Statement of Purpose

of Abhijit Chowdhary (Computer Science Ph.D. applicant for Fall—2020)

I am intent on obtaining a Ph.D. in order to study and, later under a university, research the field of computational and applied mathematics. Currently my main research interest is in the theory and practice of the *numerical solution to PDEs*, especially viewing this under the high performance and parallel lens. In addition, I have more theoretical interests in the behavior of PDEs in a *nonlinear dynamical systems* setting, specifically in approximating their solutions in order to reveal underlying control parameters. In general though I'd like to be able to model and understand the behavior of interesting systems (often like those found in fluid dynamics, materials, etc.), through both a keyboard and pen.

I began to have an inkling towards these interests early in my undergraduate career, and since then I have madly dedicated myself to learning the field; which by it's nature demands a huge breadth of background in various different subjects. I intentionally loaded my schedule, took summer courses, and from my sophomore year onward I made sure to take advantage of the accelerated and more detailed graduate courses here at NYU. At the end of my undergraduate career here at NYU, I'll have taken 11 graduate courses (out of 25 including undergraduate & summer courses) in computer science and math, including finishing the numerical analysis sequence offered for incoming Ph.D. students, three advanced topic seminars in computational math topics, and graduate PDE and algebra to improve my foundations. In addition, in order to keep my algorithmic skills sharp, I maintained a department tutor position for both the undergraduate and graduate algorithms courses through four semesters, stopping this semester only because my usual professor went on sabbatical. Also, in an effort to try and evolve my maturity towards research, I occasionally ran a computer science reading group through our local ACM chapter, which I am a board member of, looking over more classical papers like the original tit-for-tat iterated prisoners dilemma article, the cyclotomic AKS primality test paper, etc. In addition, I have a few completed projects and original research under my belt.

Algebraic Point Set Surfaces: I took the graduate course geometric modeling in my sophomore year, which investigated the cutting edge research in the field. For the final project, I investigated and implemented the paper *Algebraic Point Set Surfaces*[1] by Gunnebaud and Gross, which was a modification to the usual point set surface technique for construction of surface normals and a mesh from a point cloud. I attempted to improve the matrix assembly via parallelization and understand methods to improve the efficiency of the generalized eigenvalue solve underlying the surface normal reconstruction.

Parareal: In my junior year, I wrote a topic paper on *Parareal*[2], a parallel-in-time finite difference scheme, discussing the details of its implementation, strong and weak scaling properties, and its convergence, efficiency, and stability analysis. My implementation was tested on the high performance computing cluster here at NYU, named Prince.

REU @ Ohio University: Finally, the most formal research experience I've had is in collaborating with Qiliang Wu from Ohio University and another student in the summer of 2019 in an REU on the diffusive stability of the Swift-Hohenberg equation near the Zigzag boundary in 2D. Originally, I was lured into the REU with the promise of a numerical project, but was swiftly distracted onto this topic instead, and despite it being out of my field at the time, the beautiful analysis within the proof we managed to construct nearing the end of project has convinced me to take a closer look at the theoretical approaches to understanding the behavior of troublesome

[1] https://abhijit-c.github.io/storage/Guennebaud07.pdf

[2] https://abhijit-c.github.io/Research/resources/Parareal/Parareal.pdf

systems; it's why I'm taking a course in perturbation theory now. My favorite part of the program was it's freer structure, as our days would be split into two halves, in the first of which we would research, LaTeX, and push the proof on our own, and in the second part we would gather and try and work out the major difficulties of the proof together. Through this, the REU convinced me that being a researcher is something that I'd not only desire but be good at; the process of going to sleep and waking up with a paper in hand and spending hours locked in a room with a problem and my colleagues was invigorating to the limit. My main contributions to this project, aside from those implicitly made in the group work, were in finding and subsequently correcting an error in an old classical paper in the literature, resulting in an appendix, the painstaking computation and verification (via Mathematica) of a critical eigenvalue expansion, and in working out the final details of the contraction argument, completing the proof. Although the paper is not yet in preprint, it's in the final draft stages and Professor Wu presented the research[3] at Miami University's recent conference in Differential Equations and Dynamical Systems.

During graduate school, I hope to be able make the transition, as I did in my REU, from learning about these subjects and writing survey papers on their topics, to producing my own original ideas on the field. To this end, I'm very excited to apply to the computer science department at University of Illinois, one of the stronger schools directly in my field. In general, the scientific computing group here has many different opportunities for me to get involved in full time research. Specifically, *Professor Paul Fischer's* research is exactly what I'm interested in, from spectral element methods, to computational fluid dynamics, all which applied with a parallel lens if possible. In fact, we've both[4] worked on the same topic of Parareal before. In addition, I'm interested in *Professor Andreas Klöckner's* work on the application of GPUs in the solution of PDEs, specifically for discontinuous Galerkin methods. So far my work on parallelization of numerical PDEs has been limited to OpenMP and MPI mixed strategies, but I do know CUDA and have been wanting to try my hand in these ideas (and I would have if for the fact that I currently own an AMD GPU instead). Similarly *Professor Luke Olson's* work on algebraic multigrid and sparse matrix operations on GPUs would be topics of interest for me. With such opportunities in mind, I would be very happy to join the computer science department here at the University of Illinois.

[3] https://abhijit-c.github.io/Research/resources/SHE/slides.pdf

[4] My topic paper, and his paper *A parareal in time semi-implicit approximation of the Navier-Stokes equations*