Research Description

Homepage: https://rohanchandra30.github.io/

Recent years have seen progress in theoretical guarantees for solving non-convex problems without any form regularization. One example is the development of the Wirtinger Flow algorithm to solve phase retrieval. This method requires an initial guess and then proceeds to use gradient descent without projecting the iterates to a ”trust region”. Another example of theoretical investigation of a non-convex problem is low rank matrix recovery. A recent paper from Princeton provides a polynomial time complexity for vanilla gradient descent using a suitable initializer. I am interested in studying theoretical properties of low rank matrix recovery and this is supported my background of working with non-convex problems.

Phase Retrieval (current research)- Phase Retrieval is an example of a non-convex quadratic program with quadratic constraints. In the real-valued case, it is a combinatorial problem of determining the missing signs of Ax, which is known to be NP-hard. Despite this observation, recent years have seen the development of new algorithms that solve phase retrieval problems effectively. Unfortunately, because of the lack of publicly available real-world data, the lack of a common software interface for different algorithms, and a knowledge gap between practitioners and theoreticians, only little work has been devoted to compare and evaluate newer phase retrieval methods. So we created Phasepack, comprehensive library that compiles all the algorithms within a uniform interface. I am first author on the paper on Phasepack which has been submitted to the IEEE proceedings of the 51^{st} Asilomar Conference on Signals, Systems and Computers, 2017. The project and the paper can be found on my homepage.

Through this project, I learned two very valuable skills. First, by observing how Tom discussed contemporary papers with his PhD students, I picked up on how to critique existing work. I learned that one cannot begin original research unless one first finds a flaw in prior art. I thus began to familiarize myself with the open problems in phase retrieval and the approaches taken to resolve them. My efforts paid off when I found a flaw in existing literature that I could exploit. The recently famous Wirtinger Flow algorithm to solve phase retrieval by Candes et al. attacks the non-convex objective using plain gradient descent on a least squares formulation. Gradient descent methods are sensitive to the choice of stepsize due to its asymptotic convergence property. This particularly becomes an issue in Wirtinger Flow which uses a non-adaptive stepsize. Another flaw that I identified was that the literature relies on the power method to compute leading eigenvectors. The power method can be unstable if the matrix does not have a large spectral gap (which empirical matrices may have not), and it is incapable of finding the smallest eigenvector (which is needed for orthogonality promoting initializers). Once I formed a structure of the elements that could be improved upon, I took charge of guiding the design of Phasepack. For instance, PhasePack solves least-squares formulations of the phase retrieval problem using the general gradient descent solver FASTA (Goldstein et al.), which supports adaptive stepsizes, automated stopping conditions, and conjugate-gradient acceleration. Our method significantly improves the convergence rate for Wirtinger Flow (shown in our paper). To tackle the second problem, we compute eigenvectors using the iterated Arnoldi method with restart, which is the default algorithm behind MATLAB’s “eigs” routine. This method exhibits faster convergence than the power method and can reliably resolve both the leading and trailing eigenvectors.

The second skill I learned was effectively leading a lab and collaborating with peers. My role in developing Phasepack extended to overseeing a team of three undergraduate students and one high school student. I answered questions on theory which ranged from optimization to linear algebra to convexity, and troubleshooting problems that required domain knowledge of numerical analysis. This experience of answering non-textbook questions from students gave me confidence to not become completely dependent on my adviser and motivated me to guide the development of Phasepack. For example, I observed how Tom discussed ideas with more senior PhD students and I applied that with the undergraduate students. As a result, I learned how to tie up big picture ideas and delegate tasks to undergraduates.

Low Rank Matrix Recovery Without Lifting (current research)- Another example of intractability associated with non-convexity is low rank matrix recovery where a solution is obtained by *lifting* the problem to a higher parameter space. To elaborate, lifting expresses a system of quadratic measurements as a system of linear equations whose solution is a matrix that obeys a rank constraint. However, working with matrices instead of vectors in higher dimensions generally means incurring large storage costs. As part of my MS thesis, I am trying to solve the problem of low rank matrix recovery without lifting i.e. in the natural parameter space. We observed that Phasemax (Goldstein and Studor, 2016) solves phase retrieval by recovering solutions in the same space as the input without lifting to higher dimensions. Consequently, it is a better alternative to current lifting solutions for solving SDP's. Initial sketches of my proof look promising and I am currently in the process of formalizing this.

From identifying a problem of computational complexity in low rank matrix recovery to discovering a solution embedded in phase retrieval to formalization of a proof- this approach to solving the above problem perfectly captures the way I want to continue doing research. After coming up with a solution, I realized that effective communication complements research; it is difficult to make others understand your work unless you communicate it efficiently. This motivation for effective communication made me realize that not only do I love solving research questions but I also love expressing my work through speech and writing.