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Greetings,

My name is Huay Din and I aspire to pursue a life in research in medical physics. As a modern student in the sciences, I have come to terms that precise descriptions of reality often lack closed form analytic solutions, and often these events are probabilistic in nature. But not all hope is lost! In this world of massively available data, I find great interest in using mathematical models, machine learning, and other statistical tools to obtain insights into systems of interest. In my time as an undergraduate, I've worked on a wide range of mathematical modeling projects, starting from modeling a first-principles music system, to a generalized magnetic resonance imaging fingerprinting model, to examining the dual-energy CT-Xray, and to working as a research assistant in the Griswold Lab at University Hospitals. From these experiences, I have only become increasingly fascinated by the potential for rich mathematical and physical investigations for medical imaging systems, and in the Biomedical Engineering and Physiology PhD track at Mayo Clinic, I wish to continue pushing the boundaries of models versus reality.

Background & Motivation:
So what's behind my fascination with mathematical models, and what's with my focus on using these models for medical imaging? With regards to the first question, I believe that mathematical models are the perfect mix of imagination and science. From my own experience, who would have thought that because music and physics share the same symmetry that their structure could be understood through statistical mechanics? Or since medical imaging is a subset of general image recovery, there's potentially a more robust network construction? Additional to my own research experience with modeling, my major and coursework also demonstrates a fitting undergraduate training that was both rigorous and creative. As a math and physics major, I've been introduced to not only a staggering number of perspectives and tools to apply to scientific fields, but also I have developed both the ability to strictly reason problems from math and be more flexible and intuitive with physics. One example in my coursework is a course I took called the Mathematics of Data Mining and Pattern Recognition. Alongside the techniques and their math proofs we were introduced to, SVD, SVM, Kernel Methods, and so on, the course was taught in a format I immensely enjoyed – one where we were given the question, data, and was told to run. The difference between this course and research is that I wish to dream up of novel questions and their solutions. For my own career, I believe that mastery in these models is the way to go.

But why medical physics? The root of my interest comes from pinning down that medical imaging is all about information retention. There is a sound mathematical basis in which we can understand medical physics and imaging, i.e. inverse problems, stochastic processes, data analysis, and understanding the physics of and modeling biomedical processes allows for insight into not only areas of optimization within medical imaging, but can potentially lead to novel technologies and more general advancements within math and physics. So why have I decided to pursue becoming a biomedical scientist instead of becoming a mathematician? My answer is threefold, 1) I'm drawn to the inherently interdisciplinary and highly collaborative nature of biomedical engineering and imaging. In this sphere, not only will the questions involve various fields of knowledge, but also collaborating with a variety of fellow researchers with different perspectives and training will be immensely rewarding and fun; 2) I am more motivated and love the impact of this field. I've always known that I wanted to do work in theoretical physics, but my

specialty was always uncertain; however after my many experiences in medical physics, I am certain I wish to pursue a career in theoretical medical physics; 3) I am determined to improve the lives of people through my research work. In the larger picture, the use of machine learning in healthcare has an abundance of potential, such as multi-modality patient care, individualized treatments, and in global healthcare. All in all, I would like to dedicate myself to working towards accessible healthcare through the use of medical imaging.

Research Experiences:
Disclaimer: As an application to Mayo Clinic, I feel a certain level of obligation to say that my medical research work has been my most satisfying, but for reasons that will be made clear in the following section, I have many intensely rewarding and fond memories of my work with Jesse Berezovsky. For this reason, I would like to argue that my most rewarding research project has been with Jesse Berezovsky and that my most rewarding research experience has been with Julia Dobrosotskaya.

I have had considerable research experience with mathematical modeling, data analysis, and machine learning methods. To start with, I've worked with Jesse Berezovsky in the physics department at Case Western Reserve University (CWRU) to build a system of music from first principles. More specifically, we studied emergent critical behavior in a musical phase transition via statistical mechanical methods (Kibble Zurek Mechanisms, XY Model, Metropolis Monte Carlo - Langevian equations) to simulate a system of music. To me, the project was a powerful demonstration of the universality of mathematical models, although music and condensed matter systems are so obviously different on the macroscopic level, through sharing the same symmetry group class, we were able to invoke the same physics! In this work, I obtained extensive experience with handling simulations, data analysis, and creating the software and hardware for our physical composer – skills that I was able to translate well to my future work in medical imaging. In addition, the highly interdisciplinary nature of this music-physics work was also significant in my development of becoming an effective scientific communicator – as I was doubly demanded to present both the music and physics to a variety of audiences. To highlight some achievements, I wrote and will be first authored to a paper currently in peer review with PLOS One, I presented at the 2021 American Physical Society March Meeting and I was awarded funding and presented through the SOURCE Summer Research Scholarship. Another wonderful outcome is holding a concert in collaboration with the Cleveland Institute of Music. For my work here, I was also granted the James C. Wyant Award from the CWRU physics department for research accomplishments outside the senior project.

Even after all my work with Jesse Berezovsky, I would say my most satisfying research experience has been with Julia Dobrosotskaya in the math department at CWRU to investigate the general inverse problem of Magnetic Resonance Fingerprinting (MRF) via the framework of neural networks. In greater detail, MRF already is a novel technique that trades off spatial sampling for temporal sampling - which allows for an immense speedup. We proposed another paradigm change, where we instead sought to optimize our model not through the design of a NN, or the inclusion of more clinical data, but to instead tune a general training set composed of natural images, functional piecewise smooth images, and such, and consider different MRF data representations. This research was definitely my most challenging one, and for that, it was also my most rewarding one. In this work, I was given immense freedom in developing, designing, formulating, proposing, and testing models. Not only have I built many technical skills from the ground up (familiarity with fourier transforms, mathematical formulations for research with linear algebra/real analysis, NNs, working with GPU, the high performance cluster, PyTorch, Python, etc.), but I have also more intensely gained invaluable research experience. The kind of research where the outcome was unknown, where we're developing the theory, tools, testing cases as we go along, and as a result I felt all too accurately the highs and lows of research. At times my rate of progress was immense and work was exciting, but for longer times when progress stalled, I began to doubt the idea

and despair at the time I invested. It was especially frustrating at times when progress stagnates from a silly error in code or misunderstanding in the physics of MRF, but equally thrilling when flashes of insights work! I call this my most satisfying work because I became a more resilient researcher, I gained a sound knowledge of deep learning (DL) and mathematical formulations in research (emphasized through working with a math professor), and overall became a stronger researcher and have keenly felt the effect of this work on my later experiences with Adam Wang and Yong Chen. I am confident that I would similarly succeed and thrive in the Mayo Clinic environment. We plan on publishing a paper in the coming months where I will also be first authored to.

Through my previous research experiences, I was awarded from the American Association of Physicists in Medicine (AAPM) their summer undergraduate research fellowship, where I was able to work with Adam Wang at Stanford last summer. For my summer experience there, I worked on the question of "Is Two Better Than One? Super Resolution for Dual-Layer Radiography with Convolutional Neural Networks." In more detail, I worked to investigate that when given two different lossy images with perfect spatial and temporal alignment, a) their combination will be an image with greater resolution than the two independently, and b) if through CNNs, we are able to obtain a super-resolved image that outperforms a previously demonstrated mathematically optimal multilayer image recombination algorithm. Adam Wang's hands off approach to mentoring was very appropriate for me. With weekly meetings (which were extremely useful in bouncing ideas), I was able to within the three months I was given to create the model, training sets, devised the methods to evaluate this question, and submitted an (now accepted) abstract to SPIE Medical Imaging 2023. I would say my most invaluable gain from this work is being introduced to the world of CT-Xray. Alongside MRF, CT-Xray is a modality where I strongly feel the potential for available and accessible medical imaging.

After my time with Adam Wang, I returned back to CWRU for the Fall 2022 semester. Currently although I am still working with Julia Dobrosotskaya, I have also joined the Griswold Lab under the mentorship of Yong Chen. And in three months, I've worked on accelerating MRF kidney acquisition and reconstruction through CNNs, where I have also submitted an abstract to ISMRM 2023 on our findings. Despite graduating this semester, I will be continuing to work in the lab for Spring 2023 as a student researcher.

Interests & Broader Impacts

To state explicitly, my own aspirations are to pin down mathematical theorems and establish bounds to information, datasets, and its forms; to use those findings to optimize and develop novel imaging technologies; and to work towards convenient and available imaging devices for a global audience. Conducting my PhD at the Minnesota Mayo Clinic site will bring me closer to my goals. I am particularly interested in working with Lifeng Yu. Through the AAPM fellowship program, I was able to attend their 2022 D.C Conference, and there I met with and heard about his research. I am greatly intrigued on multi-energy and photon counting CT technologies – I would love to work on establishing bounds to image reconstruction for the two techniques when combined. Another investigator I would be interested in working with is Armando Manduca, whose expertise in elastography techniques with MR/ultrasound and in biomathematics are both ones I wish to obtain. Overall there are many fantastic researchers at Mayo Clinic, and I would be amenable to working with them all.

Outside of research, I am also actively involved in providing a platform for others to communicate. I am currently co-president of Math Club, where the club role is to facilitate and inspire student math presentations. In the last two years, I have directed our club's purpose to become a more general undergraduate representative group for the Math Department. Some highlights of my actions and initiatives are organizing a new math undergraduate colloquium series and providing a better

undergraduate working space. Furthermore, this semester I founded an Association of Women in Mathematics chapter at CWRU. The aim of this club is to build a math circle of female mathematicians, where we hold discussions about our experiences in the field as mathematicians. What's more, I've been business manager for CWRU's Literary Magazine since my freshman year, where our aim is to collect creative works by the student body in all the colleges to then showcase in semesterly magazines. All these activities I've listed above have been towards building and strengthening the community around me. At Mayo Clinic, I would love to not only continue contributing to the scientific discussion and group, but to also begin building my own platform towards a broader audience.

Through my motivations and experiences, I believe I am well prepared to not only flourish in the PhD program at Mayo Clinic, but to also contribute to the research community there.

Thank you for your time and consideration.

Huay Din