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Locality in online, dynamic, sequential, and distributed graph algorithms

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Abstract: In this work, we give a unifying view of locality in four settings: distributed algorithms, sequential greedy algorithms, dynamic algorithms, and online algorithms.

We introduce a new model of computing, called the online-LOCAL model: the adversary reveals the nodes of the input graph one by one, in the same way as in classical online algorithms, but for each new node we get to see its radius-T neighborhood before choosing the output. Instead of looking ahead in time, we have the power of looking around in space.

We compare the online-LOCAL model with three other models: the LOCAL model of distributed computing, where each node produces its output based on its radius-T neighborhood, its sequential counterpart SLOCAL, and the dynamic-LOCAL model, where changes in the dynamic input graph only influence the radius-T neighborhood of the point of change.

The SLOCAL and dynamic-LOCAL models are sandwiched between the LOCAL and online-LOCAL models, with LOCAL being the weakest and online-LOCAL the strongest model. In general, all four models are distinct, but we study in particular locally checkable labeling problems (LCLs), which is a family of graph problems extensively studied in the context of distributed graph algorithms.

We prove that for LCL problems in paths, cycles, and rooted trees, all four models are roughly equivalent: the locality of any LCL problem falls in the same broad class - O(log* n), Theta(log n), or n^{Theta(1)} - in all four models. In particular, this result enables one to generalize prior lower-bound results from the LOCAL model to all four models, and it also allows one to simulate e.g. dynamic-LOCAL algorithms efficiently in the LOCAL model.

We also show that this equivalence does not hold in two-dimensional grids or general bipartite graphs. We provide an online-LOCAL algorithm with locality O(log n) for the 3-coloring problem in bipartite graphs - this is a problem with locality Omega(n^{1/2}) in the LOCAL model and Omega(n^{1/10}) in the SLOCAL model.

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