RESEARCH STATEMENT

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I am a PhD student at GMU advised by Dr. Dana Richards. My broad research interests are in combinatorial algorithms, graphs and probabilistic methods. In particularly, I am interested in low complexity graph problems, data structures related to order statistics, sorting, semigroup queries etc. I have a secondary interest in computational geometry and on random geometric arrangements. In particular on random orders of high dimension.

Current and Past Research: My dissertation focuses on a few well known combinatorial problems, that are mostly unrelated. As part of my research we have made several contribution to open questions that we hope would allow for a more comprehensive characterization of these problems. Currently I am working on a approximation hardness result related to routing and a problem related to matroid optimization.

Sorting Under Restrictions. Here I study a generalization of the classical problem of sorting a set of elements under the comparison tree model [1]. In the classical sorting problem an algorithm is free to choose any pair of keys to compare during its execution. One generalization is as follows. Not all pairs have uniform comparison cost. In the extreme case some pairs are allowed to be compared where others are forbidden. This is represented by a graph whose edges represent the set of allowable pairs. We give the first non-trivial deterministic algorithm for the problem, which is also optimal, if the underlying set of elements does not necessarily come from a total order. The problem is closely related to sorting partial orders and to the local sorting problem. This problem originated from studies by Charikar and others around early 2000s on non-uniform cost models [2]. These mainly focuses on monotone cost models whereas the forbidden comparison model is not monotone.

The parallel version becomes the problem of building minimum-depth sorting networks that respect edges of the input graph. In this model the comparisons are predetermined (oblivious). Since every connected graph has a spanning tree, we give such a sorting network for trees, which has optimal depth under certain conditions. This work coalesces many classical sorting networks using graph properties, while introducing some new sorting networks [3].

Routing and Connectivity. There are several parallel models for routing "pebbles" on graphs. I study a version known as the "matching model." This was originally introduced by Alon and others [4] and is a special case of the classical *minimum generator sequence* problem on groups. Given a labeled graph and a permutation of the vertices the task is to move every pebble to its destination by a sequence of matchings whose length is minimum, where we swap pebbles across matched edges. We show this to be computationally hard, even for a fixed permutation. We also give an upper bound

result based on the connectivity properties of the graph [7]. Currently I am investigating some approximate version of the problem. This problem has generated recent interest and in particular some researchers have worked on the serial version, such as Yamanaka, Demaine and others [5].

Semigroup Queries. This problem, both in the offline setting as well as the online setting (where queries arrive in an online manner) have a rich body of research. For arbitrary semigroups there is a well established lower bound [6]. However matching upper bounds are known for only a few semigroups and for certain semigroups with some specific query structures. One example of this type are the interval queries over a set of elements where the semigroup is the "sum" operation. I focus on the semigroup "max" for which a general result is unknown for the offline case. The work has possible applications in matroid optimization problems such as the minimum spanning tree problem.

Short-term Research Goals (Next 1-2 Years). The next couple of years I see as a transition period. Firstly, I would work to extend some of the results we discovered during my PhD. For example, a non-trivial characterization of graphs with low routing time still remains open. The routing problem also fits into a larger class of problems known as reconfiguration problems on graphs. These problems are important as they can be seen as models for processes in computational biology. In these contexts I am particularly interested in exploring approximation algorithms for reconfiguration type problems.

The structure of semi-groups such as max, gcd etc are not well understood. It has been conjectured that in order to determine the optimal complexity of the minimum spanning forest (MSF) problem we may require a deeper understanding of the structure of the semigroups inherent to the MSF problem. This is a very long standing open problem and a solution remain elusive. I believe a non-constructive approach may be helpful and a "ramsey-type" result may be achievable.

Medium-term Research Goals (Next 3-5 Years). In the medium term, I am looking to like to study some specific set of low complexity problems. By low complexity problems, I mean problems that exhibit quadratic or sub-quadratic runtime. There have been a renewed interest for a deeper understanding of such problems as it pertains to a better understanding of the structure of the class P. In particular determining non-trivial (non-information-theoretic) lower bounds for many such problems have proven to be formidable. One class of problem seem particularly difficult, whose complexity is believed to be between searching and sorting. These include, MST, Set-Maxima, Sorting $x + y$ etc. One of my goal in these studies would be to develop a framework to show equivalence between many low-complexity problems with respect to the hardness of these open problems.

Finally, I should emphasize that the general nature of my research grants me the liberty to pursue a wide gamut areas within the field of algorithms. And I look forward to collaborating with different researchers in the coming years on variegated topics.

Some of my publications can be found at cs.gmu.edu/~ibanerje/publications.

References

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