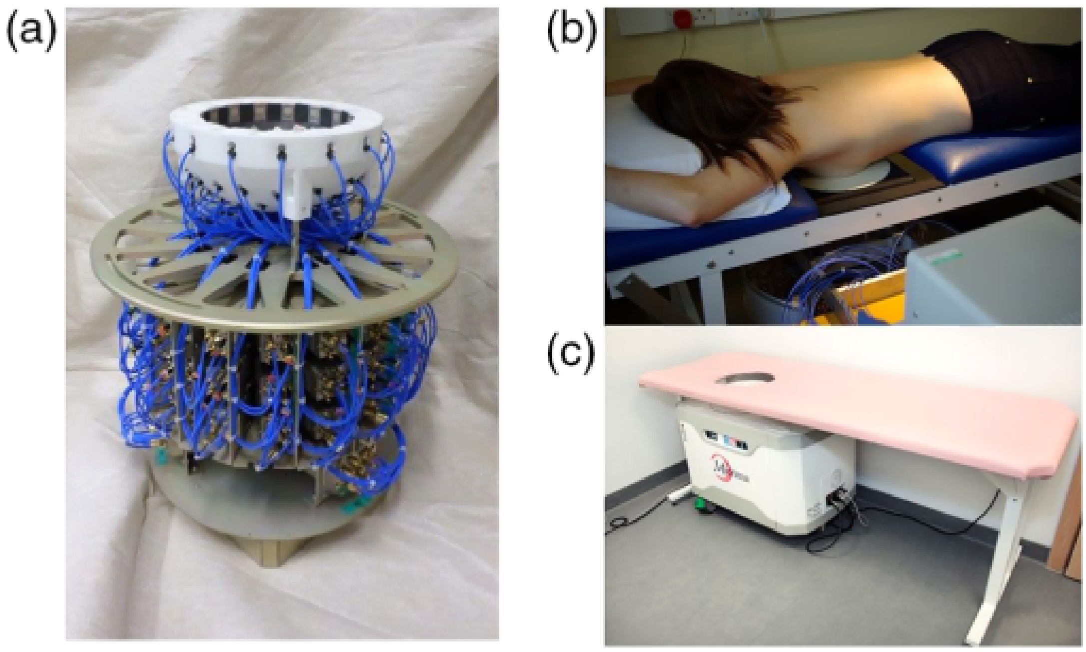

Figure 1.2: The MARIA M4 and M5 system. (a) The MARIA M4 antenna array. (b) The M4 in a clinical setting. (c) The integrated M5 package

Bibliography

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