FOSDEM '23
Rust Devroom

Scalable graph algorithms in Rust (and Python)

Who?

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Our day job …

- Neo4j Graph Data Science
  - Plugin for Neo4j Graph Database
  - Provides a collection of graph and machine learning algorithms
  - Customer use cases with up to 10+ bn nodes and 65+ bn edges
  - Top 3 use cases: fraud detection, recommendation, identity resolution

- Product: https://neo4j.com/product/graph-data-science/

- Source: https://github.com/neo4j/graph-data-science/

- Docs: https://neo4j.com/docs/graph-data-science/current/

Neo4j Graph Data Science 2.3

Pathfinding & Search

- A* Shortest Path
- All Pairs Shortest Path
- Breadth & Depth First Search
- Delta-Stepping Single-Source
- Dijkstra Single-Source
- Dijkstra Source-Target
- Minimum Spanning Tree & K-Spanning Tree
- Random Walk
- Yen's K Shortest Path
- Minimum Directed Steiner Tree

Centrality & Importance

- ArticleRank
- Betweenness Centrality & Approx.
- Closeness Centrality
- Degree Centrality
- Eigenvector Centrality
- Harmonic Centrality
- Hyperlink Induced Topic Search (HITS)
- Influence Maximization (CELF)
- PageRank
- Personalized PageRank

Community Detection

- Conductance Metric
- K-1 Coloring
- K-Means Clustering
- Label Propagation
- Leiden Algorithm
- Local Clustering Coefficient
- Louvain Algorithm
- Max K-Cut
- Modularity Optimization
- Speaker Listener Label Propagation
- Strongly Connected Components
- Triangle Count
- Weakly Connected Components

Supervised Machine Learning

- Link Prediction Pipelines
- Node Classification Pipelines
- Node Regression Pipelines

Heuristic Link Prediction

- Adamic Adar
- Common Neighbors
- Preferential Attachment
- Resource Allocations
- Same Community
- Total Neighbors

Similarity

- K-Nearest Neighbors (KNN)
- Node Similarity
- Filtered KNN & Node Similarity
- Cosine & Pearson Similarity Functions
- Euclidean Distance Similarity Function
- Euclidean Similarity Function
- Jaccard & Overlap Similarity Functions

Graph Embeddings

- Fast Random Projection (FastRP)
- FastRP with Property Weights
- GraphSAGE
- Node2Vec
- HashGNN (Knowledge Graph Embedding)

… and more!

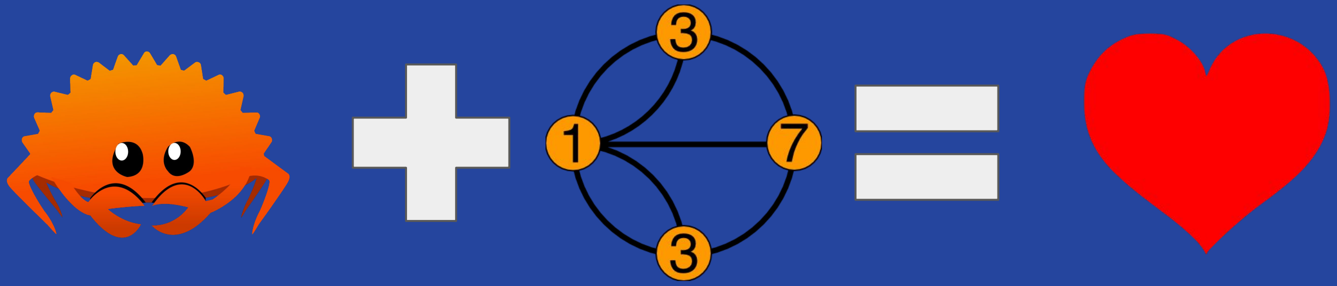
- Collapse Paths
- Graph Sampling
- Graph Stratified Sampling
- One Hot Encoding
- Pregel API (write your own algos)
- Property Scaling
- Split Relationships
- Synthetic Graph Generation

Graph Algorithms in Rust … Why?

- Rust is a popular systems programming language known for its memory safety, modern type system, and native performance

- We are curious, performance-focused engineers who always want to learn more about what’s happening outside of our (JVM) box

- We like Rust and wanted to explore how a graph library for graphs with billion+ nodes and relationships would look like and perform in Rust

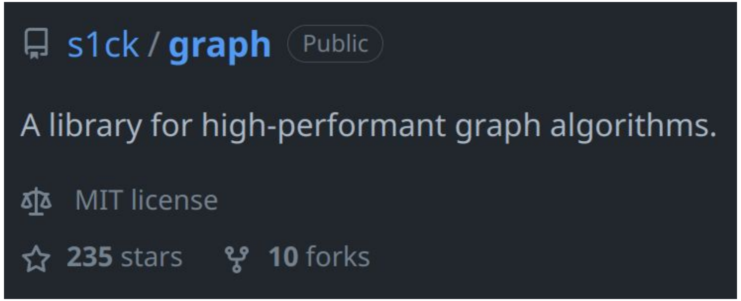


The `graph` project

The graph project

- Started in May 2021 as an experiment / hobby project
  - Pure interest in combining Rust and graph algorithms
  - Initial goal was to learn what level of performance we can achieve
  - Using parallel implementations wherever possible
  - Added more algorithms, features and API improvements over time

- Code is available on GitHub: https://github.com/s1ck/graph



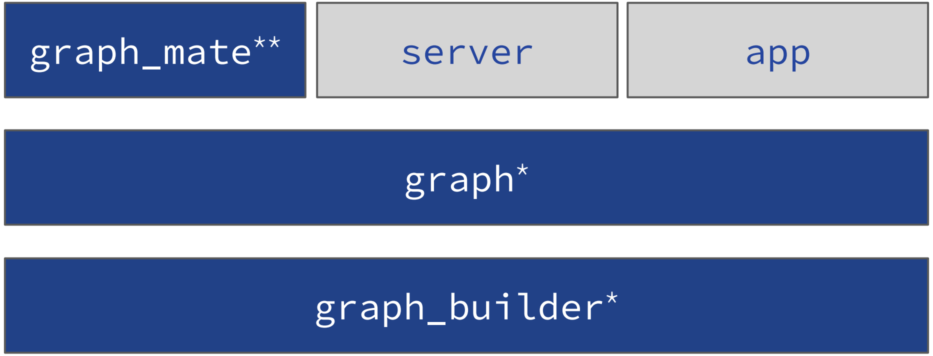
s1ck / **graph** Public

A library for high-performant graph algorithms.

MIT license

235 stars **10** forks

The graph project - crates



graph_mate** | server | app

graph*

graph_builder*

* available on crates.io

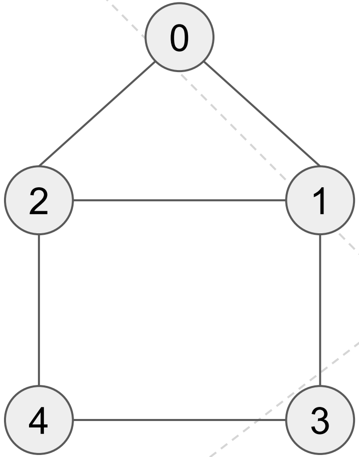
** available on pypi.org

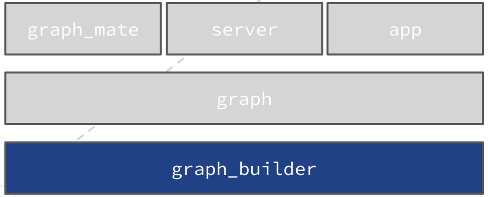
The graph project - crates - graph_builder

- Graph API for building directed and undirected property graphs

```
let g: UndirectedCsrGraph<u64> = GraphBuilder::new()
          .edges([
               (0, 1),
               (0, 2),
               (1, 2),
               (1, 3),
               (2, 4),
               (3, 4)
          ])
          .build();

assert_eq!(g.degree(1), 3);
assert_eq!(g.neighbors(2).as_slice(), &[0, 1, 4]);
assert_eq!(g.neighbors(4).as_slice(), &[2, 3]);
```



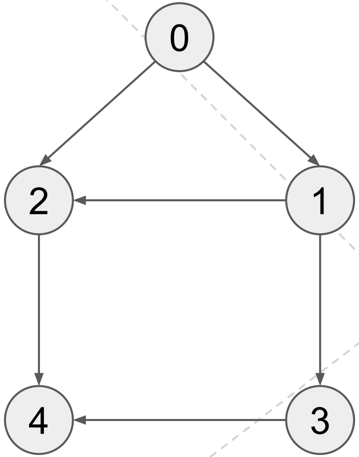


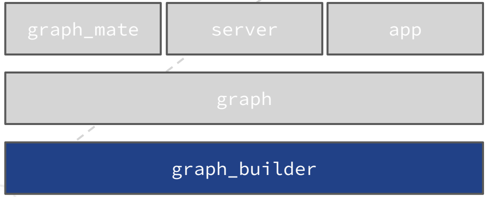
The graph project - crates - graph_builder

- Graph API for building directed and undirected property graphs

```rust
let g: DirectedCsrGraph<u64> = GraphBuilder::new()
            .edges([
                 (0, 1),
                 (0, 2),
                 (1, 2),
                 (1, 3),
                 (2, 4),
                 (3, 4)
            ])
            .build();

assert_eq!(g.out_degree(1), 2);
assert_eq!(g.out_neighbors(2).as_slice(), &[4]);
assert_eq!(g.in_neighbors(4).as_slice(), &[2, 3]);
```

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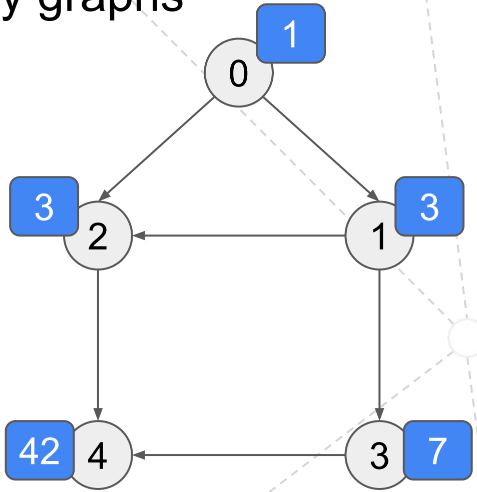
graph_builder

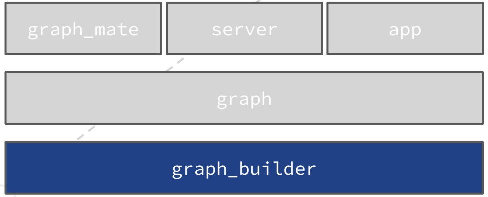
The graph project - crates - graph_builder

- Graph API for building directed and undirected property graphs

```
let g: DirectedCsrGraph<u64, u32> = GraphBuilder::new()
           .edges([
                (0, 1),
                (0, 2),
                (1, 2),
                (1, 3),
                (2, 4),
                (3, 4)
           ])
           .node_values([1, 3, 3, 7, 42])
           .build();

assert_eq!(*g.node_value(0), 1);
assert_eq!(*g.node_value(4), 42);
```

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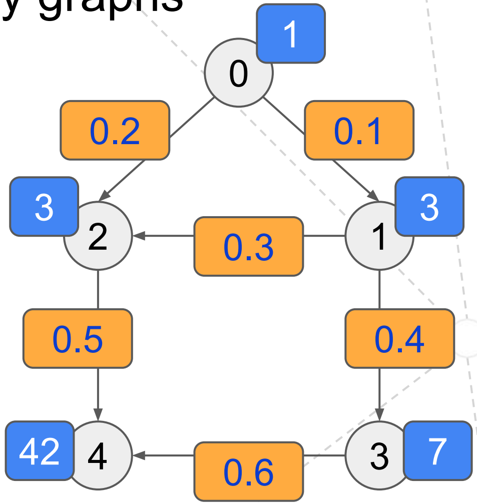
graph_builder

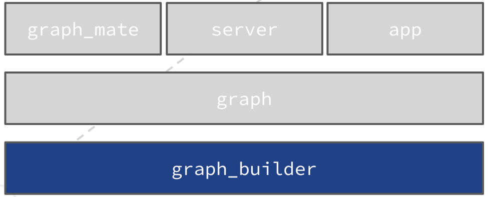
The graph project - crates - graph_builder

- Graph API for building directed and undirected property graphs

```
let g: DirectedCsrGraph<u64, u32, f32> = GraphBuilder::new()
            .edges([
                  (0, 1, 0.1),
                  (0, 2, 0.2),
                  (1, 2, 0.3),
                  (1, 3, 0.4),
                  (2, 4, 0.5),
                  (3, 4, 0.6)
            ])
            .node_values([1, 3, 3, 7, 42])
            .build();

assert_eq!(
      g.out_neighbors_with_values(2).as_slice(),
      &[Target::new(4, 0.5)]
);
```





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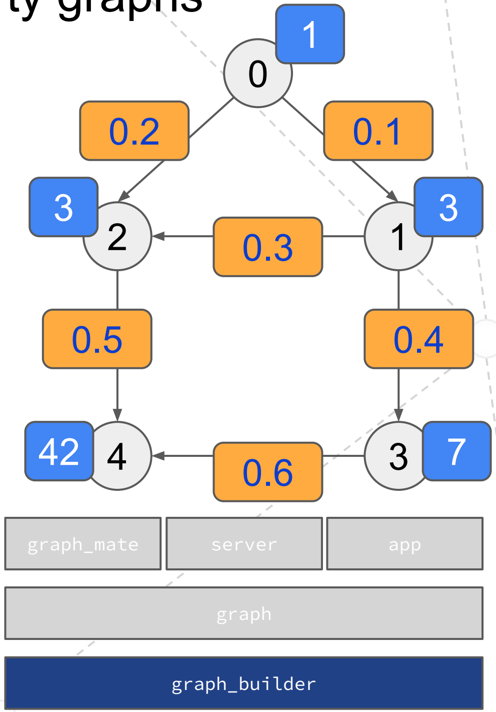
graph

graph_builder

The graph project - crates - graph_builder

- Graph API for building directed and undirected property graphs

```
let g: DirectedCsrGraph<u64, u32, f32> = GraphBuilder::new()
            .gdl_str::<u64, _>("
                "(n0 {p: 1}), (n1 {p: 3}),
                 (n2 {p: 3}), (n3 {p: 7}),
                 (n4 {p: 42}),
                 (n0)-[{ f: 0.1 }]->(n1),
                 (n0)-[{ f: 0.2 }]->(n2),
                 (n1)-[{ f: 0.3 }]->(n2),
                 (n1)-[{ f: 0.4 }]->(n3),
                 (n2)-[{ f: 0.5 }]->(n4),
                 (n3)-[{ f: 0.6 }]->(n4)",
            )
            .build()
            .unwrap();
```

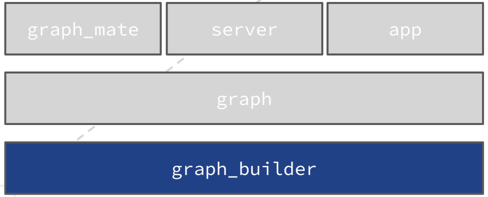


The graph project - crates - graph_builder

- Graphs can be created **programmatically** as shown before

- Graphs can be created **from files** using `GraphInput` implementations
  - **EdgeList** - text file containing ”`source target [value]`” tuples per line
  - **Graph500** - binary file storing the output of the Graph500[1] data generator
  - **Serialized** - binary file serialized using the graph_builder crate

- Graph creation is fully parallelized using the rayon crate[2]



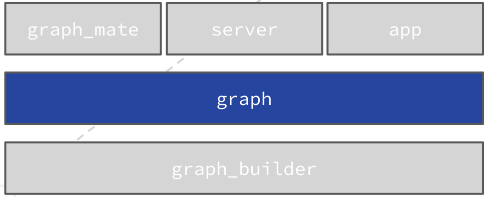
[1] https://graph500.org
[2] https://crates.io/crates/rayon

The graph project - crates - graph

- Provides a small set of parallel graph algorithms
  - Page Rank
  - Weakly Connected Components
  - Global Triangle Count
  - Single-Source Shortest Path

- Graph algorithms are also parallelized using the rayon crate

- Contributions are very welcome!



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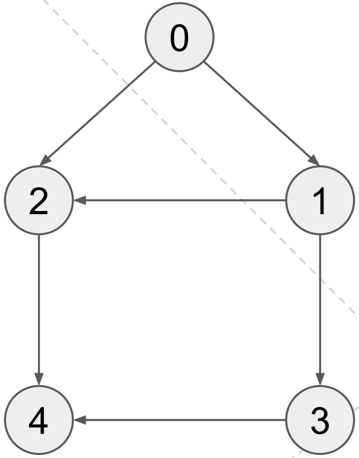
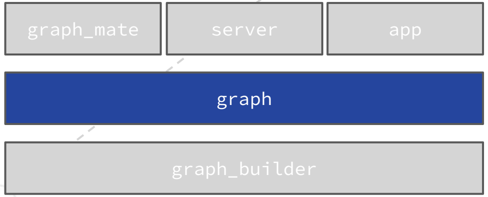
The graph project - crates - graph

```
let gdl = "(n0)-->(n1)-->(n2),(n0)-->(n2),(n1)-->(n3)-->(n4),(n2)-->(n4)";

let graph: DirectedCsrGraph<u32> = GraphBuilder::new()
    .csr_layout(CsrLayout::Sorted)
    .gdl_str::<u32, _>(gdl)
    .build()
    .unwrap();

let (scores, _, _) = page_rank(&graph, PageRankConfig::default());

let expected: Vec<f32> = vec![
    0.029999996,
    0.042749994,
    0.06091874,
    0.04816874,
    0.122724354,
];

assert_eq!(scores, expected);
```



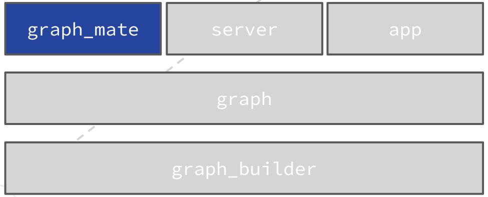

graph_mate | server | app

graph

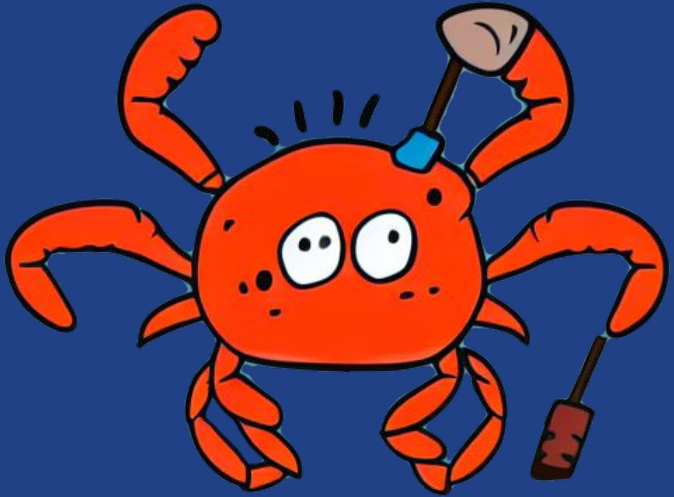
graph_builder

The graph project - crates - graph_mate

- Python bindings for the `graph_builder` and the `graph` crates
  - Expose pythonic API for Rust implementation
- Memory management and parallelism done in Rust
- Integrates with `numpy` and `pandas`
- Alpha state, not everything is available yet
- Available on PyPI: `pip install graph-mate`



STOP! Demo Time.



Demo scenario

- Uses Graph500[1] dataset scale 24 (~17M nodes, ~260M edges)
  - Generates a graph where degrees follow a power-law distribution

- Demo workflow:
  1. Create directed graph from Graph500 binary graph file
  2. Compute Page Rank
  3. Compute Weakly Connected Components
  4. Convert graph to an undirected and relabeled graph
  5. Compute Triangle Count

- 3 Implementations: **graph_mate**, graph, pyarrow + server

[1] https://graph500.org/?page_id=12#sec-3

Demo 1: graph_mate (Python)

Demo 2: graph (Rust)

Demo 3: pyarrow + server

Lessons Learned

Lessons Learned from building the graph project

- Using Rust as a Java developer (with *some* understanding of the JVM)
    - Rust paradigms require a different thinking about how to design code
    - Mechanical sympathy improves when working with Rust
    - Different, but nicely integrated ecosystem (Cargo, rust-analyzer, …)
    - Debugging and profiling requires learning about tools from the C/C++ world

- What about the performance?
    - For algorithms that we implemented in Java and Rust, we could see a better performance in Rust for all cases
    - Predictable runtime behaviour
        - No latency spikes, consistent allocation rate
        - AOT compiler and LLVM backend

Outlook

Outlook

- What we want to work on next
  - Add more algorithms
  - Expand the Python and Arrow Server APIs
  - Add algorithm framework to allow users to write their own algos
  - Explore native capabilities even further (SIMD, GPU, …)
- The library is usable, but not battle tested
- What we need from you
  - Feedback (reporting issues, etc.)
  - Contributions!
- For a longer version of this talk with all demos check out YT

Thank you!

Q&A offline