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Abstract

We will write this at the end

Introduction

The FOCS conference or IEEE Annual Symposium on Foundations of Computer Science is an academic conference that coveres a broad range of theoretical computer science. It is sponsered by the IEEE Computer Science Technical Committe on the Mathematical Foundations of Computing (TCMF) [1].

The FOCS 2024 took place in Chicago - Voco Chicago Downtown, from October 27-30, 2024 [2]. It covered a variety of topics, for submissions the following were mentioned [2]:

- Communication complexity
- Circuit complexity
- Average-case algorithms and complexity
- High-dimensional algorithms
- Online algorithms
- Parametrized algorithms
- Spectral methods
- Streaming algorithms
- Randomized algorithms
- Cryptography
- Computational complexity
- Algorithms and data structures
- Quantum computing
- Foundations of machine learning
- Algorithmic coding theory
- Sublinear algorithms
- Algorithmic graph theory
- Continuous optimization
- Foundations of fairness, privacy and databases
- Pseudorandomness and derandomization
- Markov chains
- Analysis of Boolean functions
- Economics and computation
- Combinatorial optimization
- Algebraic computation
- Approximation algorithms
- Parallel and distributed algorithms
- Computational learning theory
- Computational geometry
- Algorithmic game theory
- Combinatorics

The official welcome message of FOCS 2024 states that nearly 500 papers were submitted, but does not specify the exact number, out of which 133 were accepted and 131 were presented as talks during the event.

In the following three sections we present three curated papers from the conference... (dopisemo na koncu ko vemo katere)

Paper 1

Hi, I'm paper 1!

Computing the 3-Edge-Connected Components of Directed Graphs in Linear Time

Abstract

The paper describes a significant improvement of a *randomized* (Monte-Carlo) algorithm for computing the 3-edge-connected components of a digraph with m edges in polylogarithmic time $\widetilde{O}(m^{3/2})$. The algorithm described bests the previous one by being deterministic and computable in linear time.

Preliminaries and primary problem

This algorithm solves the problem of finding **3-edge-connected components in directed graphs**, for preliminaries; Let $G = (V, E)$ be a strongly connected directed graph with $|V(G)| = n$ and $|E(G)| = m$.

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Generally a set of edges $C \subseteq E$ is a **cut** if $G \setminus C$ is not strongly connected i.e. there does not exist a directed path between every pair of vertices, if $|C| = k$ we refer to C as a k**-sized cut** of G. Hence a digraph G is k-edge-connected if it has no $(k-1)$ cuts.

We say that two vertices v and w are k-edge-connected, and we denote this relation by $v \leftrightarrow_k w$, if there are k-edge-disjoint directed paths from v to w and k-edge-disjoint directed paths from w to v. We define a k**-edge-connected component** of a digraph G as a maximal subset $U \subseteq V(G)$ such that $u \leftrightarrow_k v, \forall u, v \in U$.

How they achieved this improvement

The new method relies on a substructure of digraphs, known as 2**-connectivity-light graph** (denoted 2CLG). This is because the decomposition of digraphs into a collection of 2CLGs exists in linear time, and maintains the 3-edge-connected components of the original graph. They also define the minimal 2-in and -out sets, which contain vertices with out- or in-degree of 2. Formally, we define both here.

Definition 1. *A* 2***-connectivity-light*** *graph G is a strongly connected digraph that contains two types of vertices;* ***ordinary*** *and* ***auxiliary****, that satisfy the following conditions:*

1. *Any two ordinary vertices are* 2*-edge-connected,*
2. *each auxiliary vertex has an in- or out-degree of 1,*
3. *for every vertex u with out-degree > 1 and every vertex v with in-degree > 1, there are 2 edge-disjoint paths from u to v,*
4. *for each auxiliary vertex v with out-degree (resp. in-degree) of one, all paths from v to any vertex in G (resp. from any vertex in G to v), we have exactly one common edge, the unique out-edge (resp. in-edge).*

Definition 2. *For a strongly connected digraph G we arbitrarily choose a start vertex s. For any vertex $v \neq s$ we define $M(v)$ as a* ***minimal*** *2****-in set*** *that contains v, i.e. a minimal set of vertices which contains v, does not contains s, and has two incoming edges from $V(G) \setminus M(v)$, we denote by $M_R(v)$ the analogous sets in G^R, which is the reverse graph of G.*

The technique is then based on the following proposition and theorem.

Proposition I.3. *Let G be a 2GLC with a fixed ordinary start vertex s. Then for any two ordinary vertices u and v, we have $v \leftrightarrow_k u$ if and only if $M(u) = M(v)$ and $M_R(u) = M_R(v)$.*

Theorem II.5. *Let G be a strongly connected digraph. In linear time, we can construct a collection $H_1, ..., H_t$ of 2CLG graphs, such that:*

- *For every vertex of G there is exactly one graph among $H_1, ..., H_t$, that contains it as an ordinary vertex.*
- *Every two vertices u and v of G are 3-edge-connected if and only if there is an $i \in \{1, ..., t\}$ such that u and v are 3-edge-connected.*

Paper 3

Random walk d-ary cuckoo hashing

Cuckoo hashing algorithm's basic idea is to resolve collisions by using two hash functions instead of one. When inserting a new object x into the table, if the slot $h_1(x)$ is occupied, the existing object x' is replaced by x, and then x' is inserted into slot $h_2(x')$. If the number of iterations exceeds a threshold, the whole table is rehashed with new hash functions. Random Walk d-ary Cuckoo Hashing generalizes the idea by using d hash functions and using a random walk to choose the next hash function in case of a collision. Standard cuckoo hashing, equivalent to the $d = 2$ case, has a load threshold of 0.5, meaning it can use up to 50% of the hash table space. The d-ary hashing improves this threshold. For example, the $d = 3$ case has the threshold at approximately 0.9, while the insertion time increases linearly with d. The insertion algorithm guarantees $\mathcal{O}(1)$ lookup and deletion time, as the object can be retrieved by checking its d positions.

Insertion time

This paper shows that for any $d \geq 4$ hashes and load factor $c < c * d$, the expectation of the random walk insertion time is constant. It shows that the expected number of reassignments during insertion does not depend on the size of the hash table m, but only on d and c. The article uses bipartite graphs as a representation for the hash functions and objects. In the graph, the objects in set X are connected to their d possible locations in the hash table Y. In this representation, a valid perfect matching corresponds to a valid assignment of objects to slots. The existence of such a matching is subject to Hall's Theorem, which states that a perfect matching exists if and only if every subset $W \subseteq X$ is smaller than its neighborhood in Y. Neighborhood meaning all nodes connected to at least one vertex in W. The paper shows that when the load factor is below the threshold $c * d$, such perfect matchings exist with high probability as the graph exhibits strong expansion properties. The article identifies "bad" sets which have few connections to the rest of the graph. In these sets, the walk might get stuck, but the authors prove that the random

walk is unlikely to hit such a set in the first $\mathcal{O}(i^{999})$ steps, and that any random walk which avoids it for the first $\mathcal{O}(i^{999})$ steps is likely to finish in $\mathcal{O}(i)$ steps.

Super-polynomial tail bounds

The paper also provides super-polynomial tail bounds on the insertion time, showing that the probability of a walk exceeding ℓ steps decays exponentially in ℓ, with the exponent approaching 1 as d increases. They relate their findings to previous work on BFS-based insertion algorithms, noting that random walk insertion achieves comparable or better performance without the computational overhead of BFS path searches.

References

[1] IEEE Symposium on Foundations of Computer Science, *Ieee focs conference*, Accessed: 2025-02-27, 2024. [Online]. Available: `https://ieee-focs.org`.

[2] IEEE Symposium on Foundations of Computer Science, *Focs 2024 - 65th annual ieee symposium on foundations of computer science*, Accessed: 2025-02-27, 2024. [Online]. Available: `https://focs.computer.org/2024/`.