LDBC TUC

Context-Free Path Querying: Obstacles on the Way to Adoption

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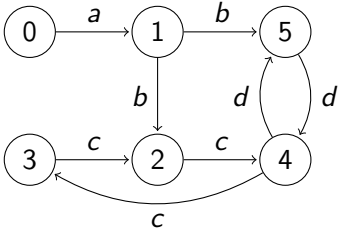
Who we are?

- !!!

- !!!

Formal language constarined path querying

Navigational queries in edge-labelled graph



- Path to find:

$$0 \xrightarrow{a} v_0 \xrightarrow{b} v_1 \underbrace{\xrightarrow{d} v_2 \xrightarrow{c} v_3 \dots v_k \xrightarrow{c}}_{c \text{ or } d \text{ in arbitrary order}} v$$

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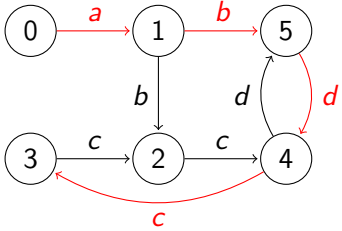

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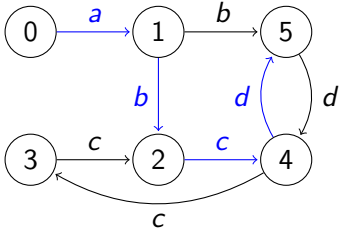

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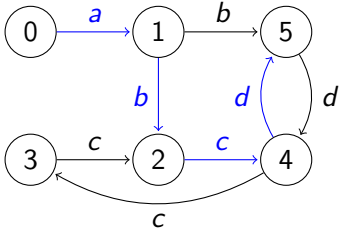

- $w(v_0 \xrightarrow{l_0} v_1 \xrightarrow{l_1} \ldots \xrightarrow{l_{k-1}} v_k) = l_0 l_1 \ldots l_{k-1}$
- $Q = \{(v_i, v_j) \mid \exists \pi = v_i \to \ldots \to v_j; w(\pi) \in \mathcal{L}\}$, where $\mathcal{L}$ — formal language
  - ✔ Regular $(ab(c \mid d)^*)$
  - **Context-Free** $(a^n b^n)$
  - Multiple Context-Free $(a^n c^m b^n d^m)$

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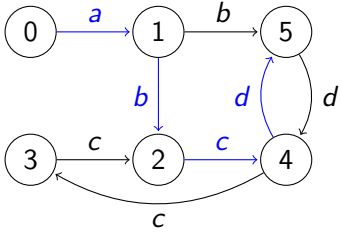

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Variations:

- All-pairs
- Multiple source
- Reachability
- All paths
- ...

Applications of Context-Free Path Querying

Hierarchy analysis: variations of the *same-generation queries* is essence of CFPQ

[1]Thomas Reps. 1997. "Program Analysis via Graph Reachability".
[2]Mihalis Yannakakis. 1990. "Graph-theoretic Methods in Database Theory".

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Graph databases

- Introduced by M. Yannakakis in 1990[1]
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Problems

- There is no unified infrastructure for solutions comparison
  - Data is spread over articles in different communities
  - There is a huge number of different subclasses of the problem
    - ⋆ all-pairs, single source, multiple source, ...
    - ⋆ reachability, single path, all path, ...
  - The first and only attempt to compare different algorithms: "An Experimental Study of Context-Free Path Query Evaluation Methods"[3]

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  - Conclusion: "We conclude that state of the art solutions are not able to cope with large graphs as found in practice."
- There is no support in real-world graph database
  - H. Miao and A. Deshpande: "Though the problem has been first studied in our community [40], there is little follow up and support in the context of modern graph databases ..."[4]

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Our Results

- ✔ Collection of linear algebra based algorithms for CFPQ
  - SuiteSparse is utilized for sparse linear algebra subroutines
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  - On the top of RedisGraph
  - openCypher extended to support CFPQ
- ⚙ Collecting of the dataset for CFPQ benchmarking is started
  - Synthetic graphs
  - Real-world graphs
    - ★ Static code analysis
    - ★ Biological data analysis
  - Published: `https://github.com/JetBrains-Research/CFPQ_Data`

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Our Results Evaluation

- All-pairs reachability queries
- *geospecies*, *taxonomy* — biological data
- *crypto*, *drivers*, *fs* — points-to analysis
- Time in seconds

- GPU: Geforce GTX 1070, 1.5GHz, 8Gb RAM, 1920 CUDA cores
- CPU: Intel core i7-6700 CPU, 3.4GHz, DDR4 64Gb RAM

Graph	#V	#E	Neo4j[6]	RedisGraph[7]	Lin.al. CPU[8]	Lin.al. GPU[9]
geospecies	450 609	2 311 461	6 953.9	80.1	7.1	0.8
taxonomy	5 728 398	14 922 125	n.a.		1.1	0.7
crypto	3 464 970	5 976 774	n.a.		84.8	28.1
drivers	4 273 803	7 415 538	n.a.		269.9	62.5
fs	4 177 416	7 218 746	n.a.		165.1	47.7

[6] Jochem Kuijpers et al. 2019. "An Experimental Study of Context-Free Path Query Evaluation Methods".
[7] Arseniy Terekhov et al. 2019. "Multiple-Source Context-Free Path Querying in Terms of Linear Algebra".
[8] Standalone linear algebra based algorithm on CPU, using SuiteSparse.
[9] Standalone linear algebra based algorithm on GPU, using spbla.

Ongoing research

- Benchmarking of linear algebra based algorithms
  - Comparison of different algorithms for different query semantics
  - Investigation of scalability on multicore machines
  - Estimation of performance on GPGPU
- Developing and evaluating GLL-based CFPQ algorithm for Neo4j
  - Multiple-source
  - All paths and reachability-only

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- Describing semantics of openCypher in terms of linear algebra (in Coq)
- Utilizing multiple context-free languages as path constraints

Topics to dicuss

- Benchmarks.
  - Algorithms
  - Query language. Semantics
  - Local and Global queries. Can start from RPQ.
  - Queries: templates and real-world queries.
- Competition on language constrained path querying.
  - Part of existing competition for graph processing systems.
  - Involve static analysis community.
- Graph database support
  - Algorithms
  - Query language. Semantics