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Fault-Tolerant ST-Diameter Oracles

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Davide Bilò, Keerti Choudhary, Sarel Cohen, Tobias Friedrich, Simon Krogmann and Martin Schirneck

Abstract: We study the problem of estimating the ST-diameter of a graph that is subject to a bounded number of edge failures. An \emph{f-edge fault-tolerant ST-diameter oracle} (f-FDO-ST) is a data structure that preprocesses a given graph G, two sets of vertices S, T, and positive integer f. When queried with a set F of at most f edges, the oracle returns an estimate $\widehat{D}$ of the ST-diameter $diam(G - F, S, T)$, the maximum distance between vertices in S and T in $G - F$. The oracle has stretch $\sigma \geq 1$ if $diam(G - F, S, T) \leq \widehat{D} \leq \sigma\ diam(G - F, S, T)$. If S and T both contain all vertices, the data structure is called an \emph{f-edge fault-tolerant diameter oracle} (f-FDO).

We design new f-FDOs and f-FDO-STs via reductions from both \emph{all-pairs} and \emph{single-source} \emph{f-edge fault-tolerant Distance Sensitivity Oracles} (f-DSOs), i.e., oracles that can estimate distances even when up to f edges of G fail. We obtain new tradeoffs between the size of the data structure, stretch guarantee, query and preprocessing times for f-FDOs and f-FDO-STs by combining our reductions with the all-pairs/single-souce f-DSOs of Weimann and Yuster [FOCS 2010], Chechik et al.~[ESA 2010], Baswana and Khanna [STACS 2010], Chechik et al.~[SODA 2017], Brand and Saranurak [FOCS 2019], Duan and Ren [STOC 2020], Bilò et al.~[Algorithmica 2022], Singh and Gupta [ICALP 2018], and Baswana et al.~[SODA 2018].

We also provide an information-theoretic lower bound on the space requirement of approximate f-FDOs. We show that there exists a family graphs for which any f-FDO with sensitivity $f \geq 2$ and stretch less than $5/3$ requires $\Omega(n^{3/2})$ bits of space, regardless of the query time.

Presenter: BILÒ, Davide

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