SFU

PEREGRINE

A Pattern-Aware Graph Mining System

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Simon Fraser University

https://github.com/pdclab/peregrine

Why should you pay attention?

Peregrine executes 700x faster

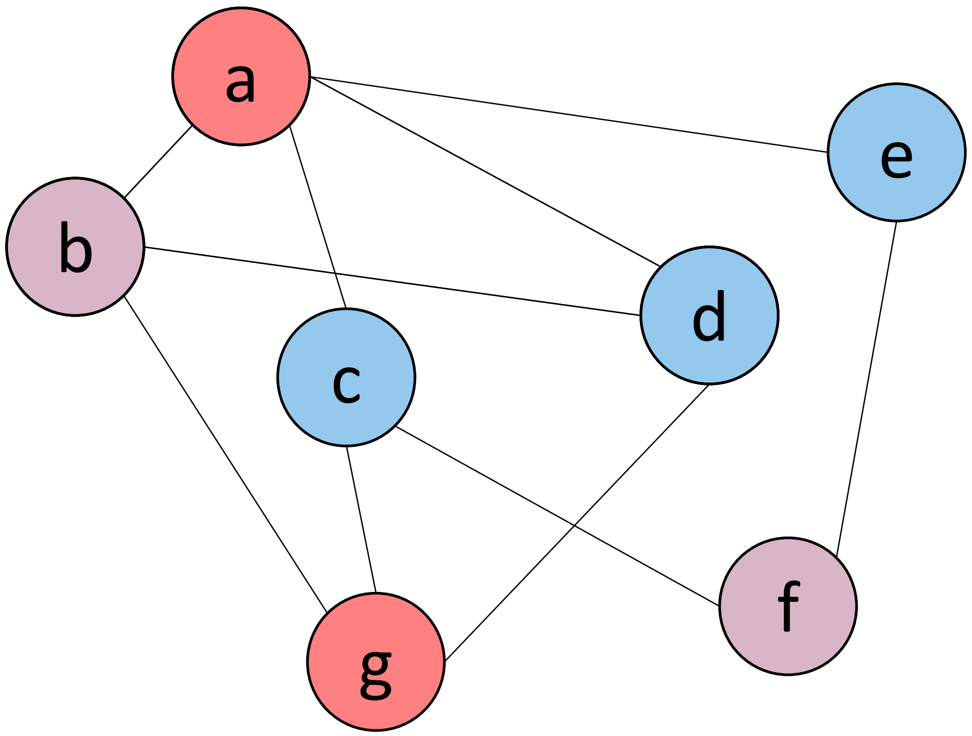
Peregrine consumes 100x less memory

Peregrine scales to 100x larger datasets

On 8x fewer machines

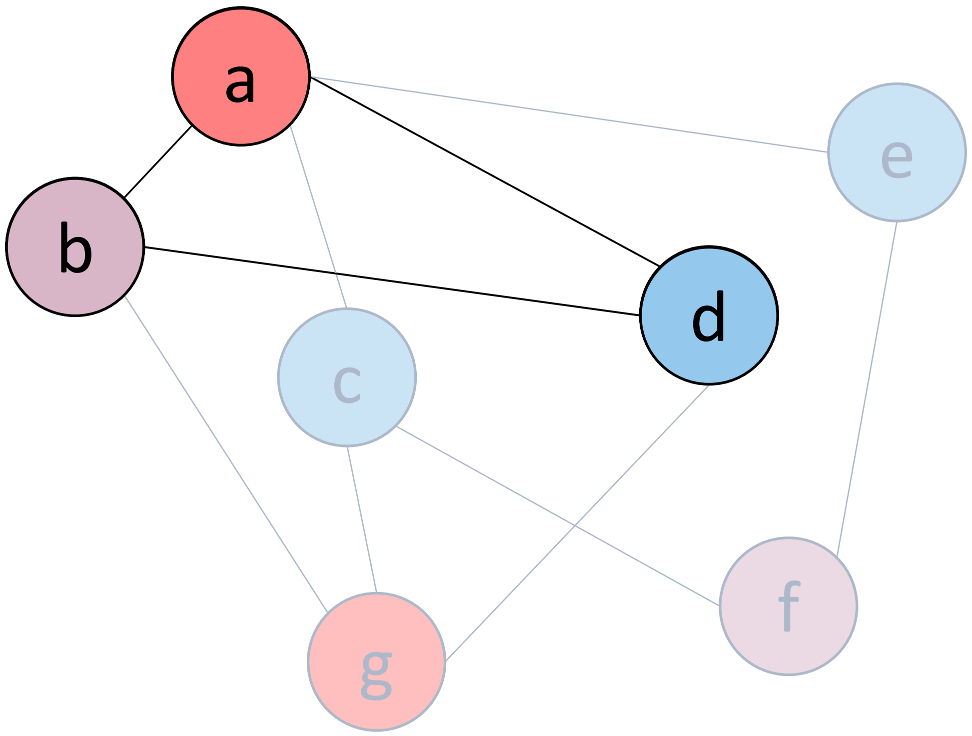
With a more expressive API

Graph Mining



Data Graph

Graph Mining



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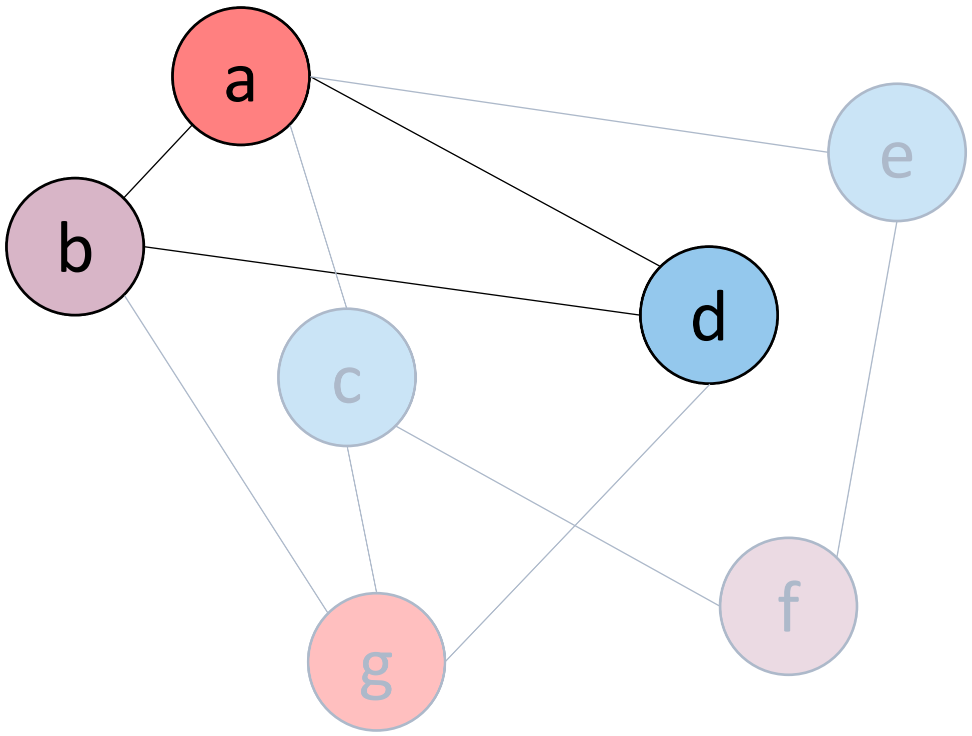

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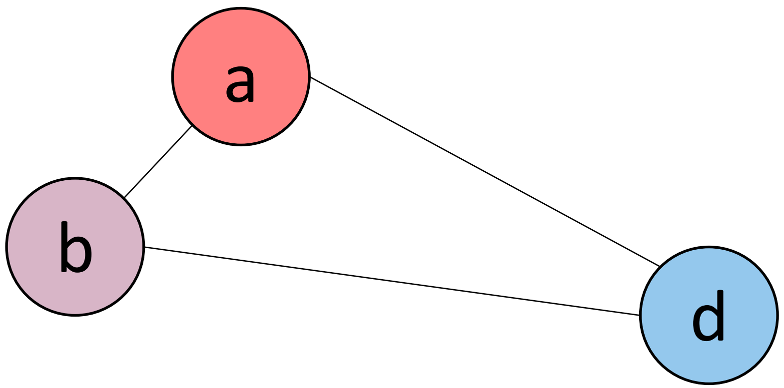
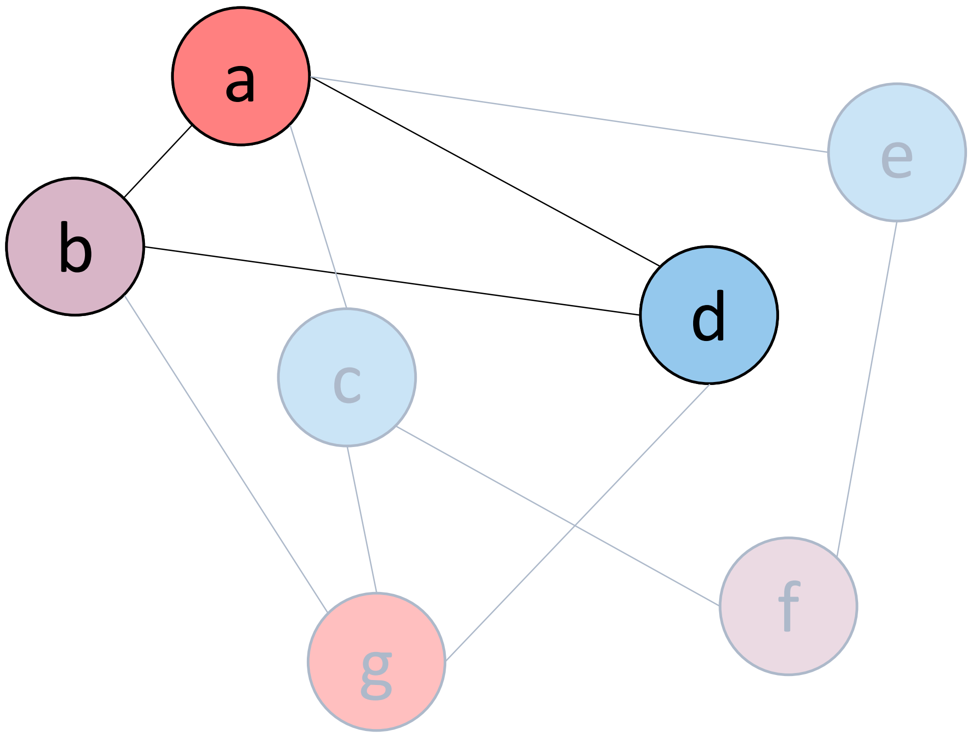
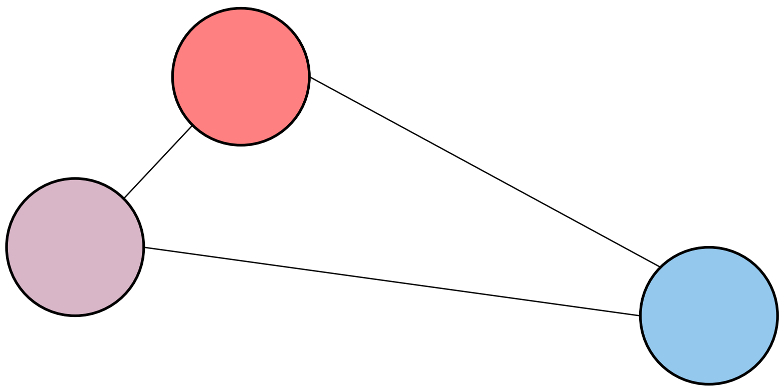


Subgraph

Graph Mining

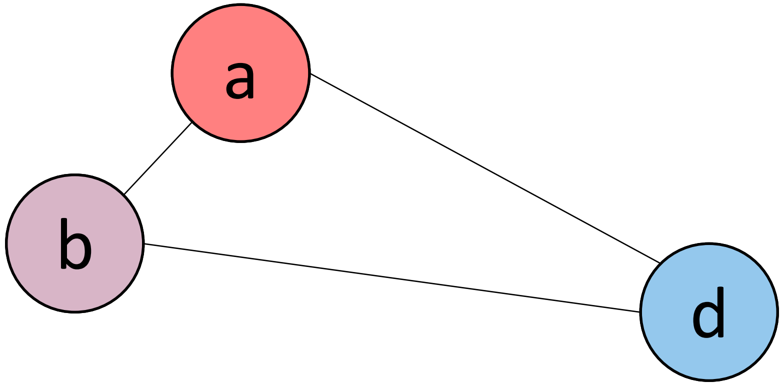


Data Graph



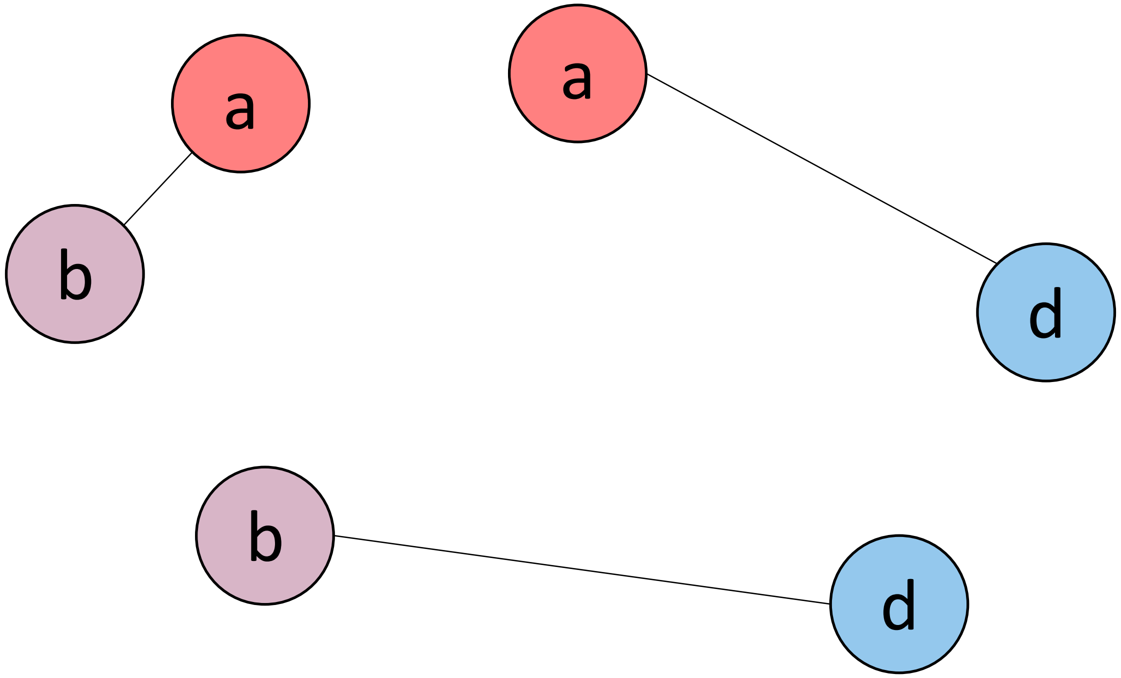
Pattern

Graph Mining



Edge-Induced

Graph Mining



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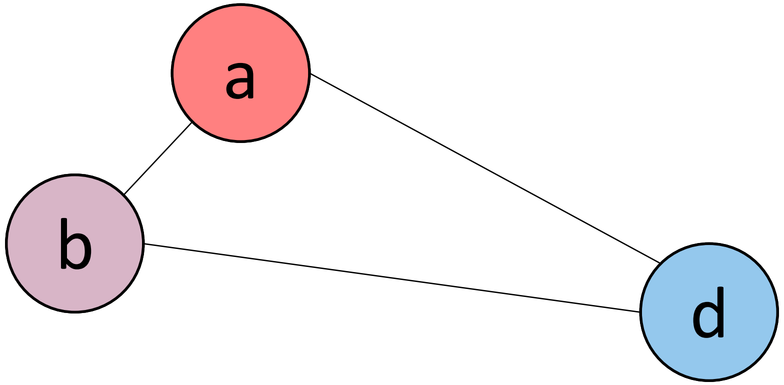

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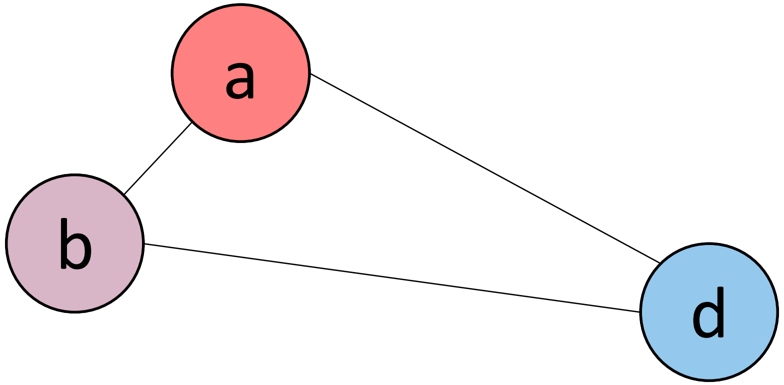
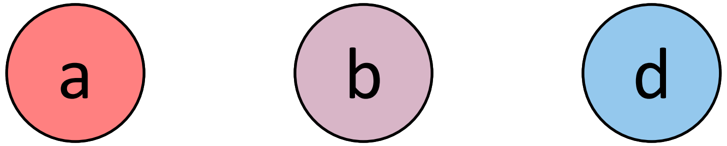


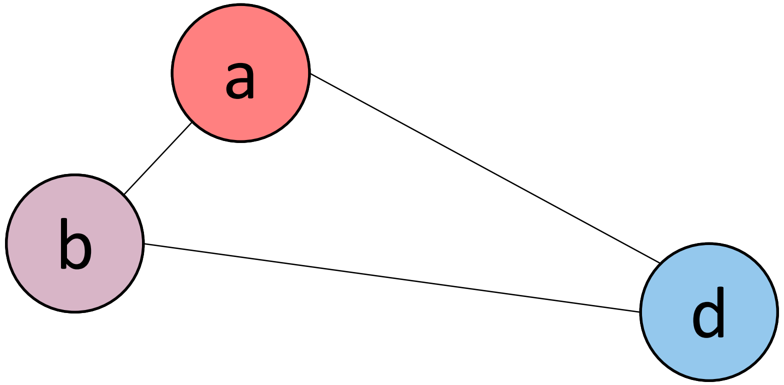
Vertex-Induced

Graph Mining



Vertex-Induced

Graph Mining



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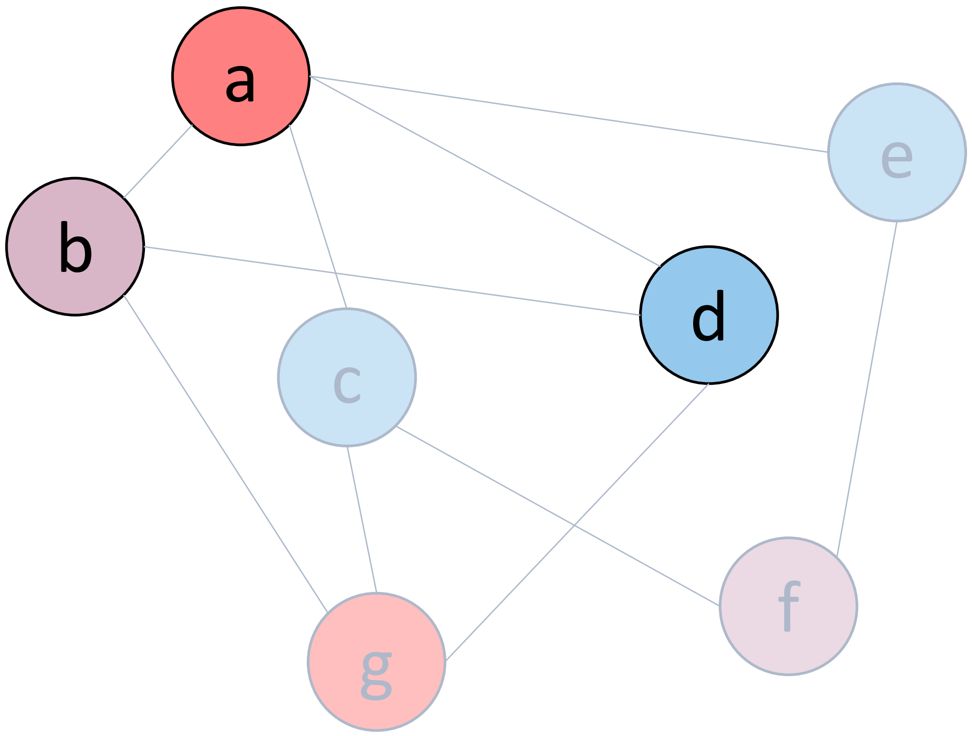
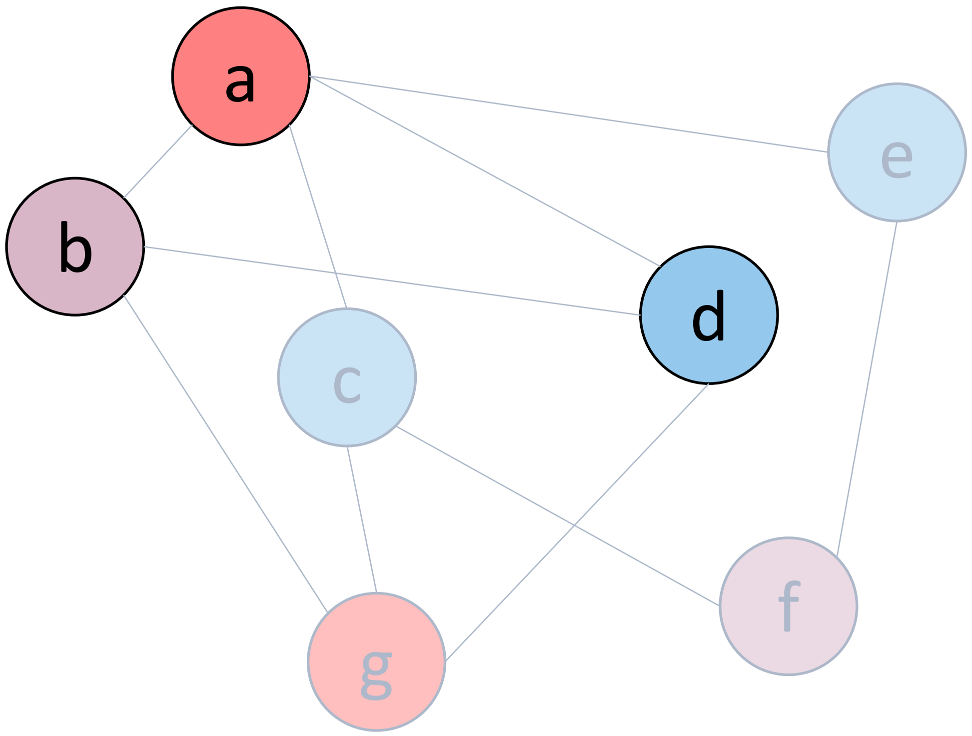


Data Graph

Graph Mining



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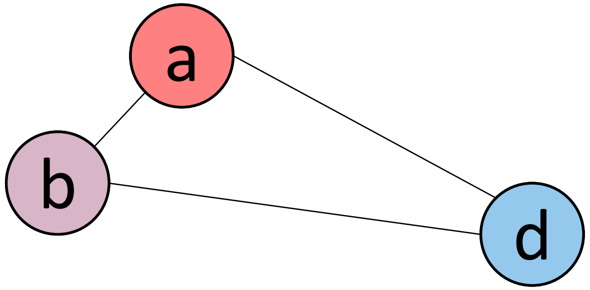
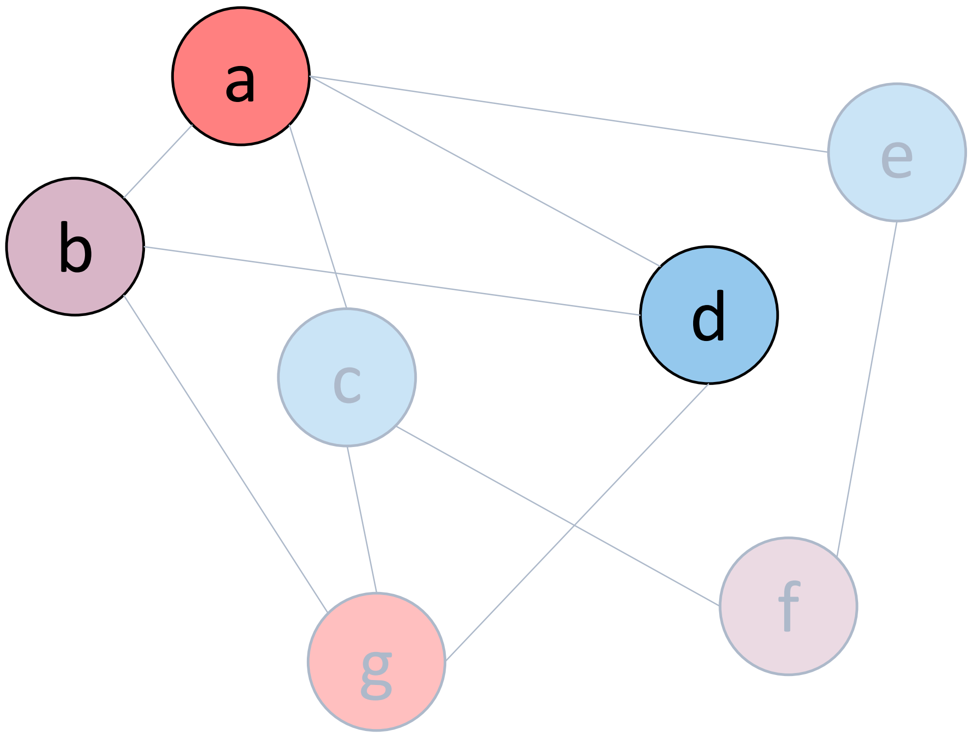


Vertex-Induced

Graph Mining



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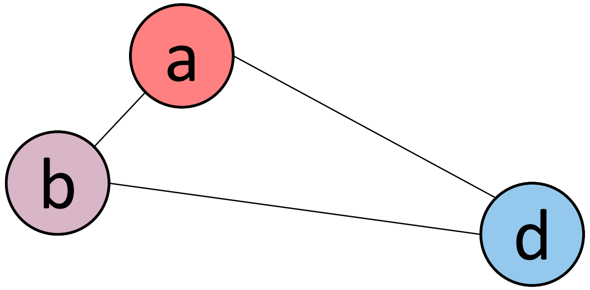

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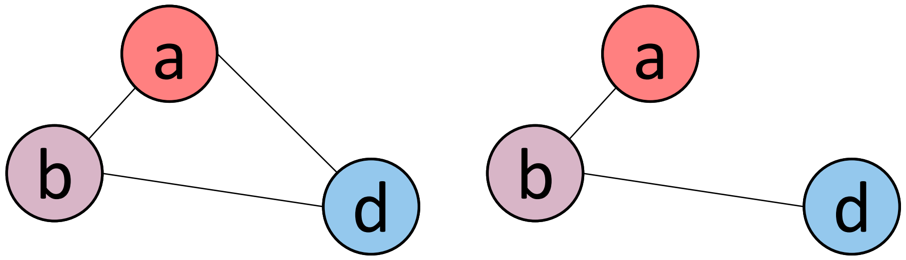

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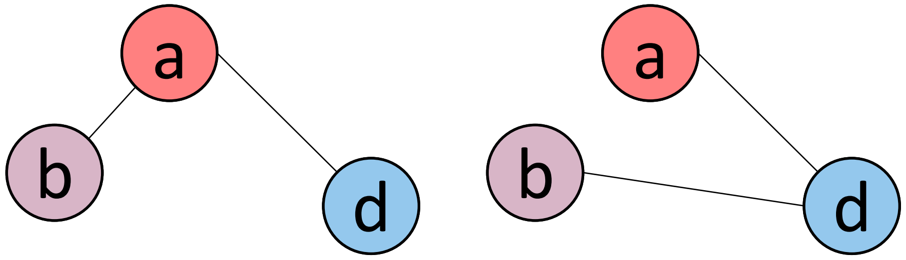
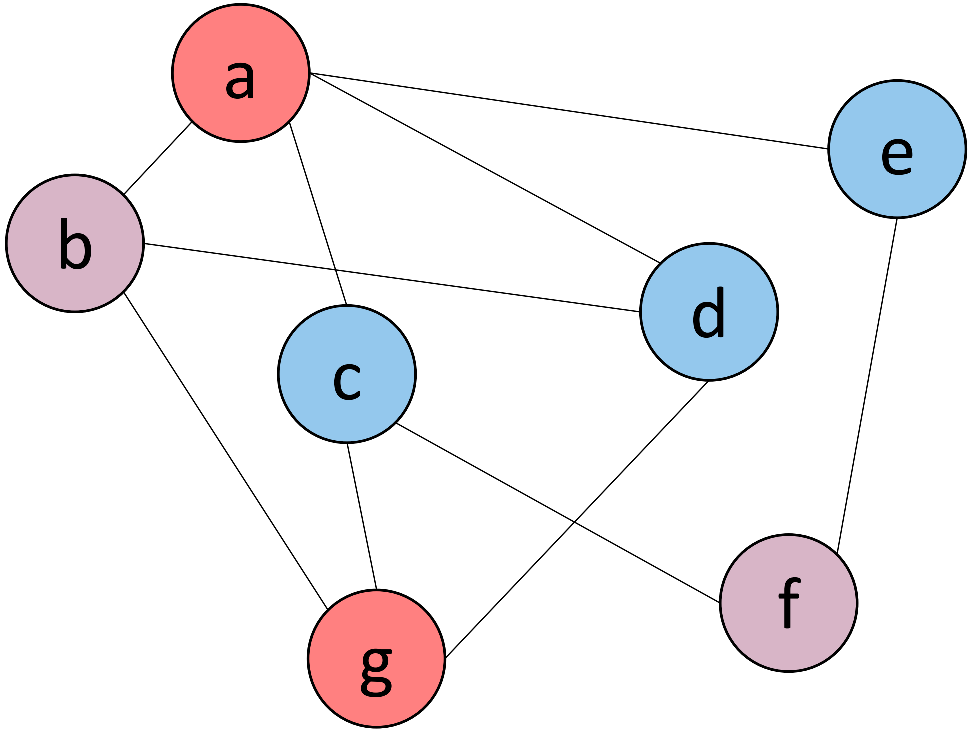
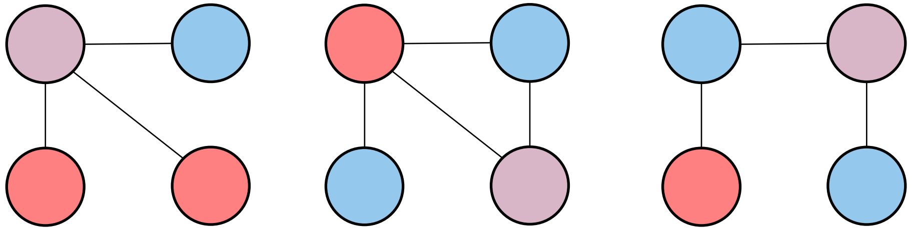


Graph Mining

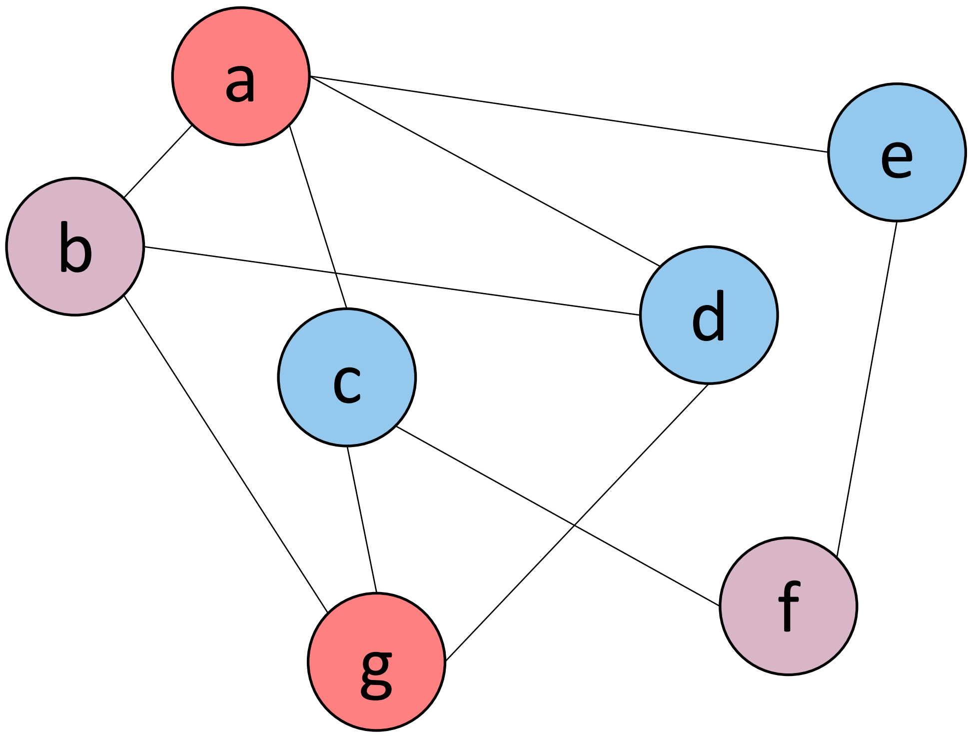


Data Graph

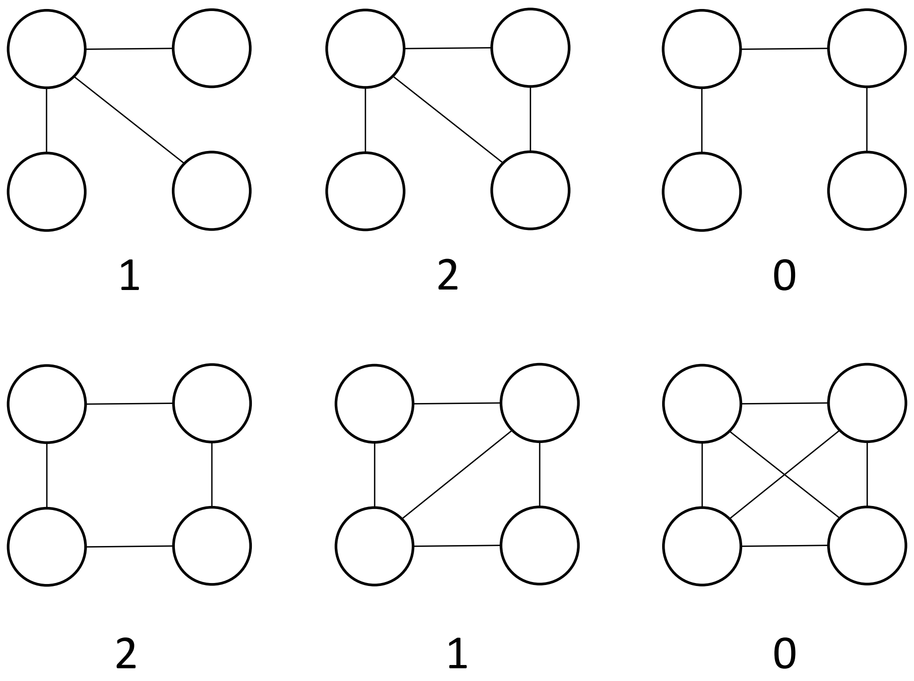


Frequent Patterns
(Edge-Induced)

Graph Mining



Data Graph

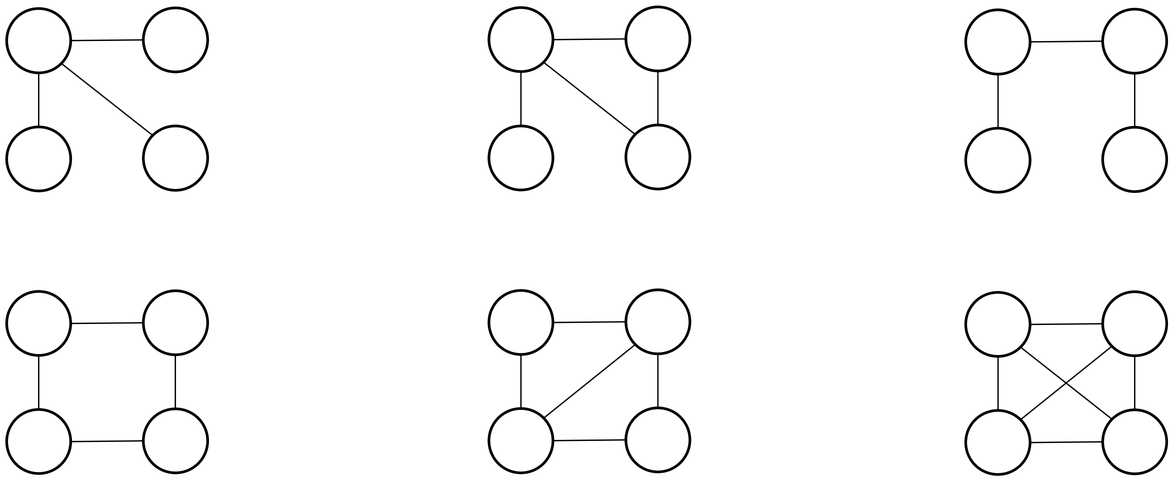


Unlabeled Pattern Distribution
(Vertex-Induced)

Scalability Challenge

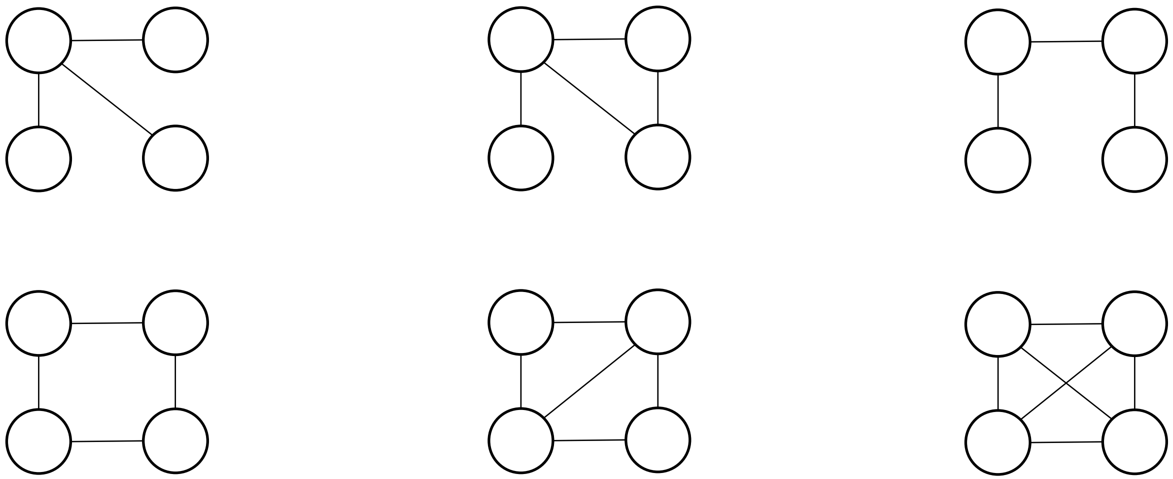
Scalability Challenge

- 4-motif counting on Orkut graph (|V| = 13M, |E| = 117M)



Scalability Challenge

- 4-motif counting on Orkut graph (|V| = 13M, |E| = 117M)

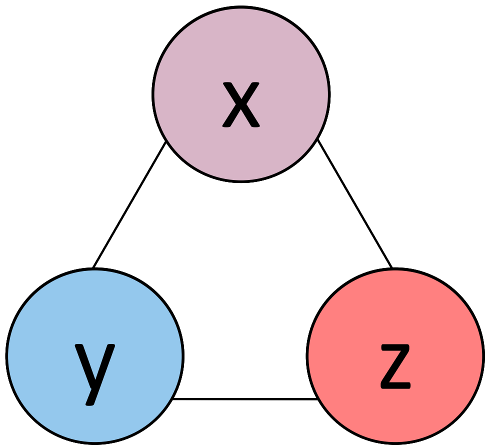


123,503,340,341,270 subgraphs

System Requirements

System Requirements

Uniqueness



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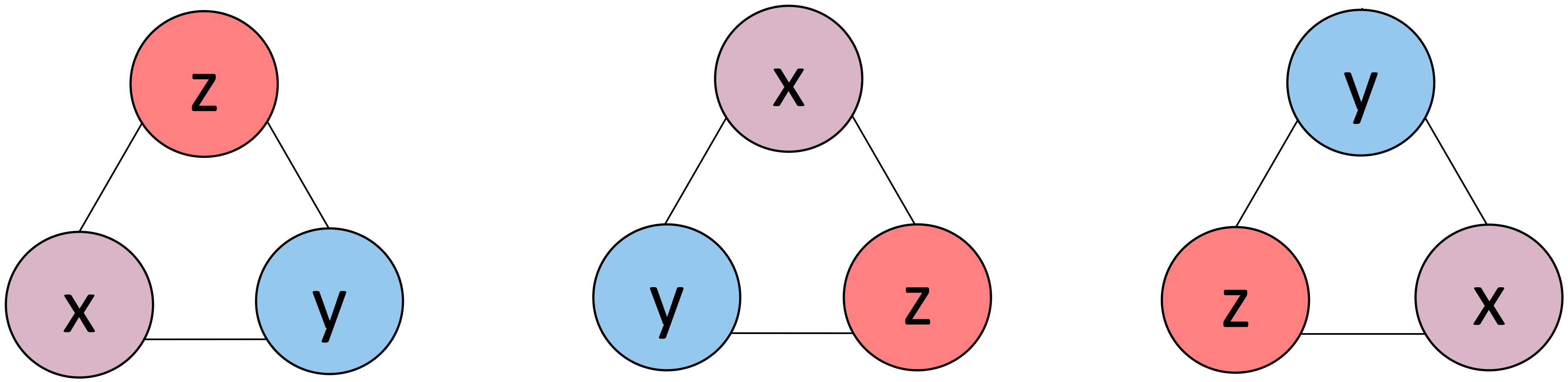

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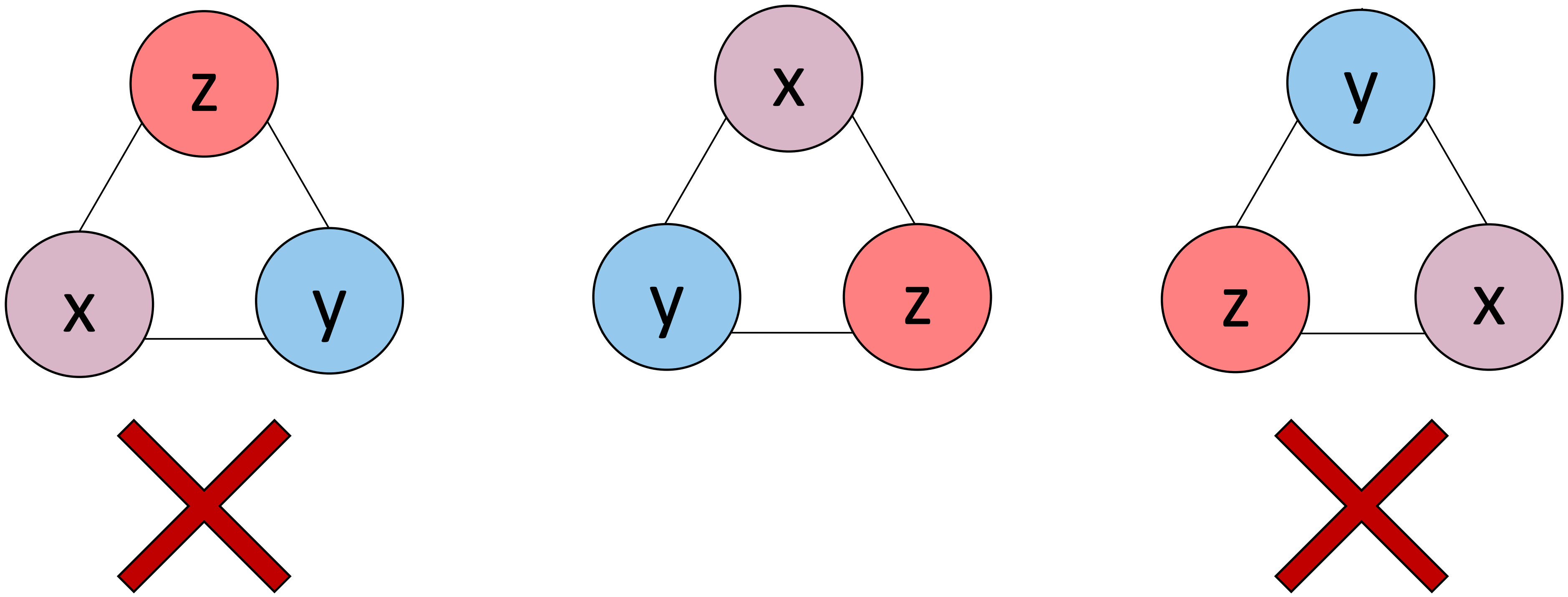
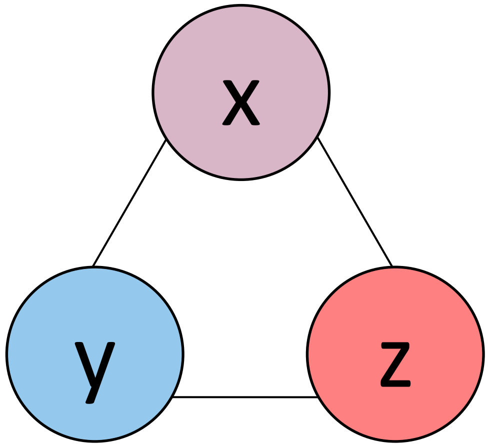


System Requirements

Uniqueness

Structure



System Requirements

Uniqueness

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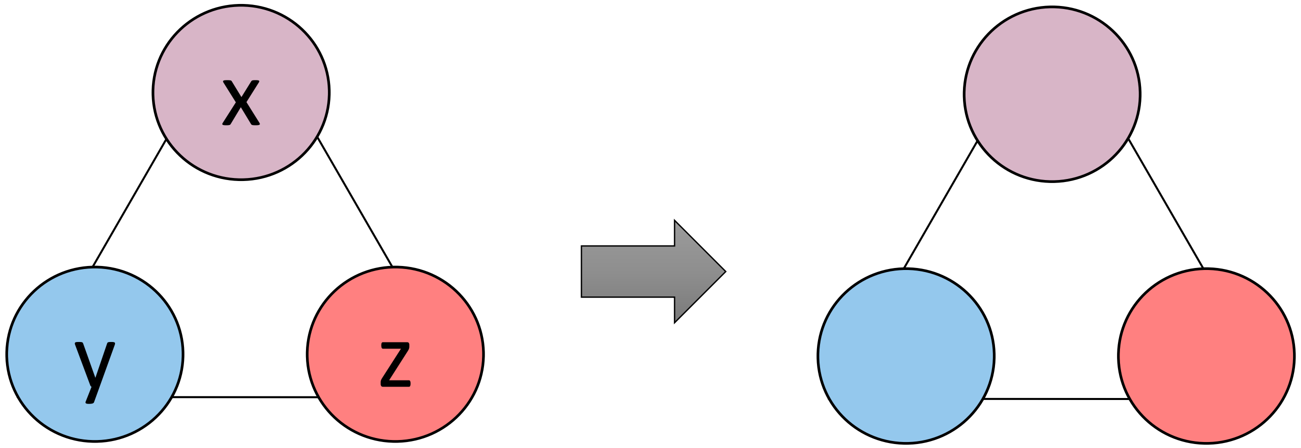
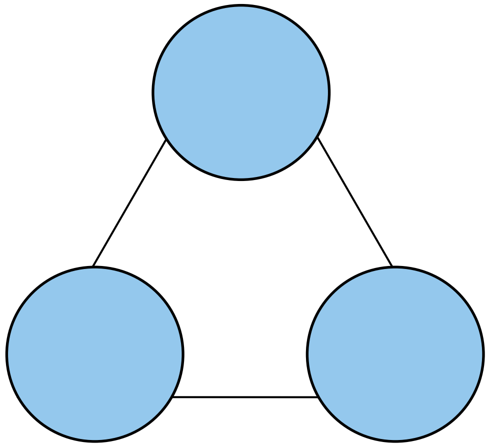


System Requirements

Uniqueness

Structure

Interestingness



System Requirements

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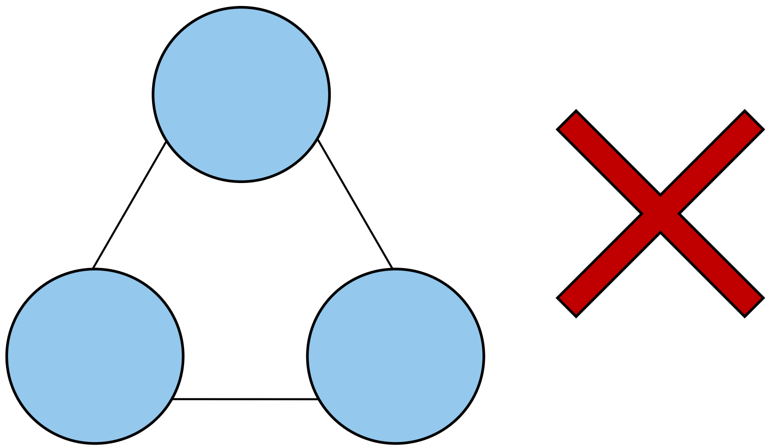

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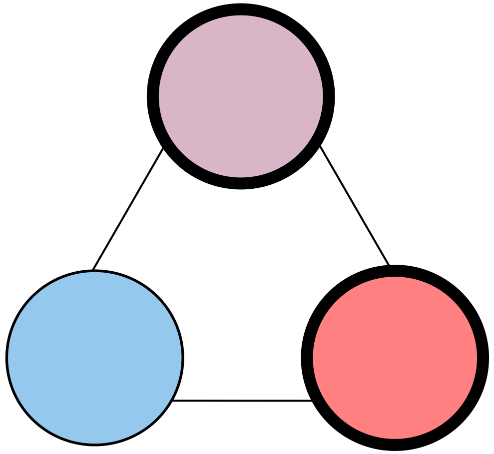

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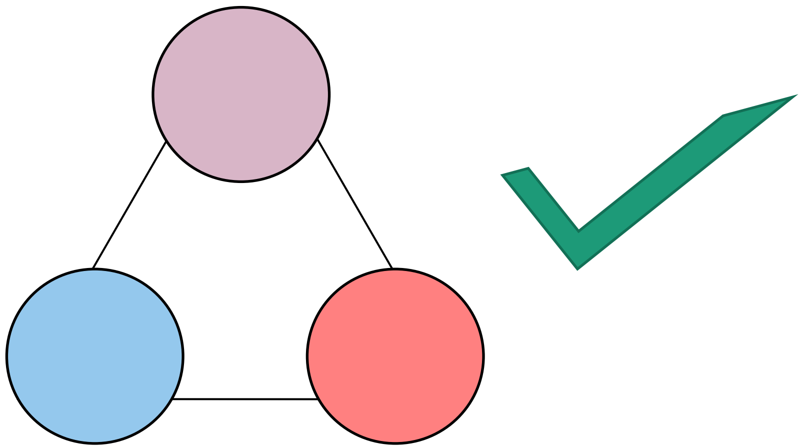

Existing Work

Uniqueness

Structure

Interestingness

Arabesque (SOSP ‘15)

RStream (OSDI ‘18)

Fractal (SIGMOD ‘19)

AutoMine (SOSP ‘19)

Existing Work

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Overlook user requirements

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Overlook user requirements

Per-subgraph computations

PEREGRINE

Pattern Awareness

Pattern Selection

Pattern Matching

Pattern Awareness

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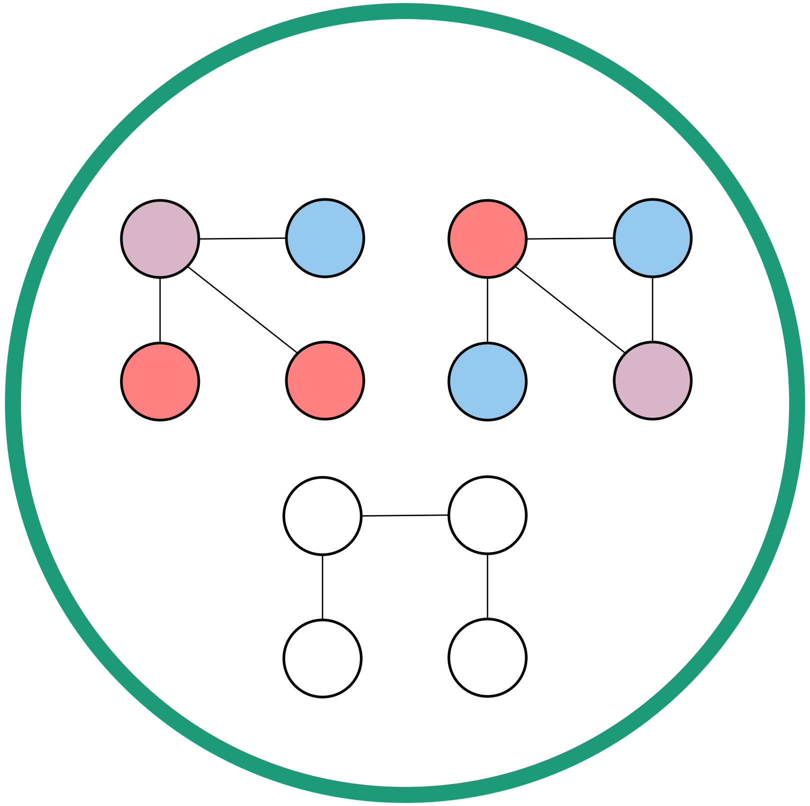
Pattern Selection



Pattern Programming

```
#include “Peregrine.hh”
using namespace Peregrine;

void motifCounting(int size)
{
    DataGraph G(“path/to/graph/”);
    auto patterns = PatternGenerator::all(size, VERTEX_INDUCED);
    auto counts = count(G, patterns);

    for (auto &[pattern, n] : counts)
      std::cout << pattern << “ ” << n << std::endl;
}
```

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auto counts = count(G, patterns);
```

Pattern Programming

```
DataGraph G(“path/to/graph/”);
auto patterns = PatternGenerator::all(size, VERTEX_INDUCED);
patterns[0].set_labels({‘a’, ‘b’, ‘c’, ‘d’});


auto counts = count(G, patterns);
```

Pattern Programming

```
DataGraph G("path/to/graph/");
auto patterns = PatternGenerator::all(size, VERTEX_INDUCED);
patterns[0].set_labels({'a', 'b', 'c', 'd'});
patterns[0].add_edge(1, 5);

auto counts = count(G, patterns);
```

Pattern Programming

```
DataGraph G(“path/to/graph/”);
auto patterns = PatternGenerator::all(size, VERTEX_INDUCED);
patterns[0].set_labels({‘a’, ‘b’, ‘c’, ‘d’});
patterns[0].add_edge(1, 5);
patterns.emplace_back(“path/to/pattern.txt”);
auto counts = count(G, patterns);
```

Pattern Programming

```
DataGraph G(“path/to/graph/”);
auto patterns = PatternGenerator::all(size, VERTEX_INDUCED);
auto pattern = Pattern().add_edge(1, 2)
                        .add_edge(1, 3)
                        .add_edge(2, 3);
auto counts = count(G, {pattern});
```

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Pattern Programming

```
void frequentSubgraphMining()
{
   DataGraph G("path/to/graph/");
   auto patterns = PatternGenerator::all(2, EDGE_INDUCED);
   auto mapDomain = [](auto &&match, auto &&aggregator)
      { aggregator.map(match.pattern, match.mapping); };

   auto results = match<Pattern, Domain>(G, patterns, mapDomain);

   for (auto &[pattern, frequency] : results)
     std::cout << pattern << " " << frequency << std::endl;
}
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Pattern Awareness

Pattern Selection

Pattern Matching

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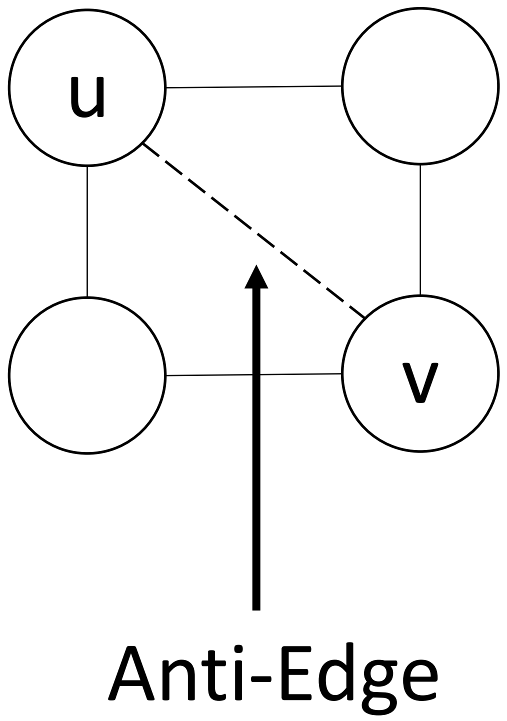
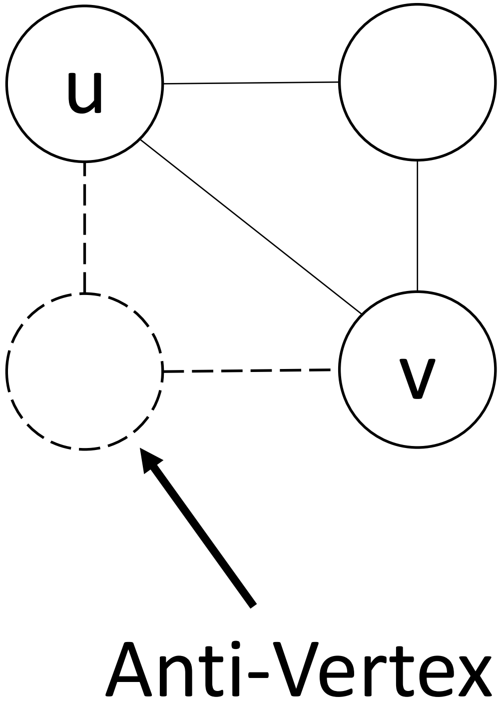
Pattern Selection



Pattern Awareness

Pattern Selection



Pattern Awareness

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Pattern Matching

- Symmetry breaking (RECOMB '07)
- Core pattern reduction (SIGMOD '16)

Symmetry Breaking

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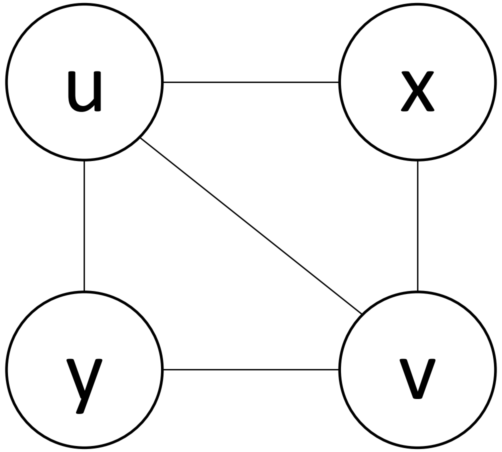
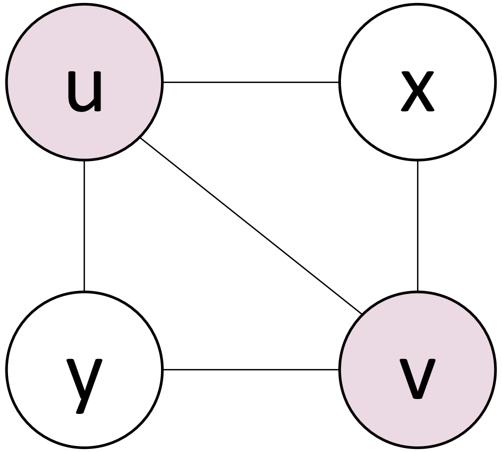


Symmetry Breaking



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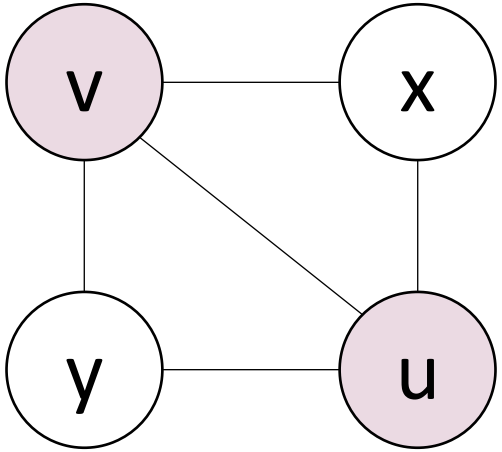

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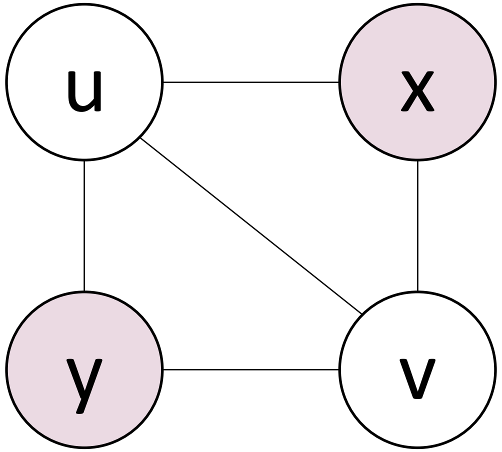

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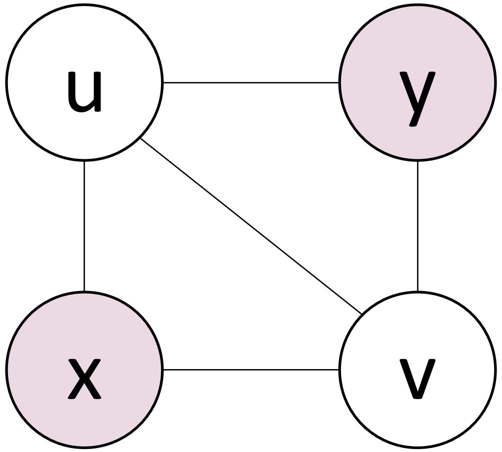

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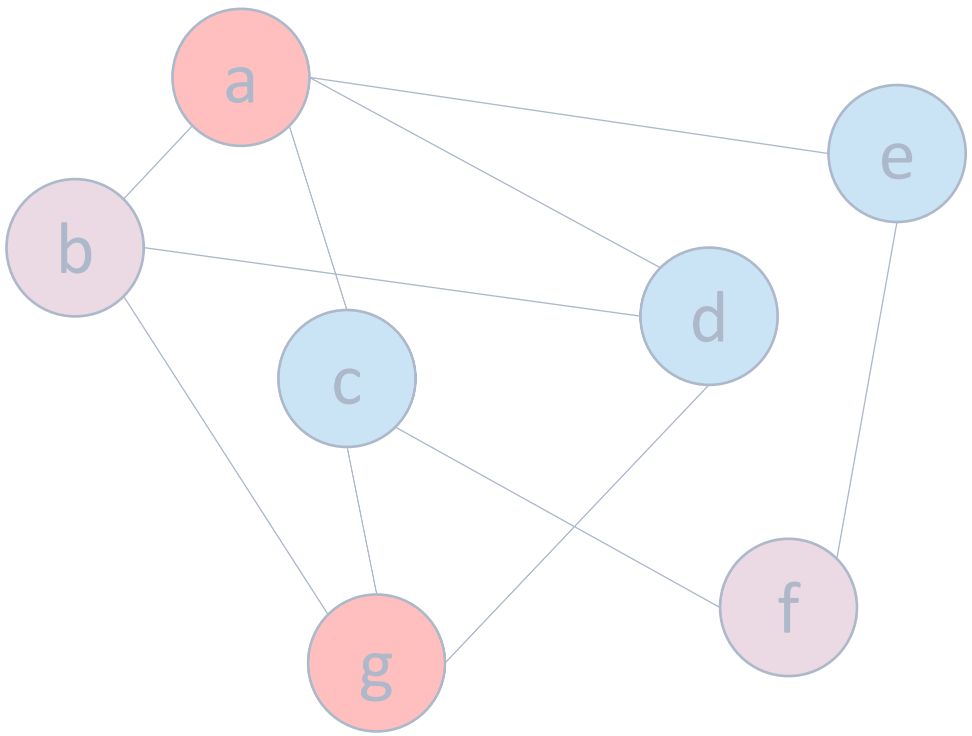
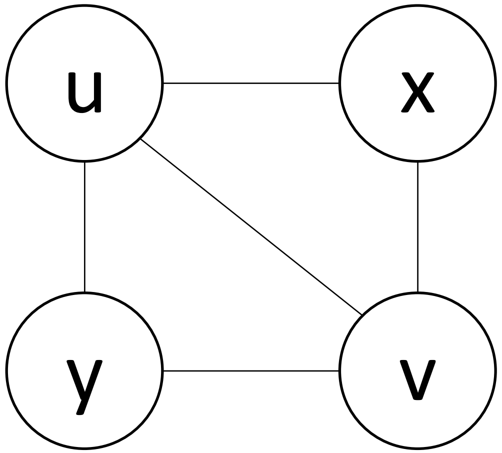
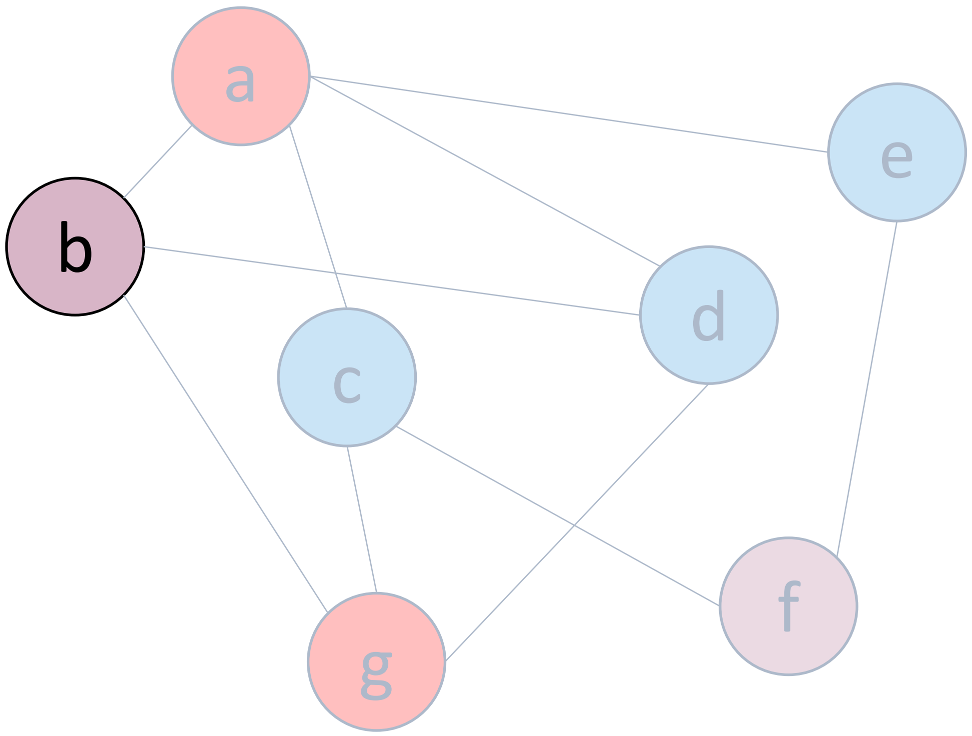


Data Graph



Worker 1

Symmetry Breaking



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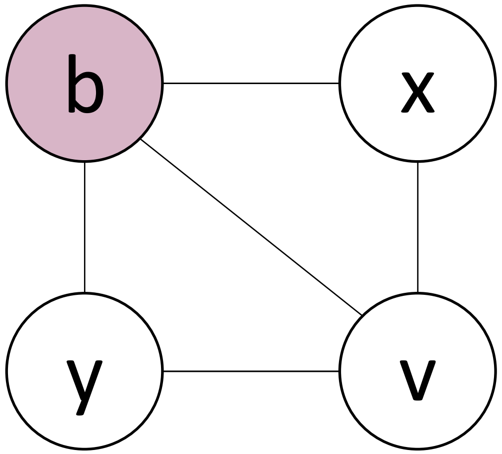
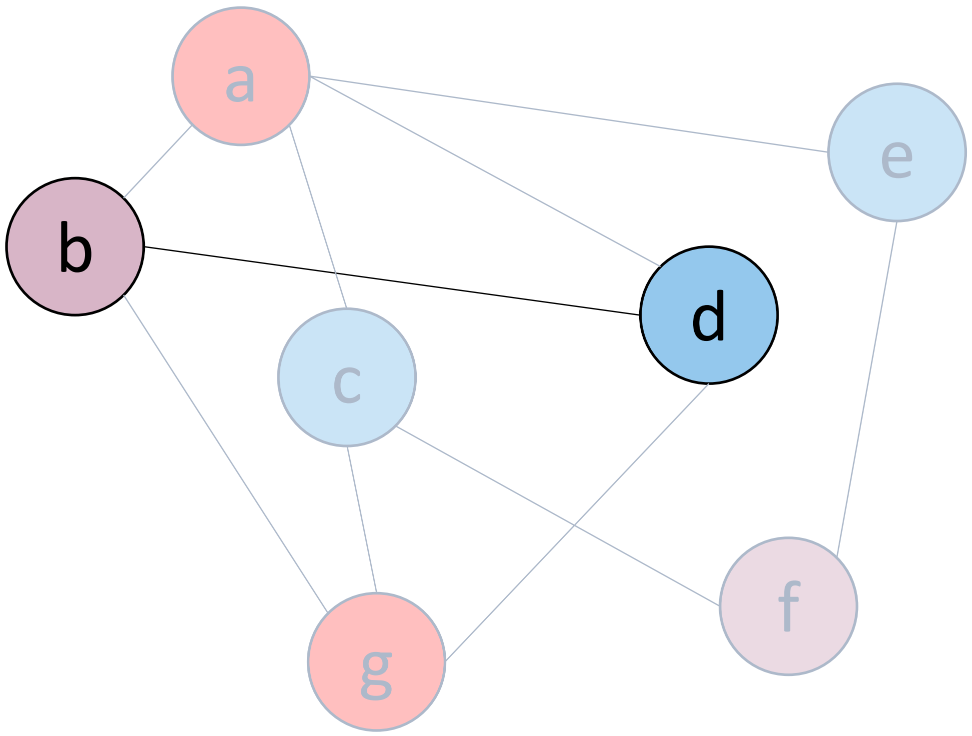


Worker 1

Symmetry Breaking



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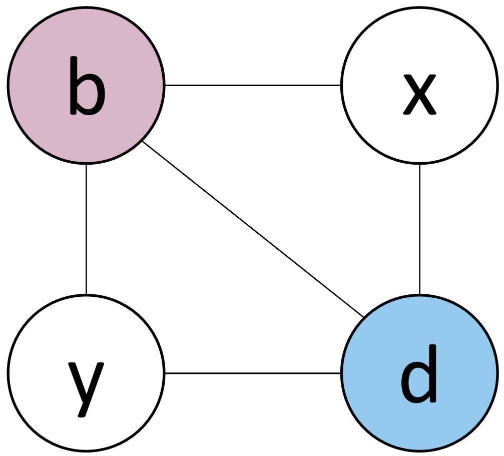

Worker 1

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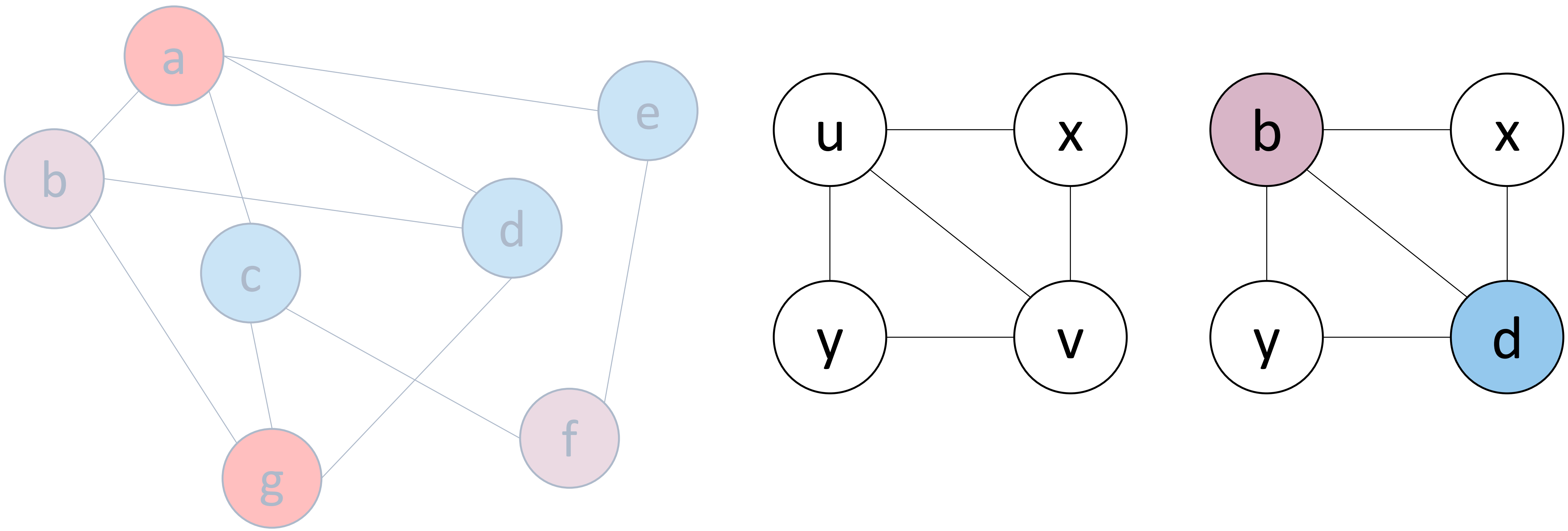
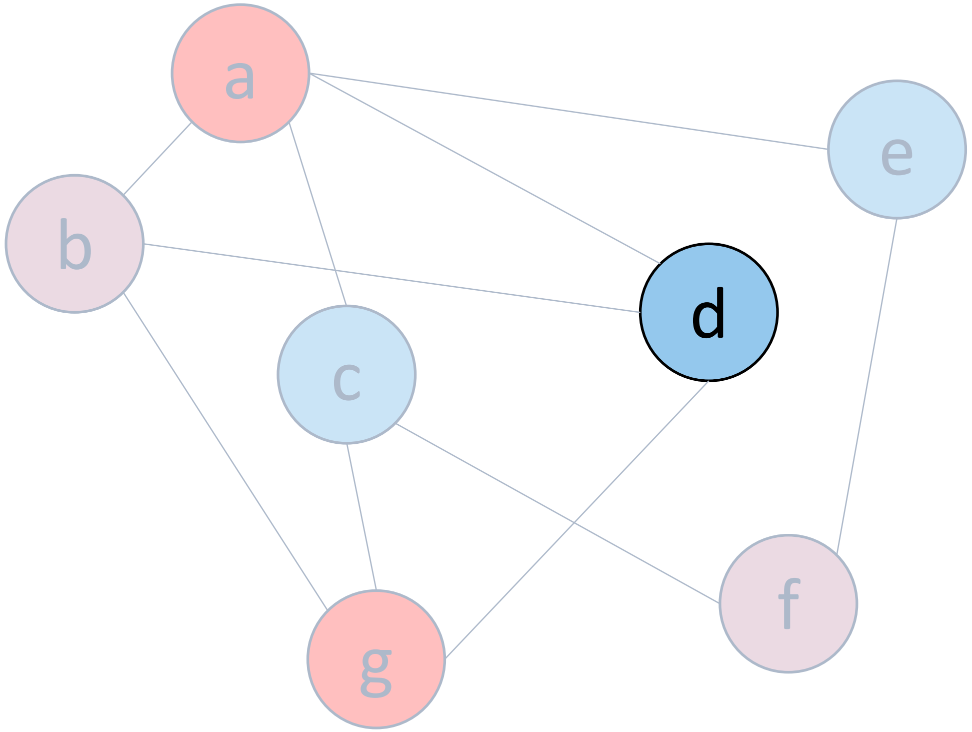


Data Graph Worker 2 Worker 1

Symmetry Breaking



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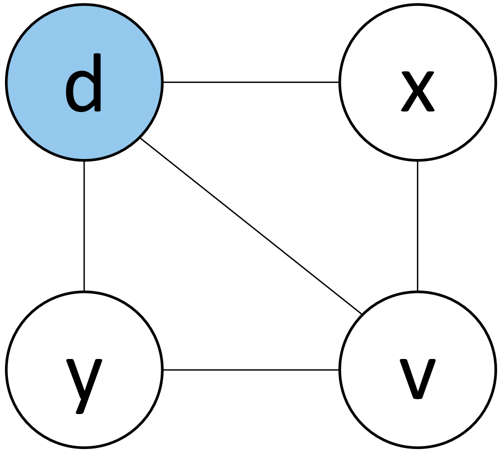
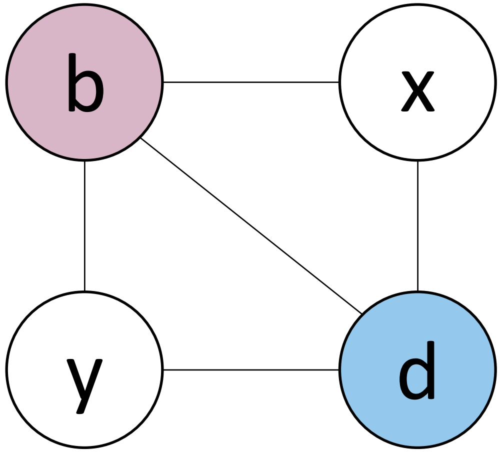
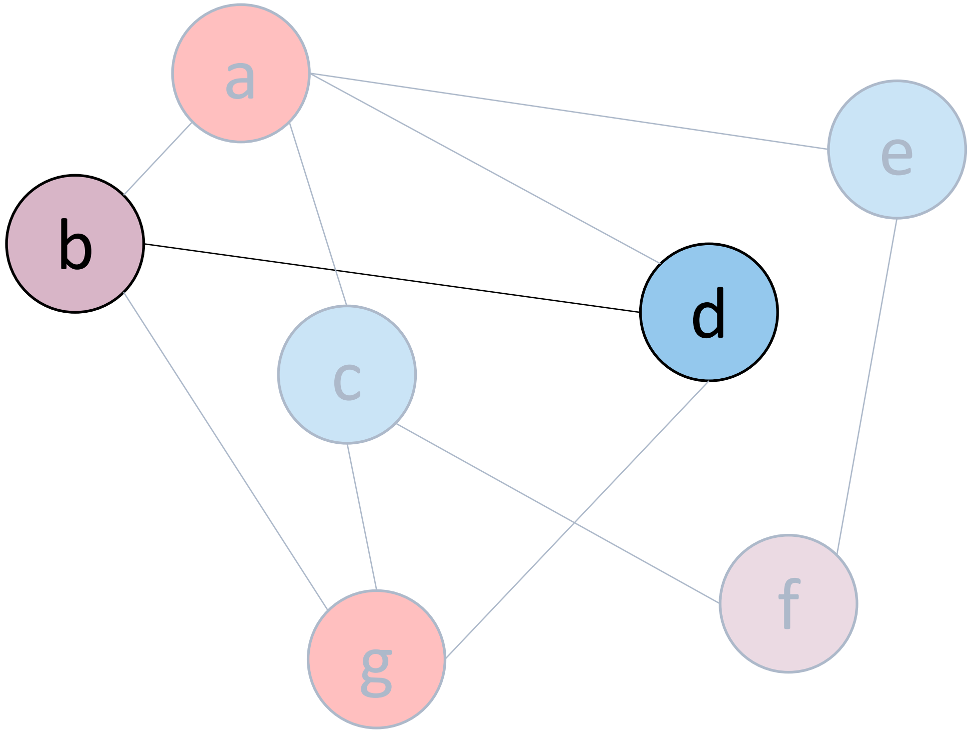


Worker 2

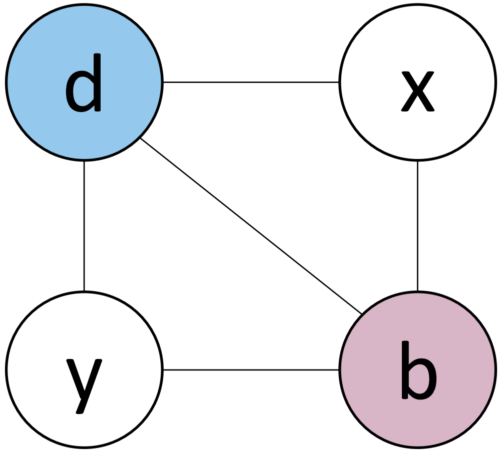


Worker 1

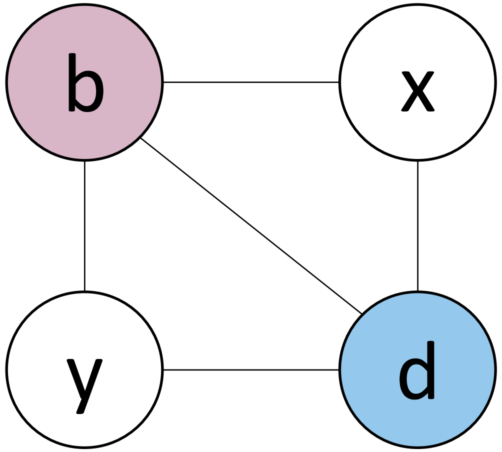
Symmetry Breaking



Data Graph

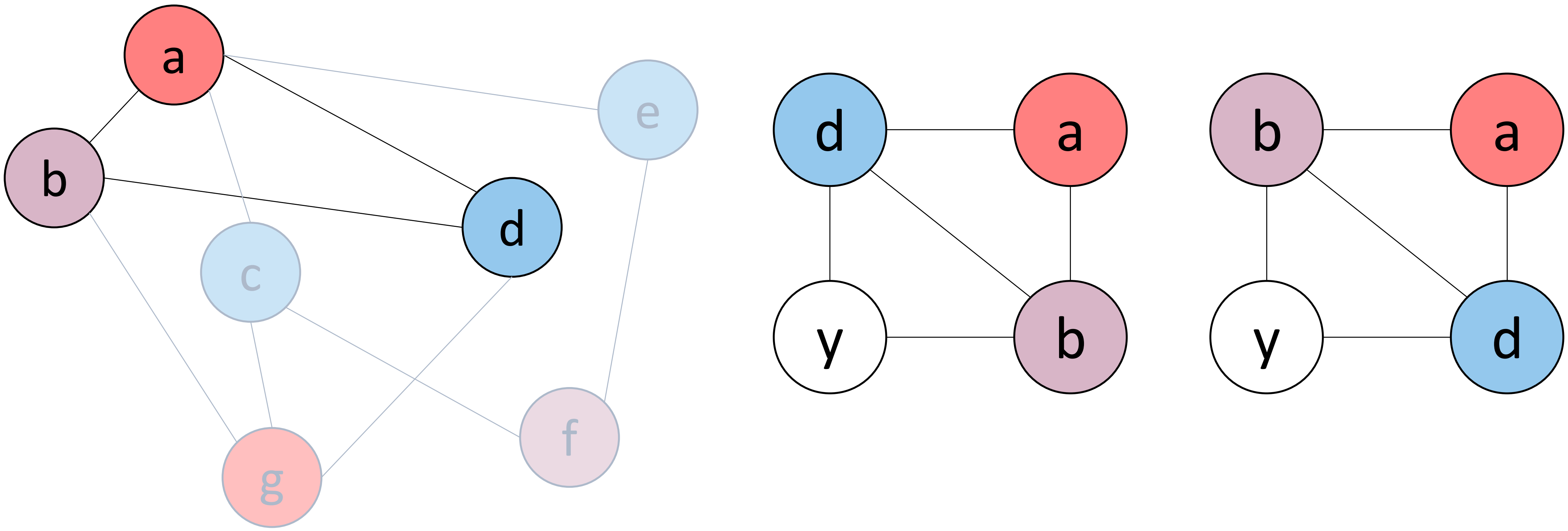


Worker 2



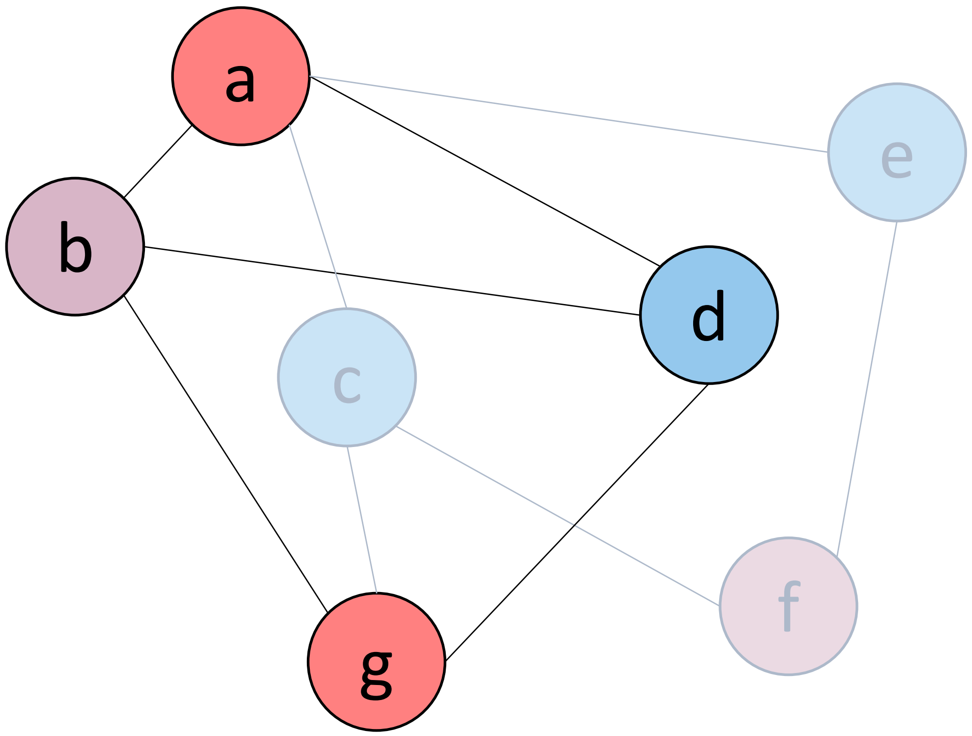
Worker 1

Symmetry Breaking

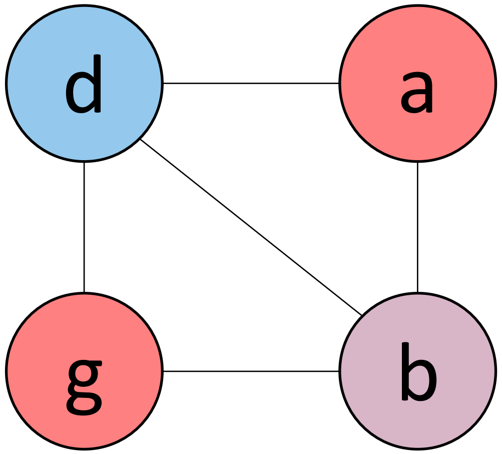


Data Graph Worker 2 Worker 1

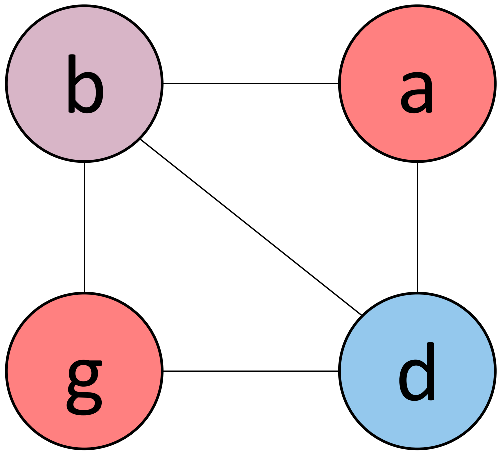
Symmetry Breaking



Data Graph

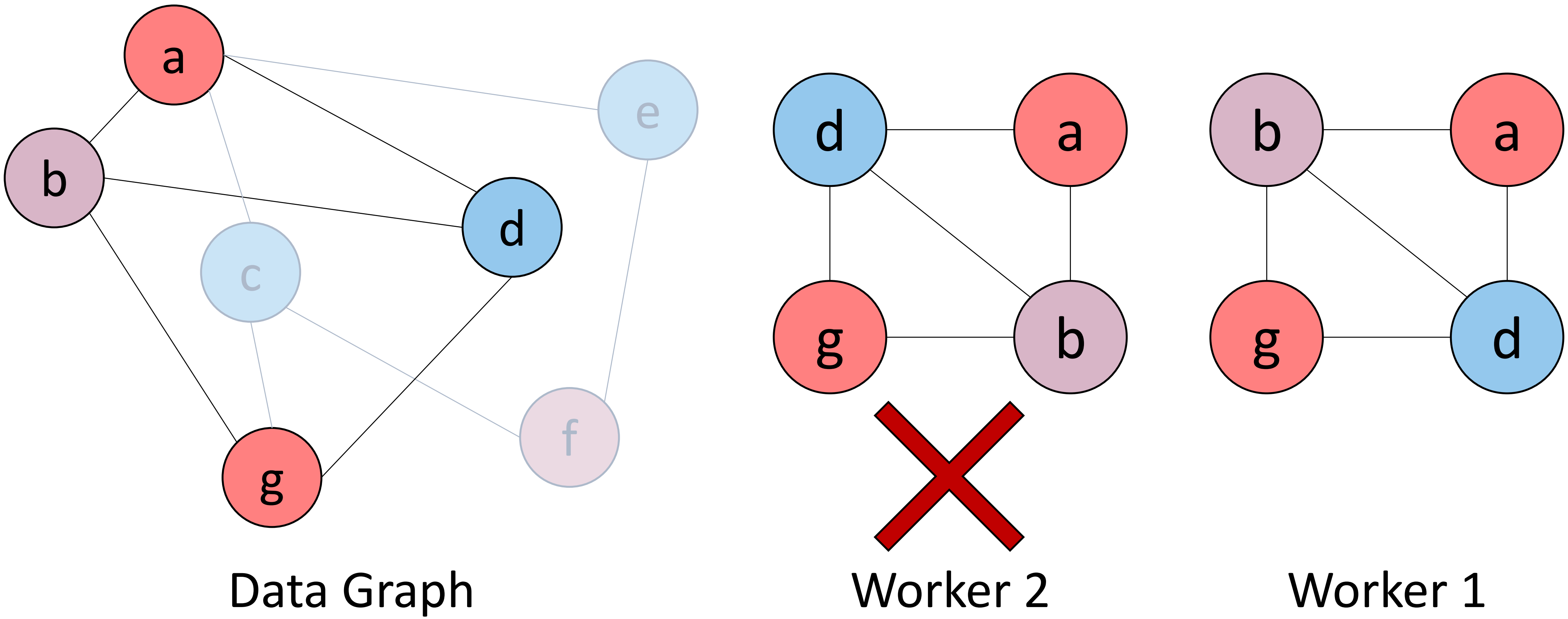


Worker 2

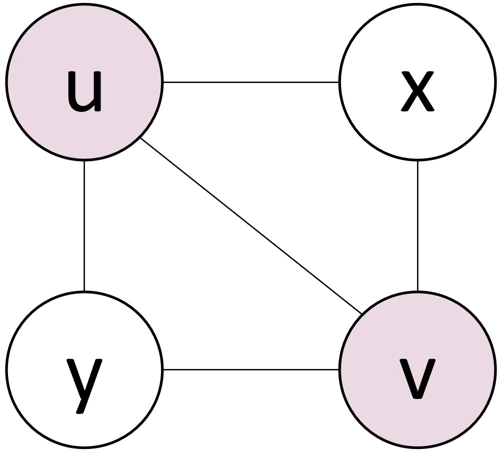


Worker 1

Symmetry Breaking

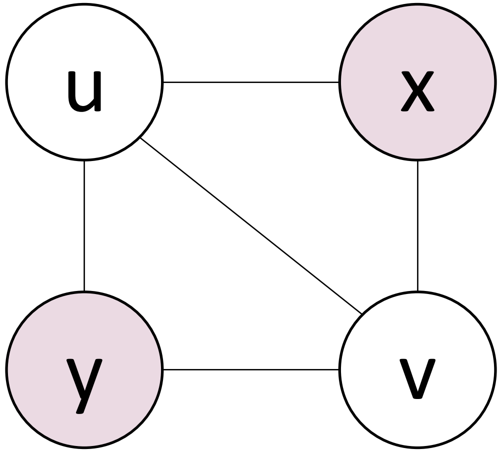


Symmetry Breaking



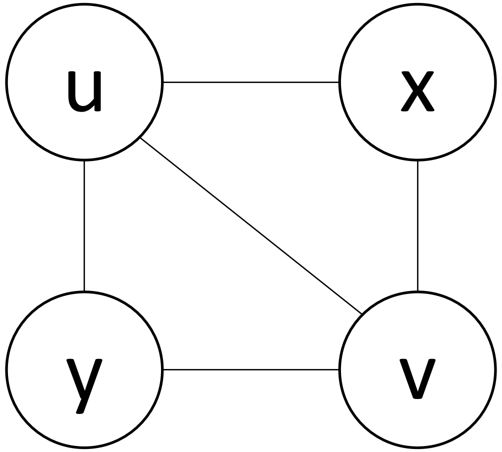
u < v

Symmetry Breaking



x < y

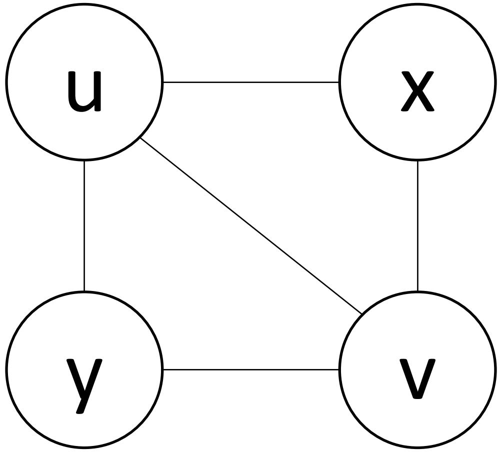
Symmetry Breaking



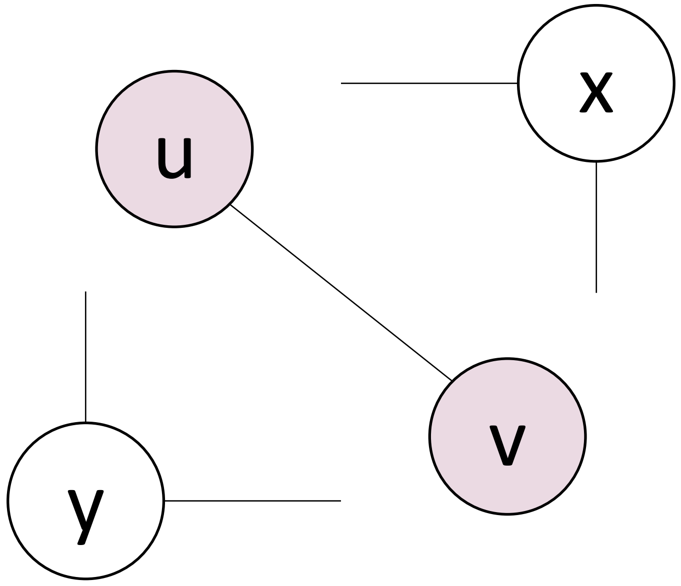
u < v

x < y

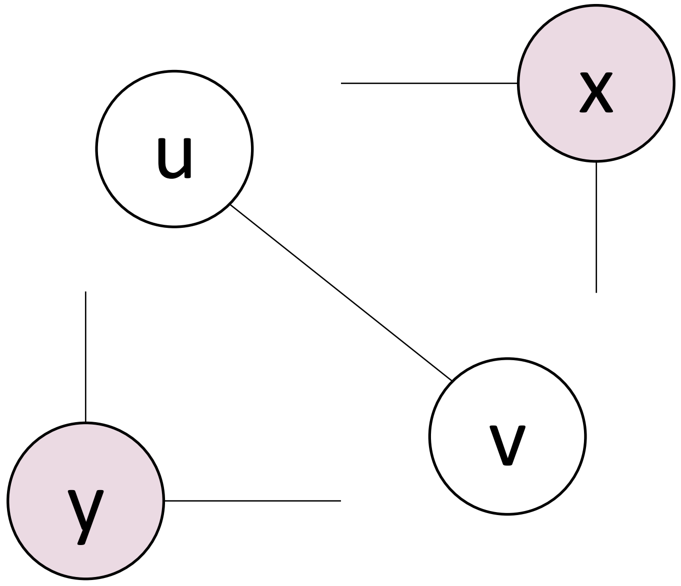
Core Pattern



Core Pattern



Core Pattern



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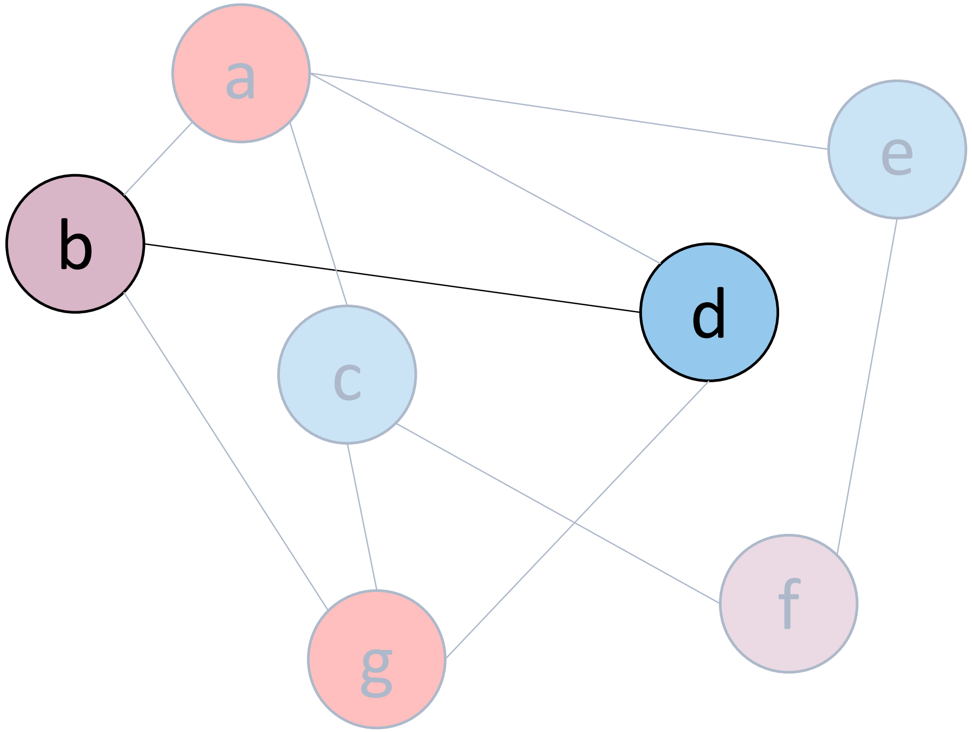
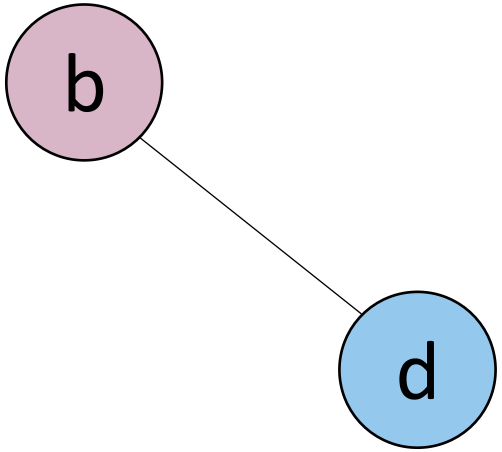
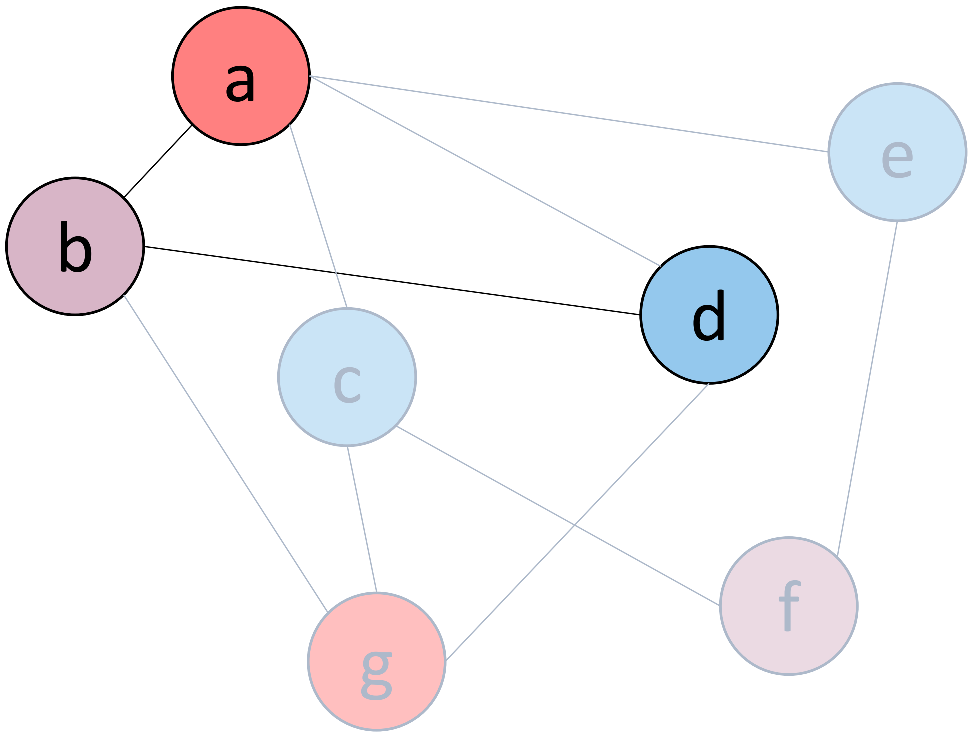


Data Graph

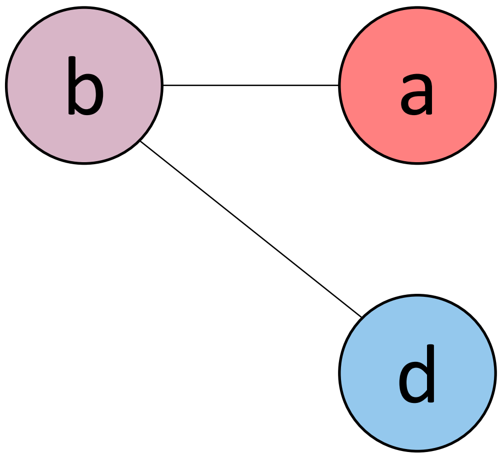


Pattern-Unaware

Core Pattern

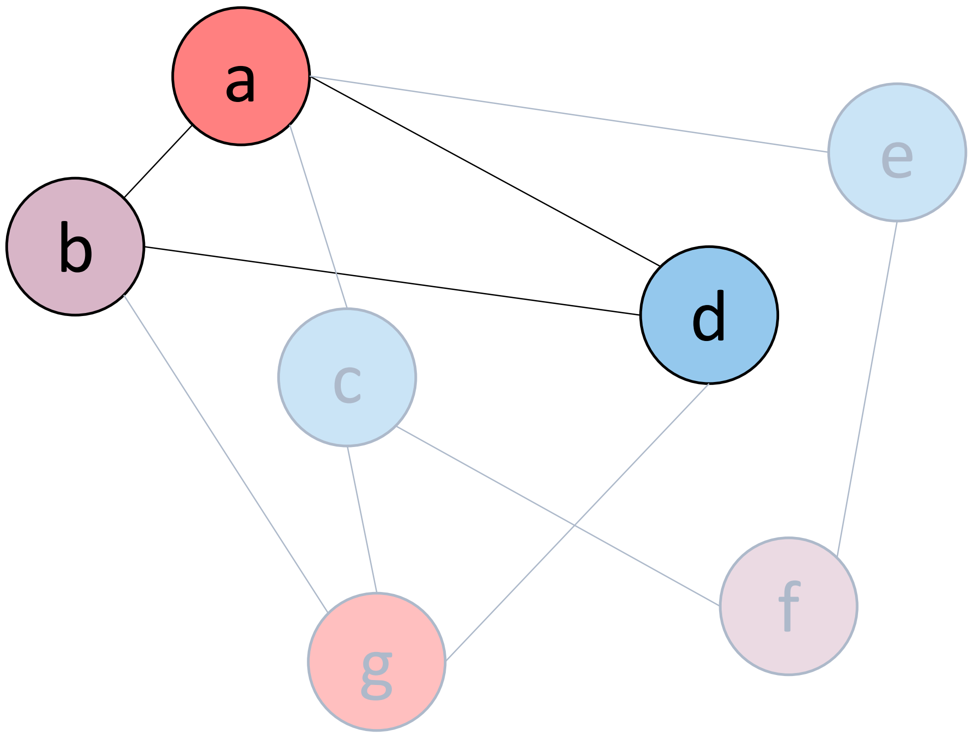


Data Graph

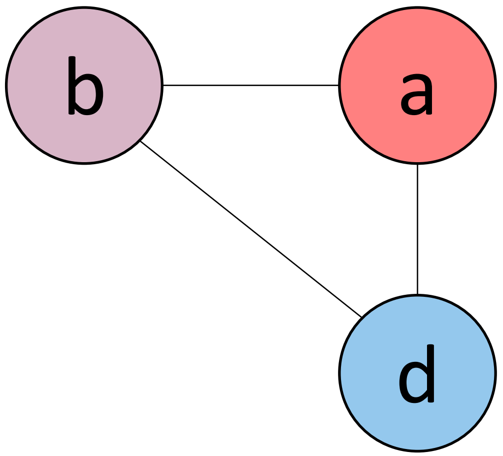


Pattern-Unaware

Core Pattern

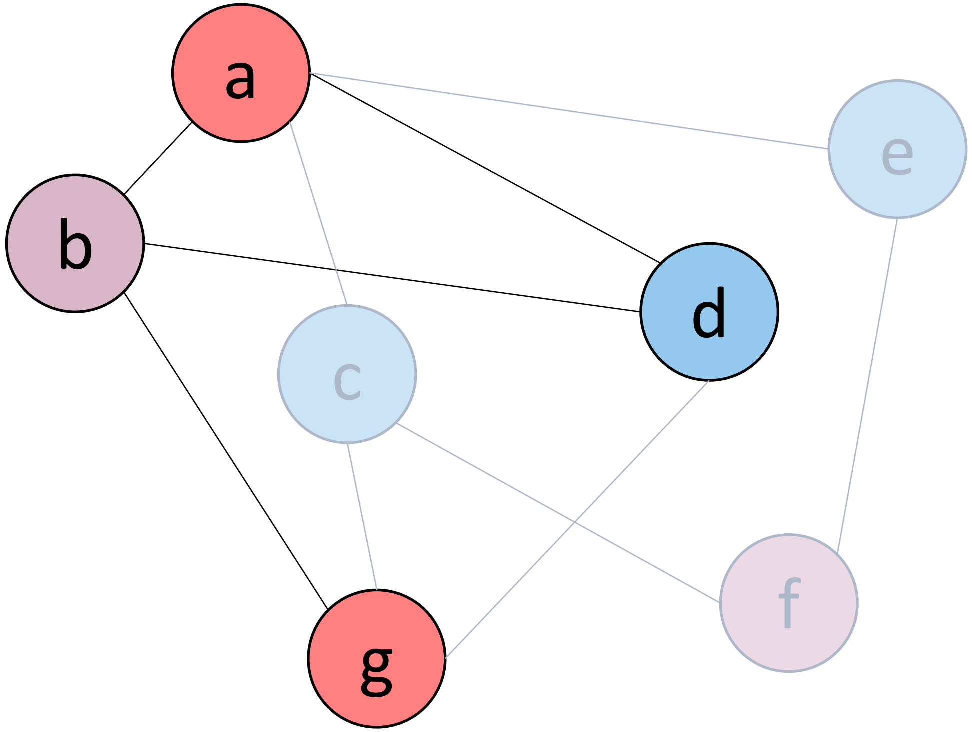


Data Graph

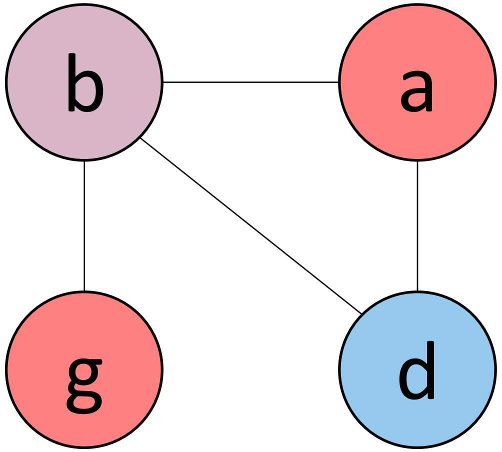


Pattern-Unaware

Core Pattern

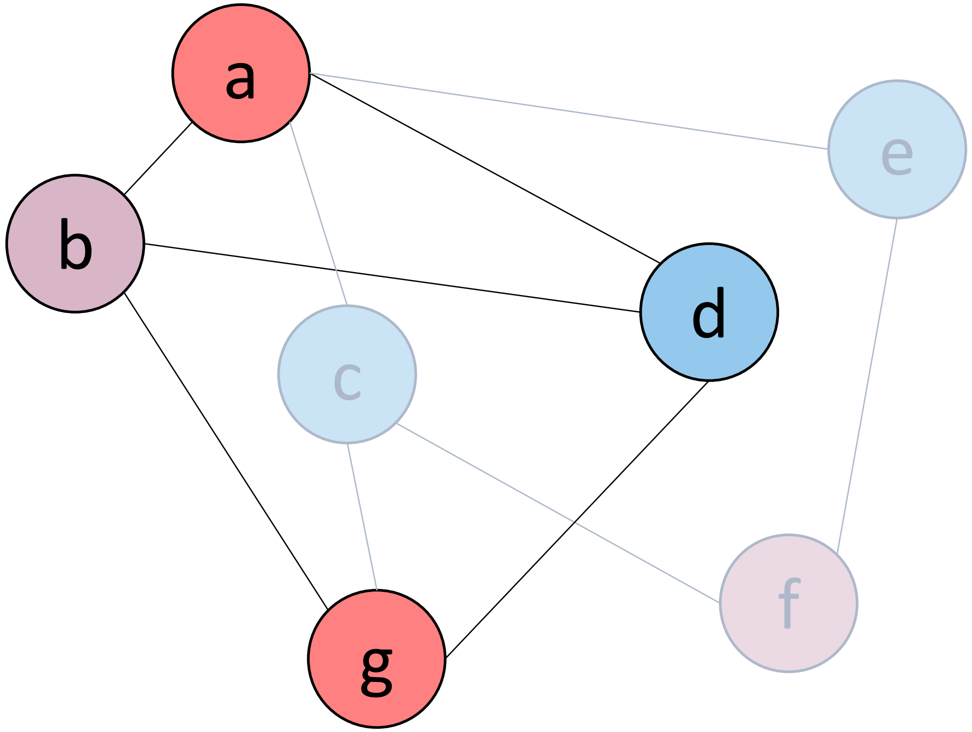


Data Graph

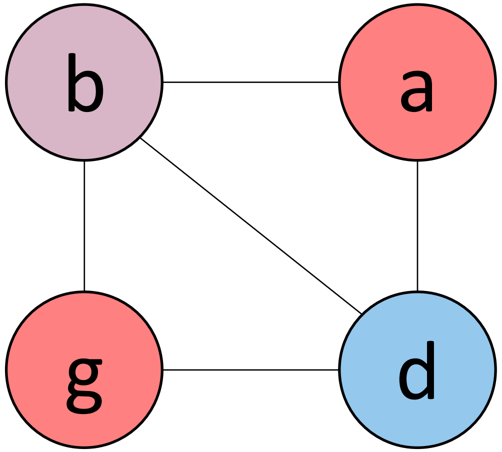


Pattern-Unaware

Core Pattern

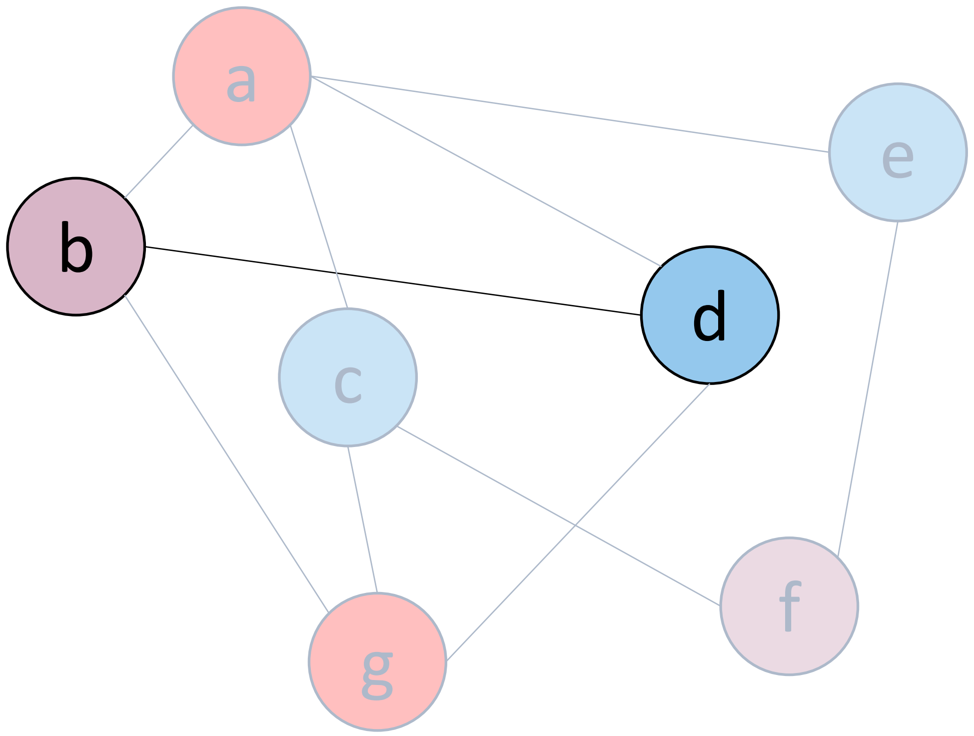


Data Graph

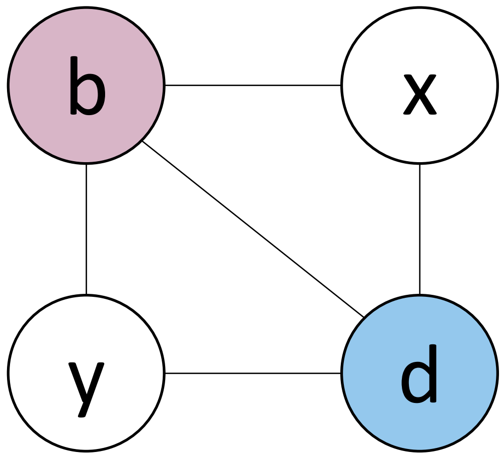


Pattern-Unaware

Core Pattern

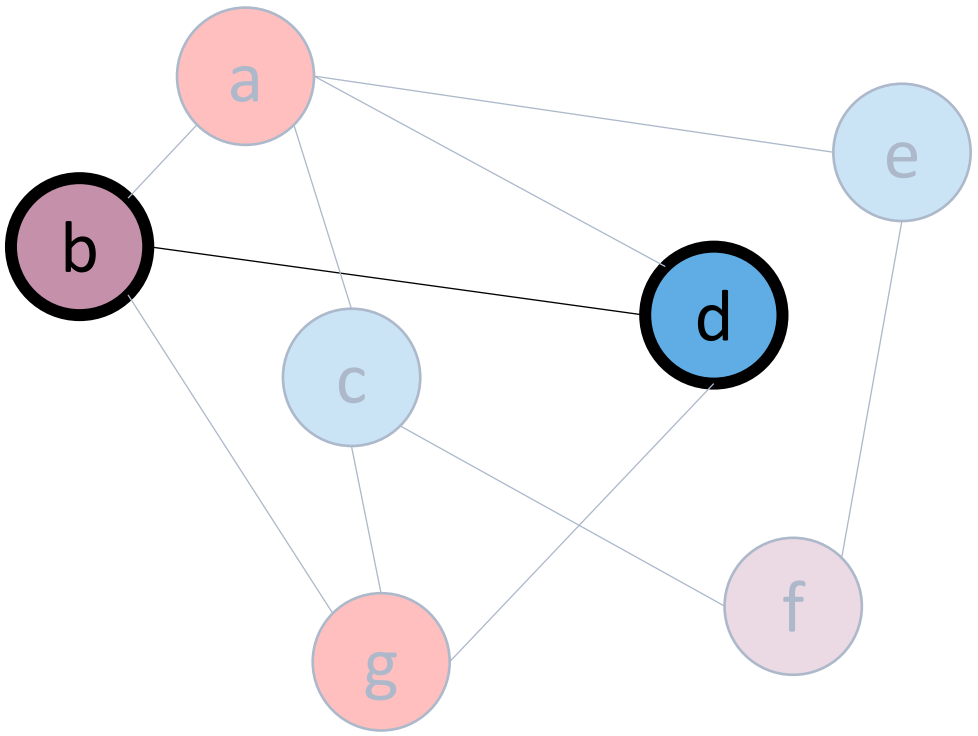


Data Graph

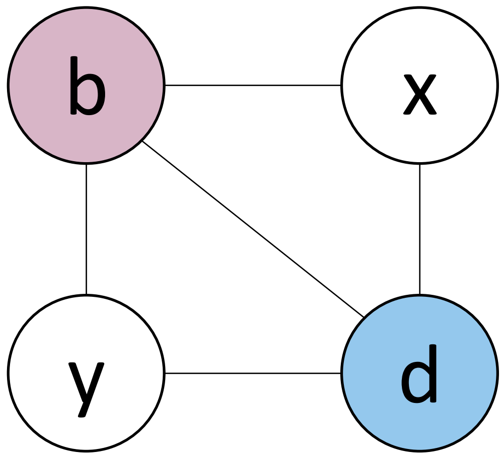


Pattern-Aware

Core Pattern

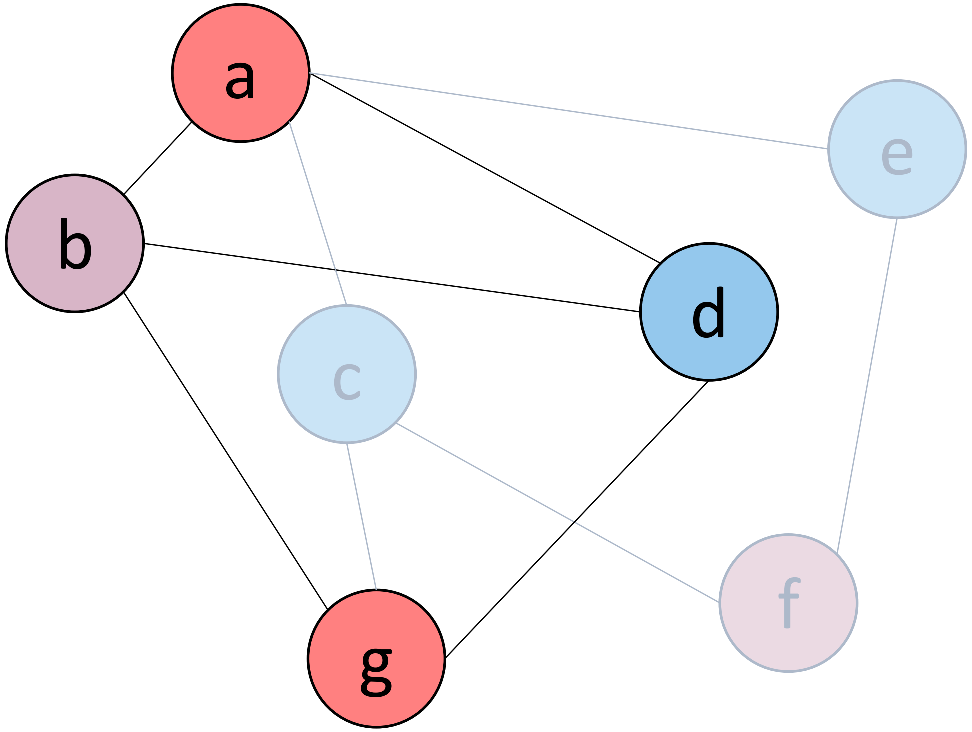


Data Graph

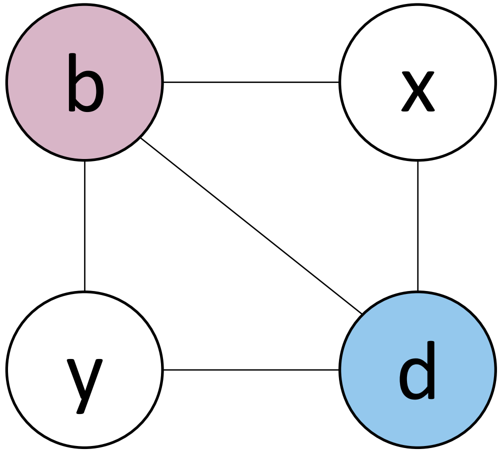


Pattern-Aware

Core Pattern

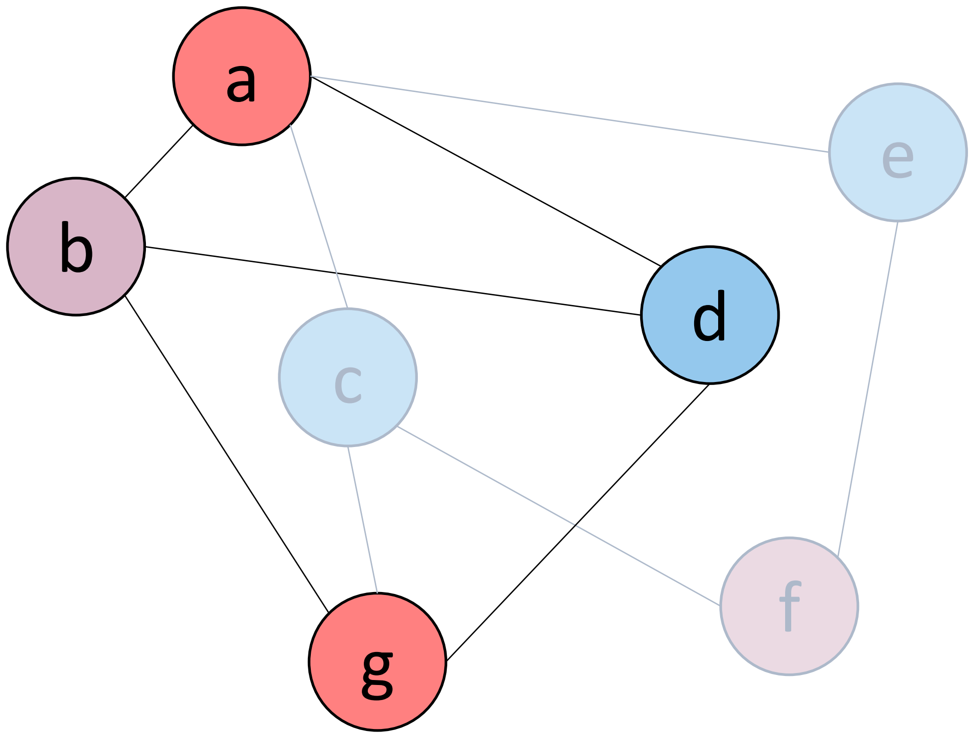


Data Graph

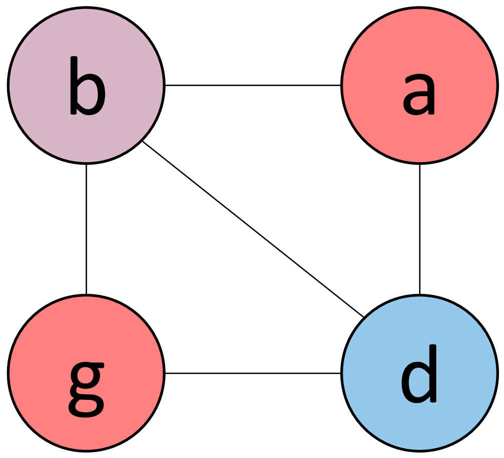


Pattern-Aware

Core Pattern

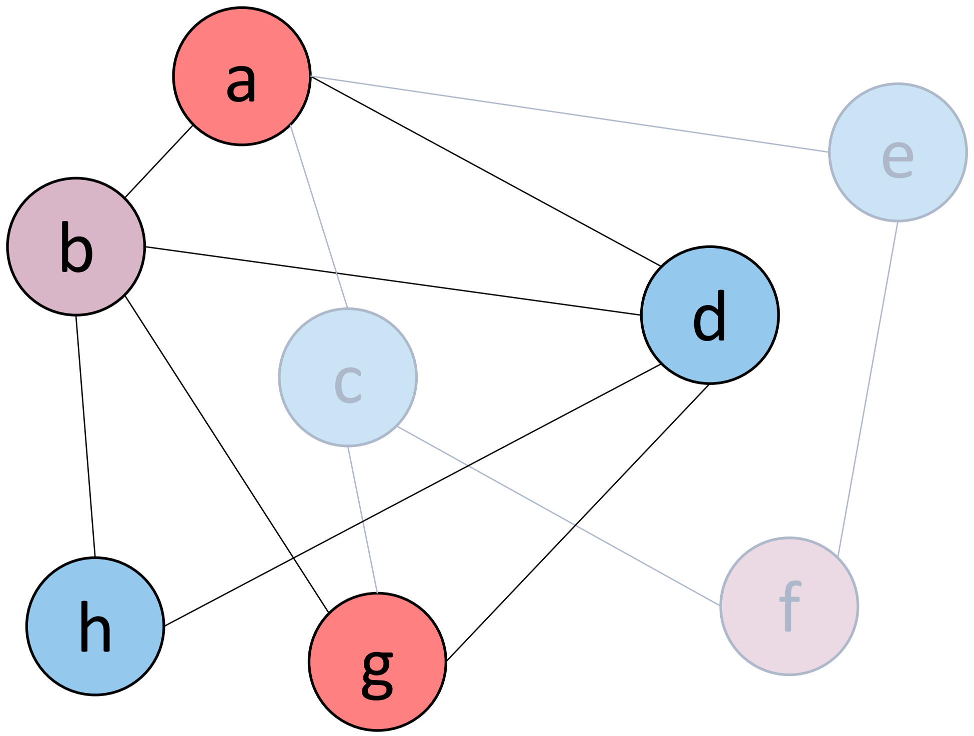


Data Graph

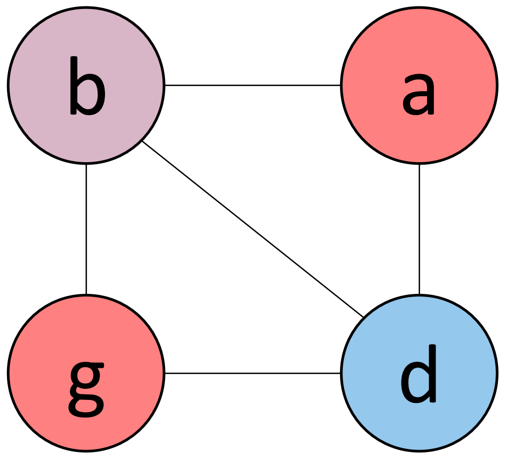


Pattern-Aware

Core Pattern

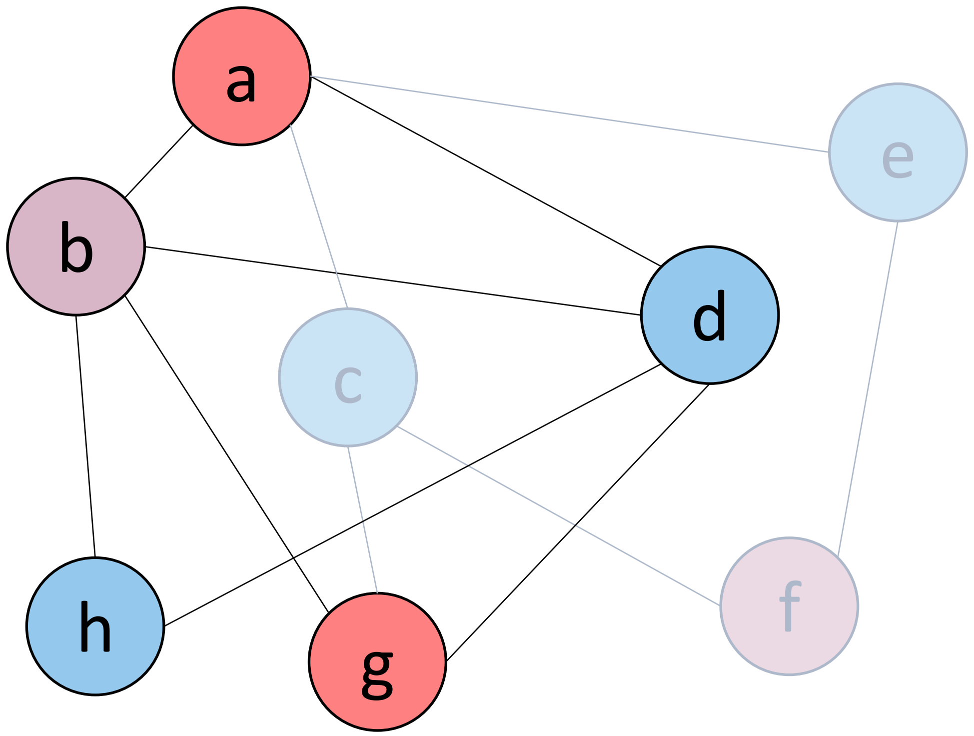


Data Graph

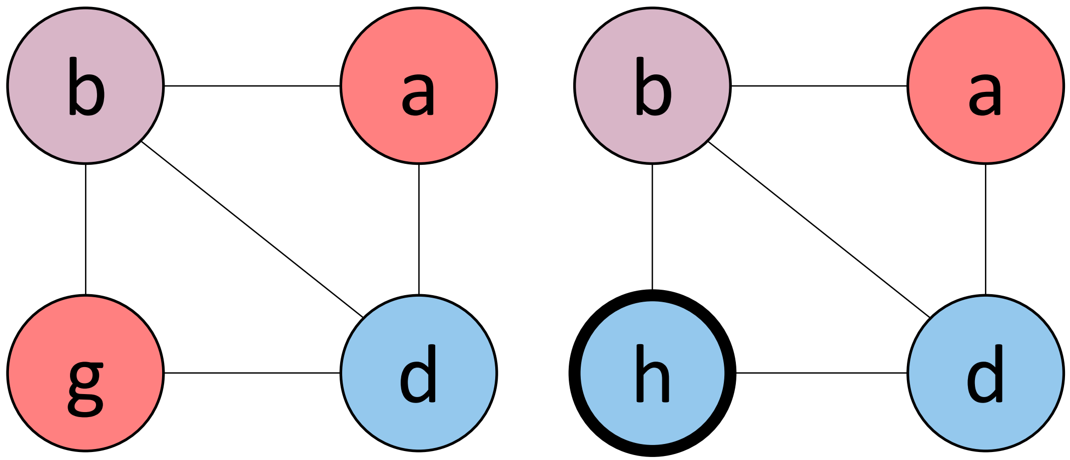


Pattern-Aware

Core Pattern

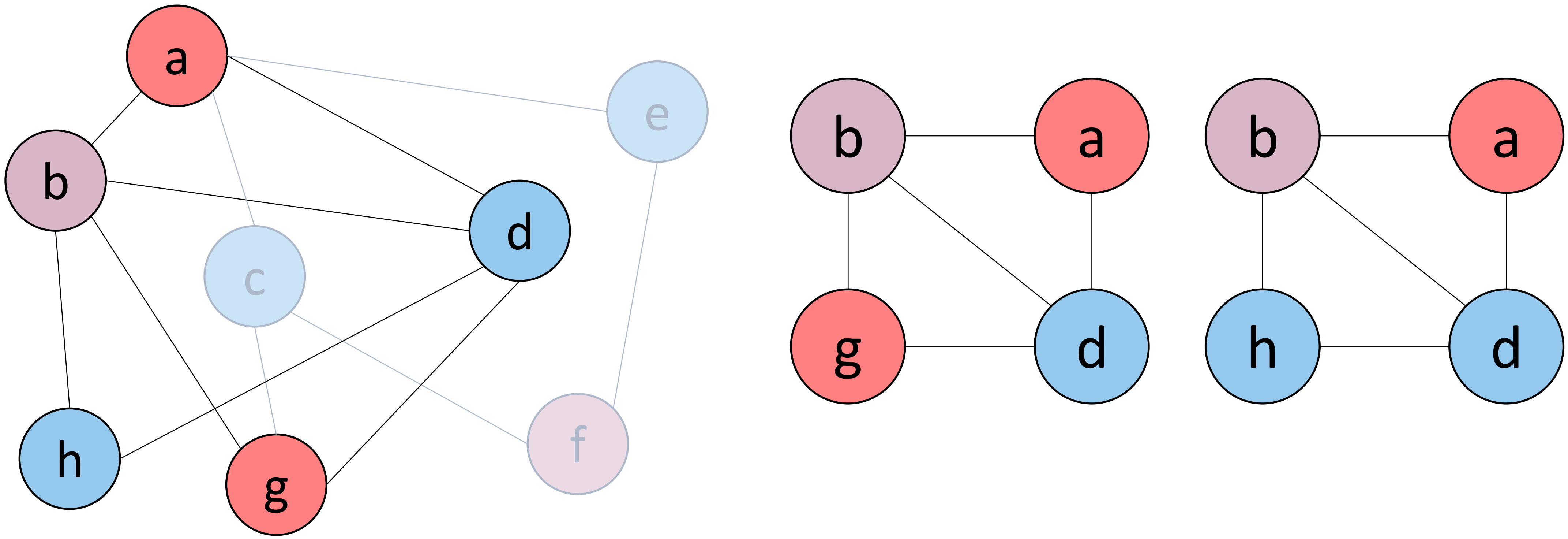


Data Graph



Pattern-Aware

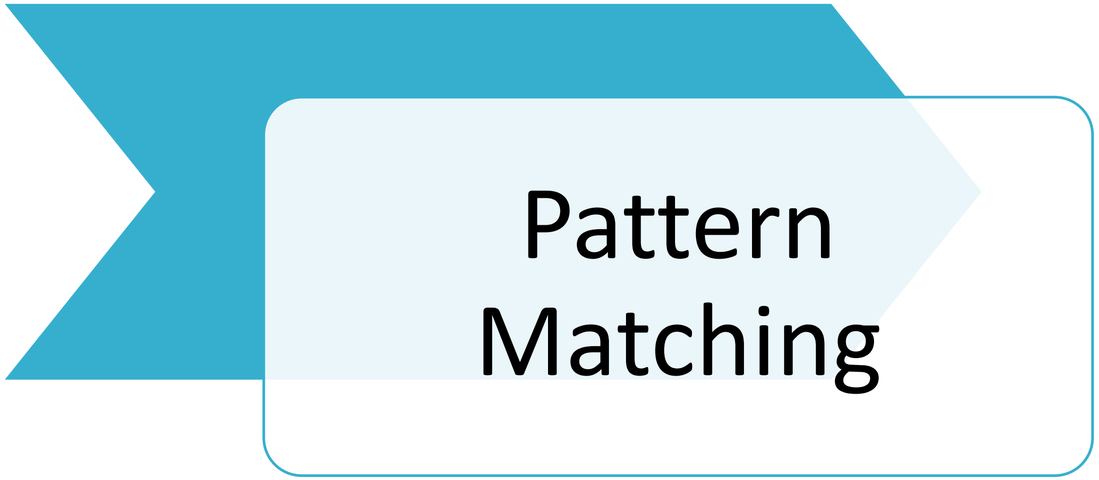
Core Pattern



Data Graph

Pattern-Aware

Pattern Awareness



- Symmetry breaking (RECOMB ‘07)
- Core pattern reduction (SIGMOD ‘16)

Pattern Awareness

- Early termination

Early Termination

```
bool globalClusteringCoefficient(int bound)
{
  DataGraph G("path/to/graph/");
  auto triplet = PatternGenerator::star(3);
  int numTriplets = count(G, {triplet});
  auto countAndCheck = [=](auto &&match, auto &&aggregator)
  {
    int numTriangles = aggregator.readValue(match.pattern);
    if (3*numTriangles/numTriplets > bound) aggregator.stop();
    else aggregator.map(match.pattern, 1);
  }
  auto triangle = PatternGenerator::clique(3);
  auto result = match<Pattern, int>(G, triangle, countAndCheck);
  return 3*result[triangle]/numTriplets > bound;
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```

Early Termination

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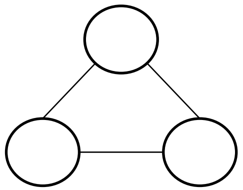
Early Termination



Triangle

```
bool globalClusteringCoefficient(int bound)
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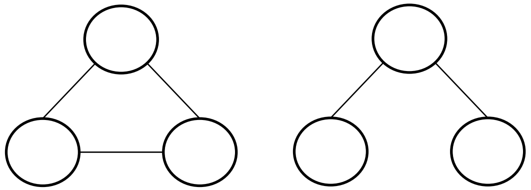
Early Termination

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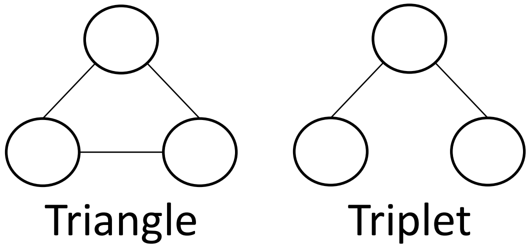
Early Termination

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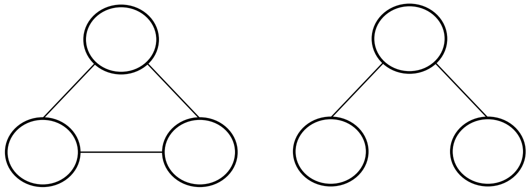
Early Termination

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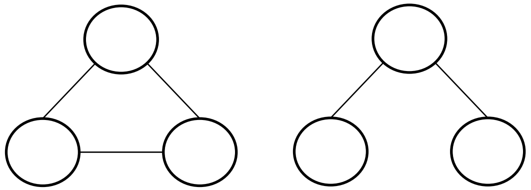
Early Termination



Triangle Triplet

```
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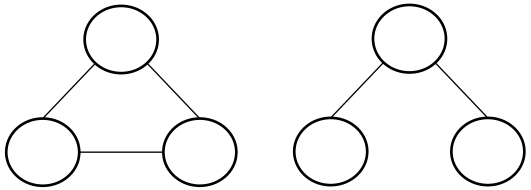
Early Termination

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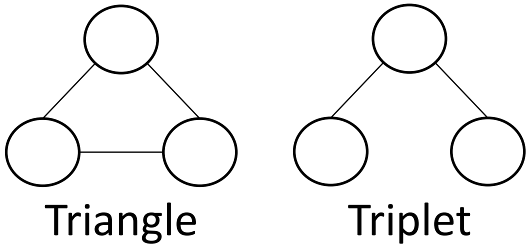
Early Termination

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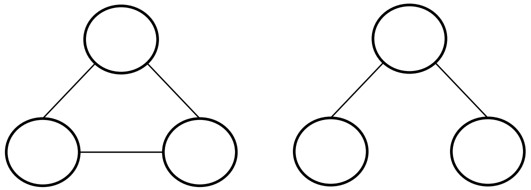
Early Termination

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Early Termination

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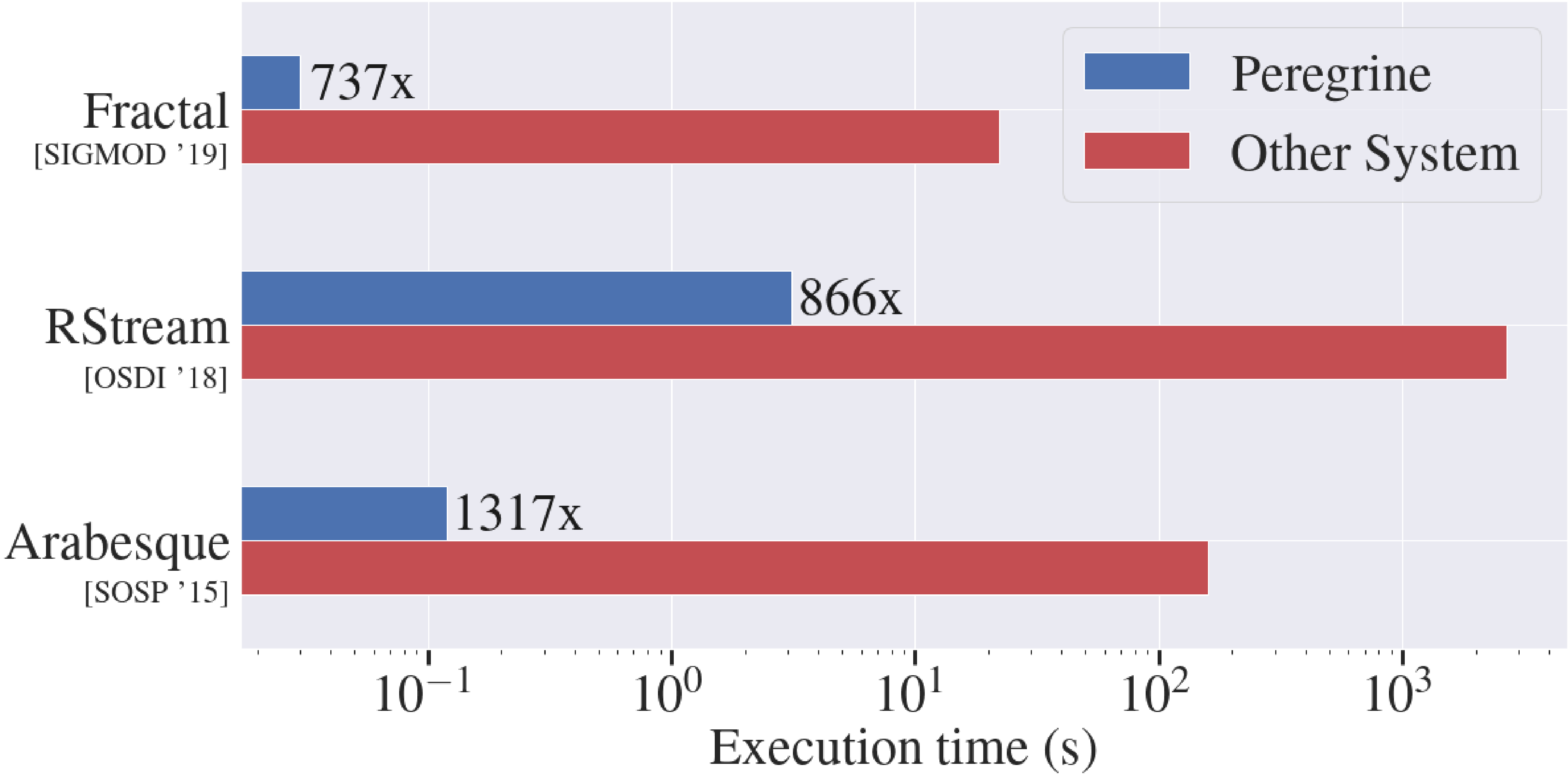
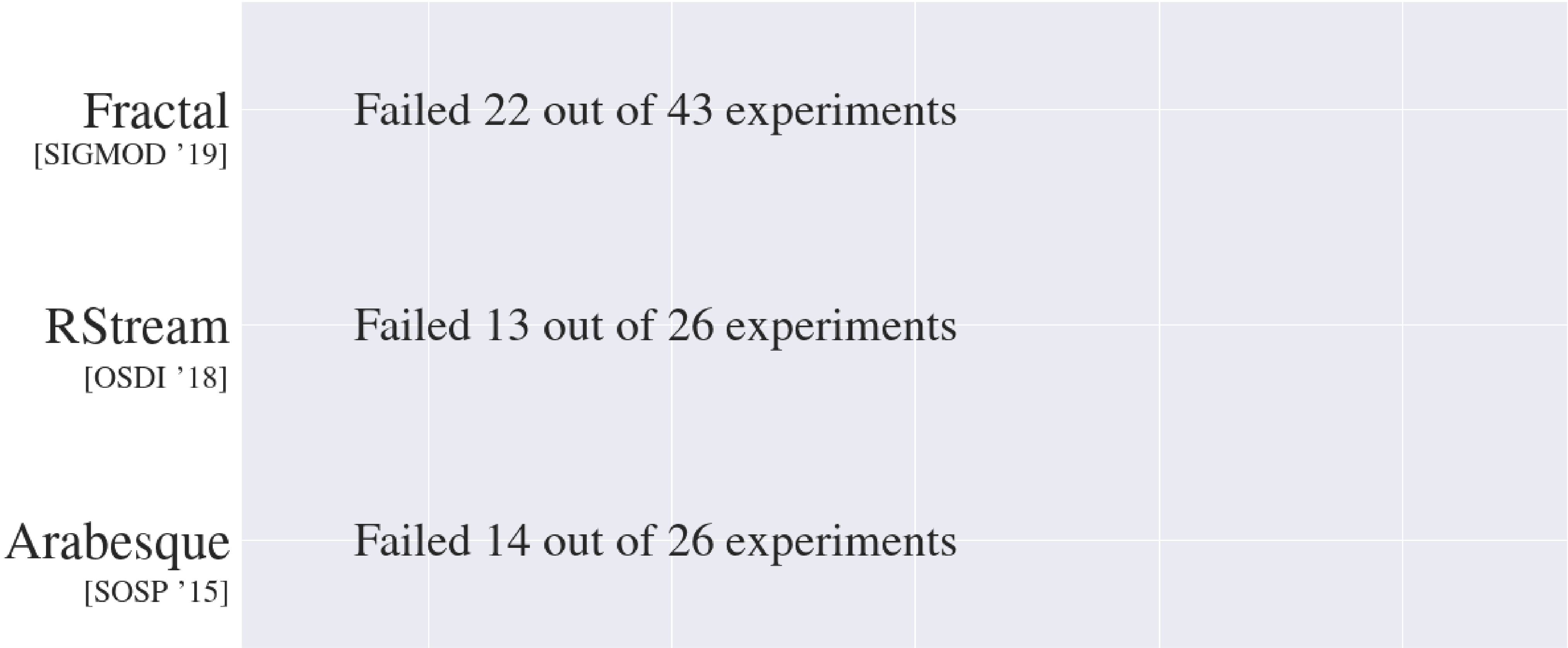
Comparison with Existing Work

- Peregrine with 16 logical cores and 32GB RAM
- Arabesque & Fractal with 8x16 logical cores and 8x32GB RAM
- RStream with 96 logical cores and 192GB RAM

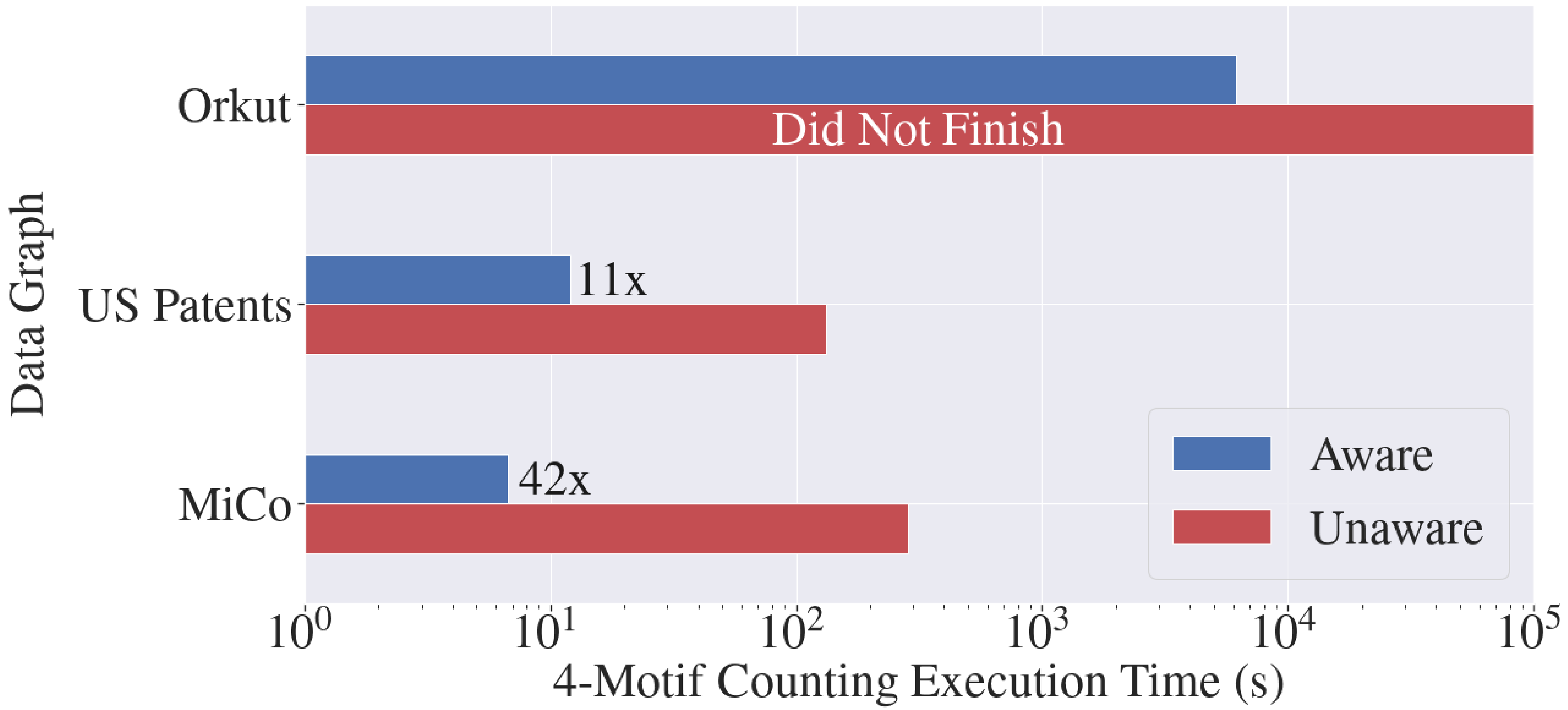
Comparison with Existing Work



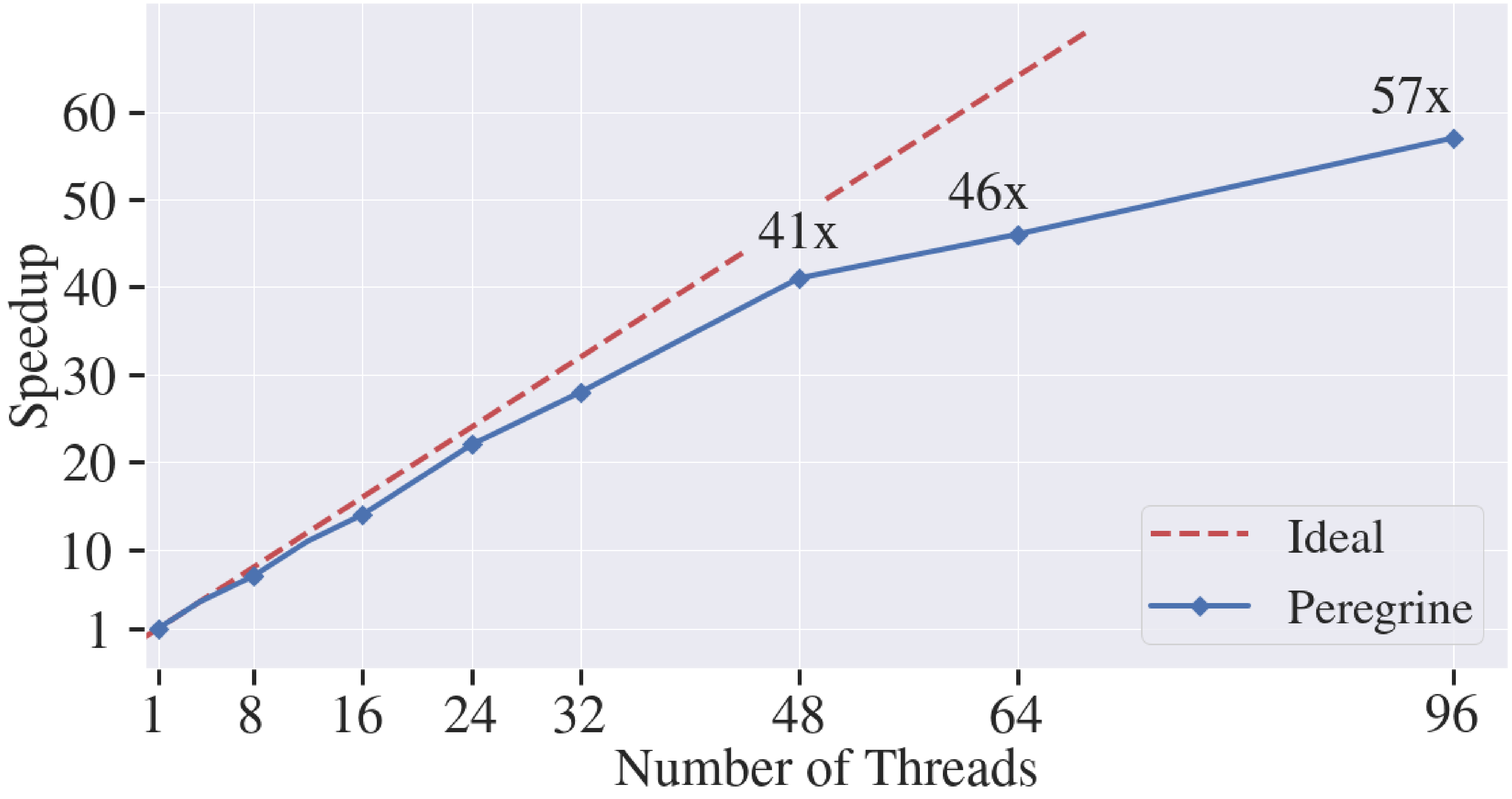
Comparison with Existing Work



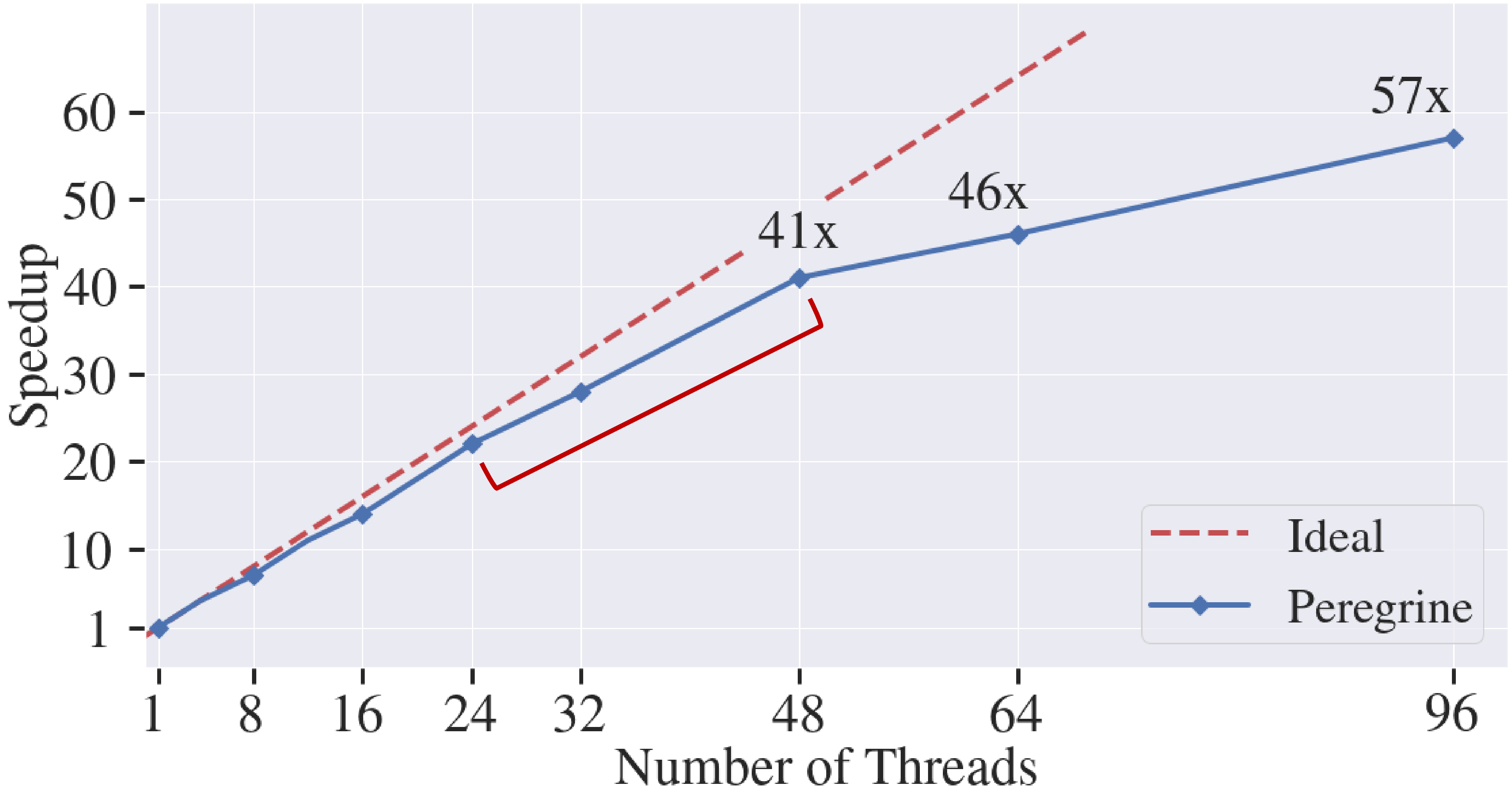
Effects of Pattern Awareness



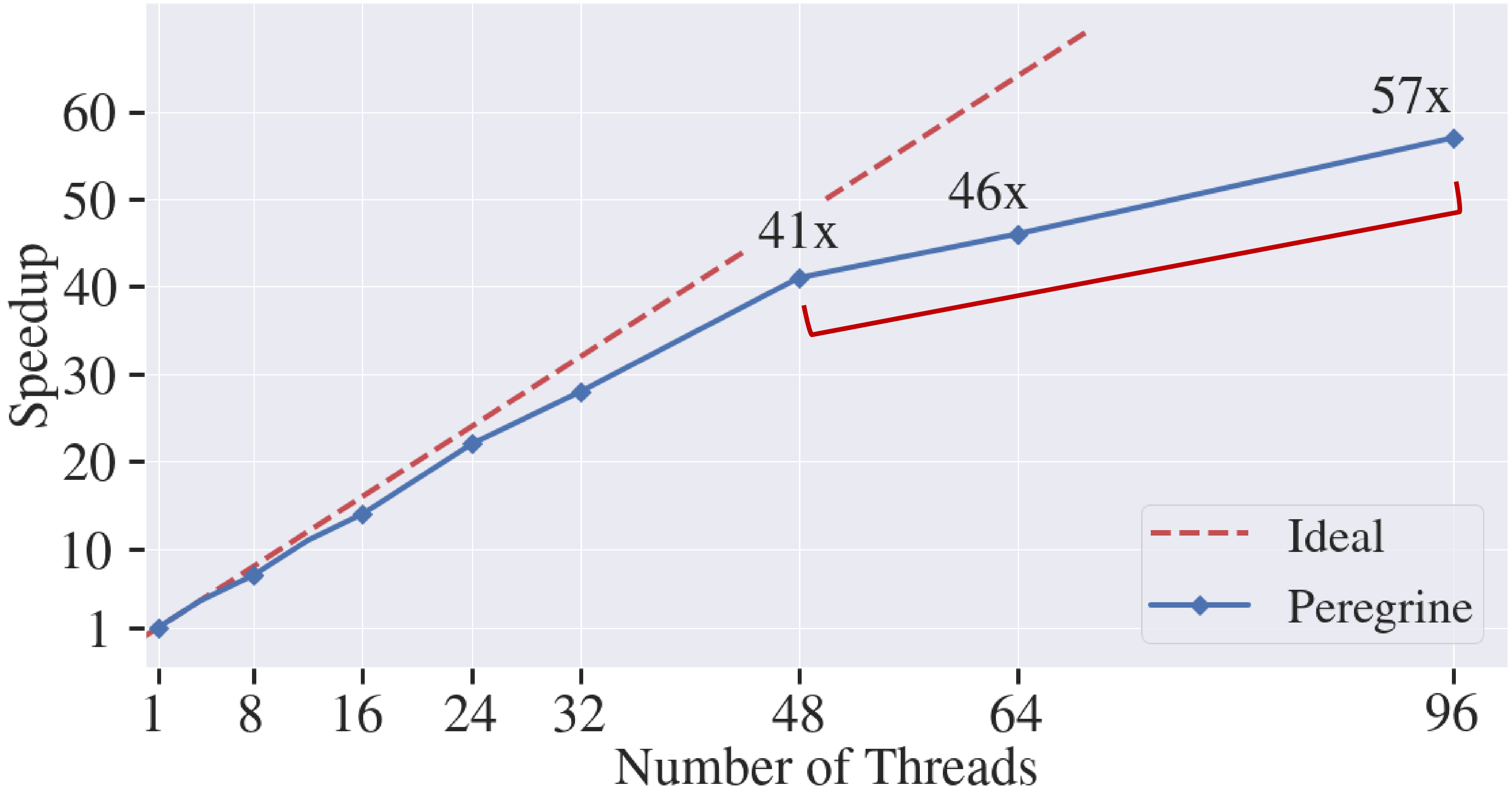
Scalability



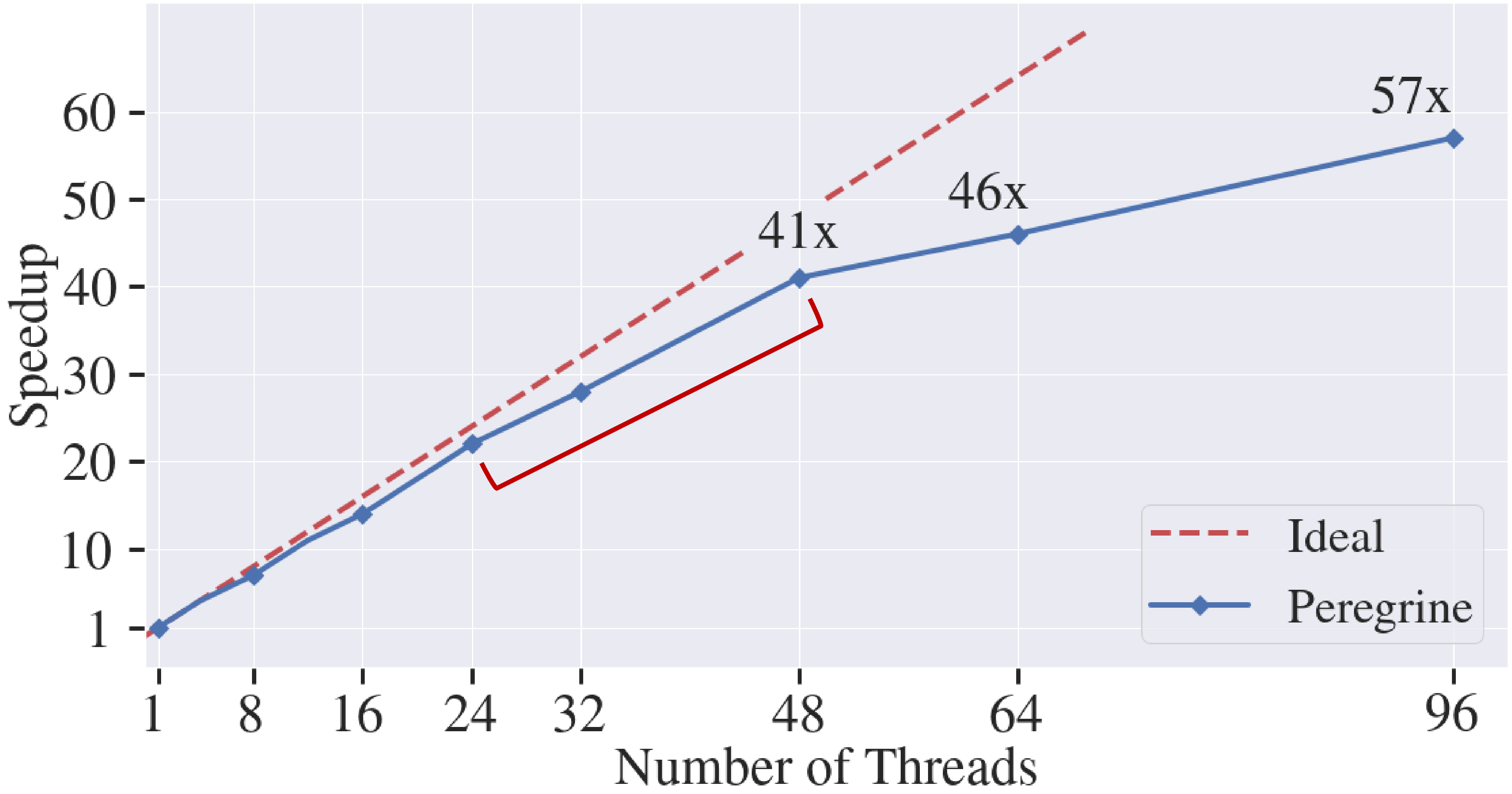
Scalability



Scalability



Scalability



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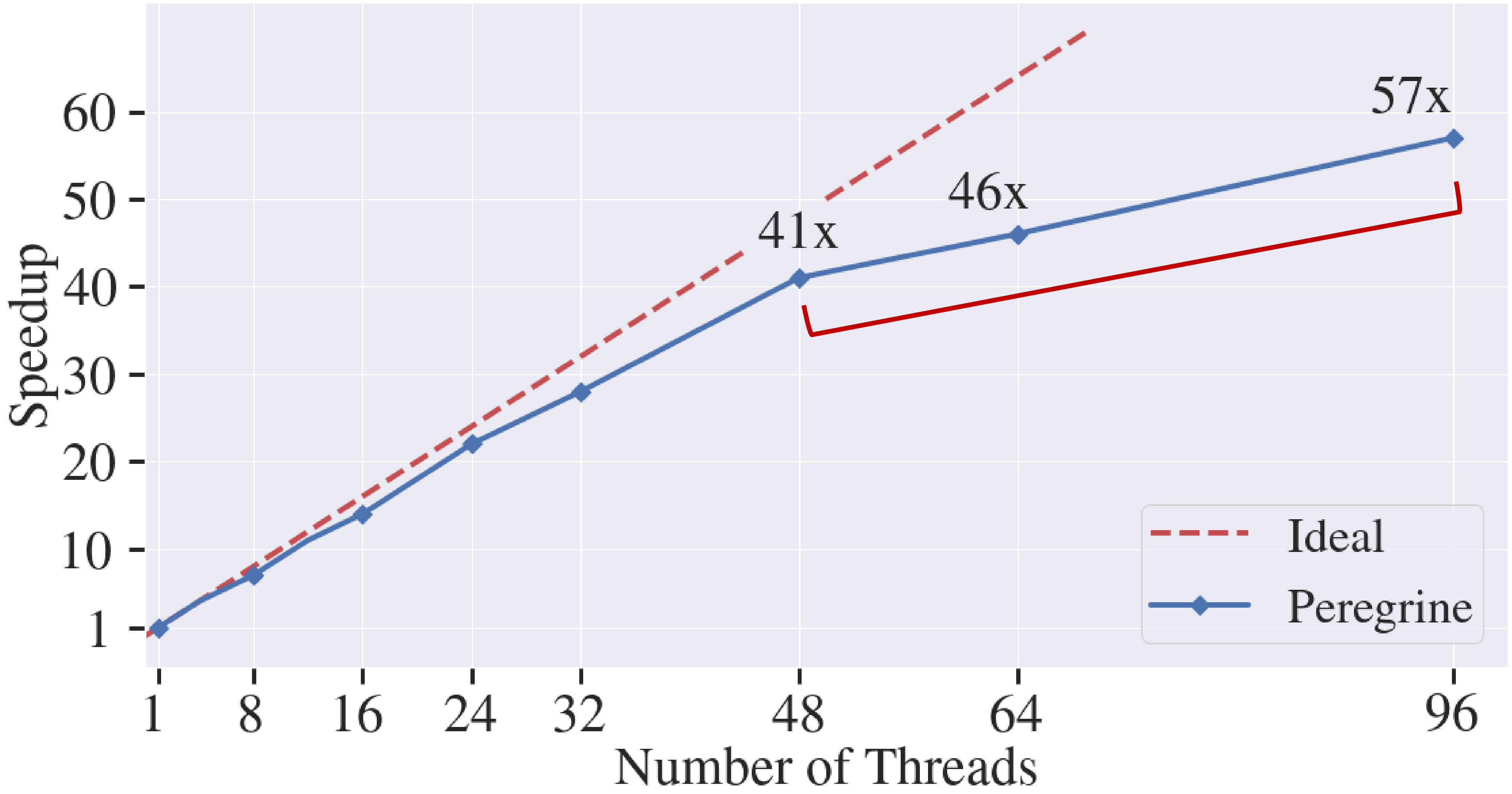

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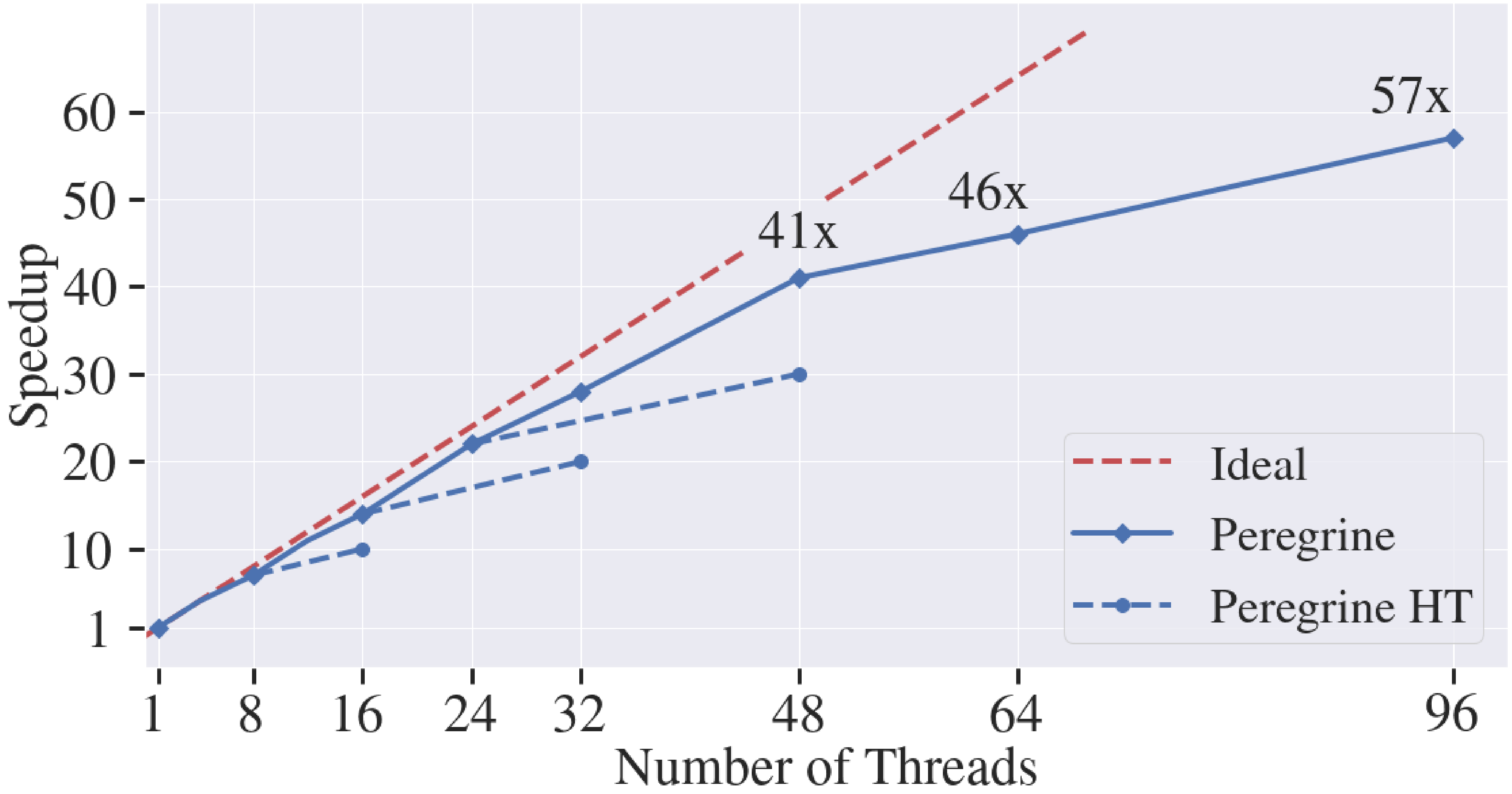

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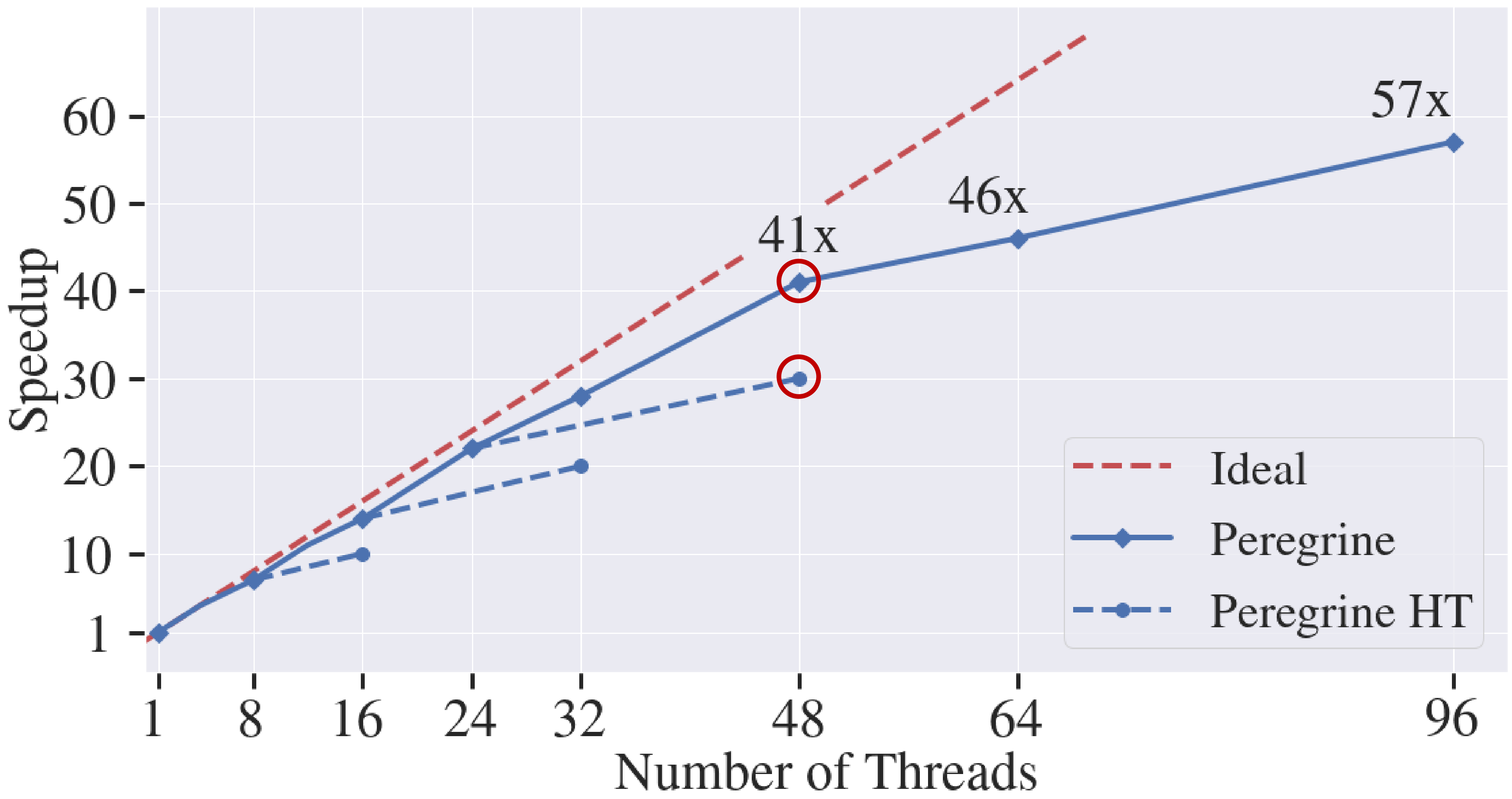

PEREGRINE

Pattern-aware programming and processing models

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- Shift abstraction from subgraph to pattern

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https://github.com/pdclab/peregrine