2022 Laidlaw Reflective Report - Peter O'Flynn

Introduction

My research project focused on the impact of antenna design on radar-based breast image quality. I planned to model various different antenna shapes and sizes in a simulation software and then translate that to an image where a clinician could easily identify a tumour mass in a breast.

From a learning perspective my project was a great success. However I unfortunately just did not have time to collect all the results I had hoped for. This was due to technical issues with the simulation software outlined in detail in the following sections.

Structure & Methodology

I spent the first four weeks of my project developing a python script that would form the signal processing pipeline. This script would take the simulation data as an input and output an image. I was not familiar with some of the open source libraries I would have to use to build the program so I had expected this to take slightly longer than my research supervisor suggested.

In parallel I modelled various different antenna designs to learn about and document their various characteristics. I quickly settled on three types of antenna which I hoped to extensively model in my remaining two weeks. These were the vivaldi, microstrip patch and horn type antennas. I chose these because they were the best performing directional antennas. This means that they direct most of their power in one direction which is ideal for an imaging application where you want to direct all the power towards what you are trying to image. This is in contrast to an omnidirectional antenna used in local communication systems such as Bluetooth and WiFi - You want to be able to receive a signal all throughout your house or workplace, not just when the antenna in your mobile phone and router are aligned.

In the final two weeks I started running into problems. Having successfully troubleshooted the python script I was finding that the data that I was getting from the simulation software had a huge amount of interference - So much so that the actual objects I was trying to image were not showing up. I spent a lot of time playing around with different simulation parameters and consulting with my research supervisor. However by the end of the six weeks we were still unable to produce a clear 2D image.

After the six weeks had concluded I was still eager to understand why my simulation setup was not working. The project turned into somewhat of an evening hobby and I eventually discovered the reason why.

The simulation software - Ansys HFSS - is a Finite Element Analysis (FEA) software package. This means that it breaks down incredibly complex problems like antenna design into tiny elements called nodes. The finer these nodes become, the more accurate the simulation becomes. However the tradeoff is that you will require far more processing time and computational power. This high node-count was unfortunately not possible with the student edition of the software that I had secured. The node-count was limited to 70,000.

It turns out that my simulation simply was not accurate enough to detect the tumours when there were alternative sources of interference such as other antennas. And I would require a much larger node-count and more computational power to generate strong results.

Results

My academic conclusions at the end of the six weeks are about the viability of certain antenna designs in a breast imaging implementation and the requirement for a high-node count, high-power computational setup if one is to perform electromagnetic simulations.

I see this as falling short of what I hoped to achieve. And while that is disappointing I have learned a huge amount while completing this project. The sheer amount of knowledge I have gained about 3D modelling, simulation, programming, electronics, antennas and signal processing more than makes up for the lack of strong academically publishable results.

Original Proposal vs. Finished Project

I was able to stick quite successfully to my proposal in the first four weeks of my project. However once the unexpected issues with the simulation software came to light I was unable to continue with my plan in the final two weeks.

Luckily, I was able to maintain a very good relationship with my supervisor throughout the project and we had bi-weekly meetings where I gave updates on where I was at and what I had tried. He would then offer guidance on what problems I may be experiencing and suggestions on how to overcome them.

I had hoped to build a fully automated framework that could automatically trial hundreds of designs and compare the results. The system would be able to trial different sizes, shapes and spacing of the antenna array. And then also vary the parameters of the individual antennas to see if that had any effect on the image quality.

Next Steps

Upon returning to college I managed to secure an academic grade licence for Ansys HFSS which means that I can verify my hypothesis that the node-count is to blame for my lack of usable simulation data.

I would love to continue this research and look at building a physical prototype to verify my designs. I believe this area of research has huge potential and I would be interested to see a commercial implementation of it in the future.

There is also a potential opportunity to implement the signal processing pipeline onto another rapidly evolving technology - the FPGA - which, in the future, could lead to image processing in real-time. This would be a game changer for the medical community and it would be interesting to see what areas radar imaging could be applied to outside of breast cancer.

Achievements & Challenges

The greatest accomplishment of this project was definitely the development of the python script. Ironically I believed that this would be the major challenge and not the simulation software itself. I gained a huge amount of technical knowledge and experience working with the various python libraries to build this script. Many of these libraries are widely used in industry so it is most certainly an invaluable experience.

The biggest challenge was certainly trying to understand why my simulation did not work as expected. The literature around high frequency simulations is highly technical and I struggled to understand a lot of it which then in turn slowed down my ability to iterate through solutions. This was compounded by the fact that the simulations took so long. I could only try a different setup roughly every four hours.

Learnings About Myself as a Researcher

My primary learning about myself is that working in eight hour blocks from 9-5 doesn't generate the best results. I would frequently split my days into four two hour blocks with at least an hour in between each block working on something completely different. Within these blocks I would use the 'pomodoro' method of 25 minutes of focused work followed by 5 minutes of something different.

I think I can do much better in displaying my results. Having a research supervisor that is very closely tied to the field meant that I was probably spoiled in that regard since even if what I was showing didn't make much sense he still knew what I was trying to display.

I found that throughout the project duration I had strong levels of determination and resilience. This was somewhat expected as, especially with technical problems, I find that the more challenging I perceive a problem to be, the more time I will want to invest in solving it. Even if that comes at the expense of my personal relationships. Many people will argue that a strong work-life balance is necessary however I think that if you want to solve challenging problems and really make an impact you need to put in the extra effort and work longer and harder.

I think the most challenging part of my project was actually writing this reflective essay as it is not something that I have ever come across in my field. As an engineer, I like clearly defined outputs and objectives. So a reflective essay where you have to answer open ended questions and thoroughly discuss things is challenging and feels verbose. This is probably one of the only times during my project where I struggled with motivation since it feels like there is no end in sight most of the time while writing it.

Learnings About Myself as a Leader

The world of radar-based breast imaging is still quite small as the technology is still in its infant stages. I did not find myself coming across many other leadership styles while working on this project simply because there were not very many people to come into contact with.

Collaboration with my research supervisor did play a major role in the project. However since he was there in an advisory capacity as opposed to actually making decisions on the direction of the project I don't feel like there was much leadership involved.

Final Experience vs. Personal Development Plan

I was able to strongly adhere to the plan I defined in the personal development plan. While I believe that this was mainly due to chance since a lot of things fell into place after my research project concluded it was still encouraging to see some parts of my summer one plan completed.

I ended up getting an offer for an 8 week internship at FoodMarble - A digestive health startup in Dublin - who required me to give a brief summary each morning to the entire engineering team on the previous day's challenges and solutions. In addition to this I was required to give many comprehensive presentations on various technical and analytical topics. I believe that this adequately satisfied my goal of gaining confidence while public speaking.

In terms of project management skills, I immediately started building a single-seater race car with the Formula Student team within Trinity. Since I have a strong manufacturing background and have spent the last nearly 5 years collecting machine tools I ended up managing a team of 18 other student engineers in my back garden building and constructing a car from scratch. This turned out to be an incredible feat of project management and logistics and I learned a huge amount while doing it. I returned from the Formula Student UK competition feeling much more confident in my project management skills and will endeavour to seek a more project management focused role on the team in the coming season.

I also completed my goal of learning 15 minutes of French on DuoLingo each day so hopefully that is another skill that will come in useful in my professional career.

Conclusion

Overall, my summer one Laidlaw was an exceptional experience. The technical skills and knowledge that I have gained, the connections that I have made and the confidence that I have built with project management and public speaking will prove useful to me in summer two and beyond. I am excited to see what the future holds and especially excited to get started on my leadership in action project.