Shared-memory Graph Truss Decomposition

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Acknowledgments

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A graph truss

Introduced by J. Cohen in 2008

A *cohesive subgraph* for social network analysis

A *k-truss* is a maximal non-trivial single-component subgraph such that every edge is contained in *at least k-2 triangles*.

Similar to *k*-dense, triangle *k*-core, and *k*-community formulations

Truss decomposition

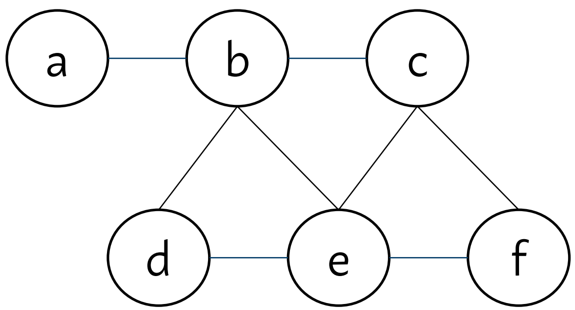
Enumerate all k-trusses in the graph

Requires computing the *trussness* of every edge

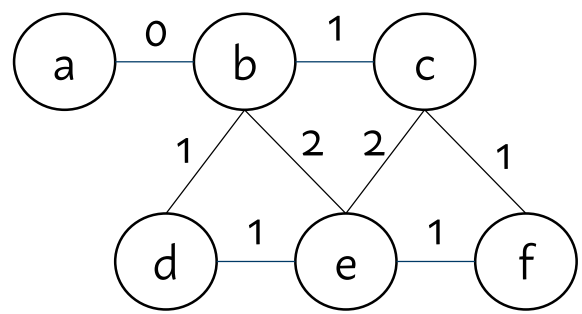
An edge has trussness l if it belongs to an l-truss but not an $(l+1)$-truss

Example: k-trusses and trussness

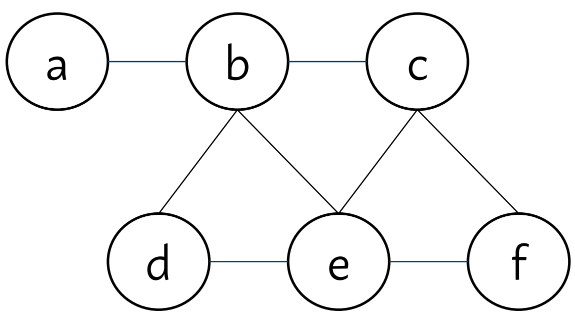
Example graph (6 vertices, 8 edges)



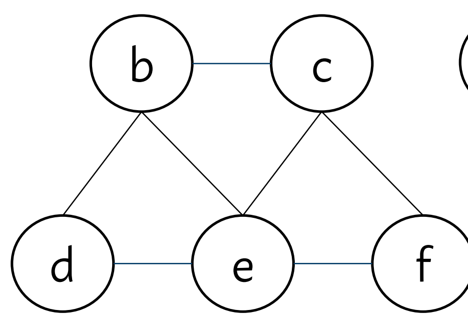
# of triangles each edge participates in



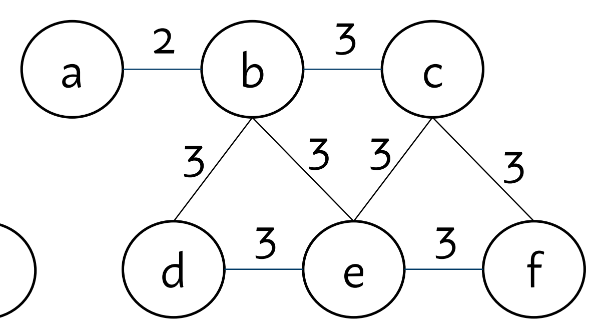
One 2-truss



One 3-truss



Trussness values



Our contributions

PKT, a shared-memory algorithm for computing trussness of every edge

Work-efficient

Level-synchronous parallelism

Memory use proportional to number of edges

Does not use a hash table to maintain edges

Uses a fast triangle counting subroutine

Truss decomposition algorithms

Two main approaches

Bottom-up peeling-based

- Work-efficient (each triangle processed only once)
- Parallelization requires fine-grained synchronization or O(#triangles) memory

h-index based

- Not work-efficient
- Parallelization is simpler

Our algorithm

Based on the bottom-up peeling strategy

Uses fine-grained synchronization to update triangle counts (instead of enumerating all triangles)

Number of barrier synchronizations are proportional to t_{max} (maximum trussness)

High-level overview of our algorithm

Compute support (# of triangles an edge participates in), store in array T

$k = 2$

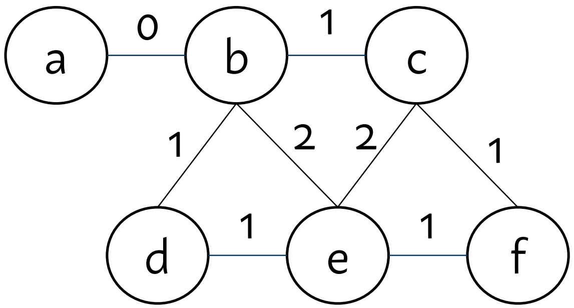
while (edges remain to be processed)

1. $S \leftarrow$ set of edges with support k-2
2. Update support of edges that form triangles with edges in S
3. Remove edges in S from the graph
4. Empty S, go to step 1.

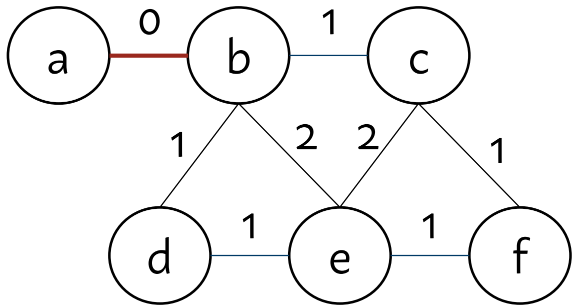
   Increment k

Example: two iterations of PKT

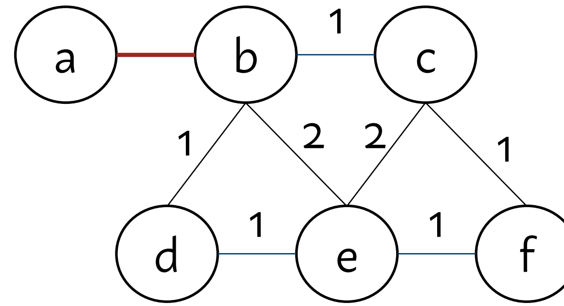
Compute support of all edges



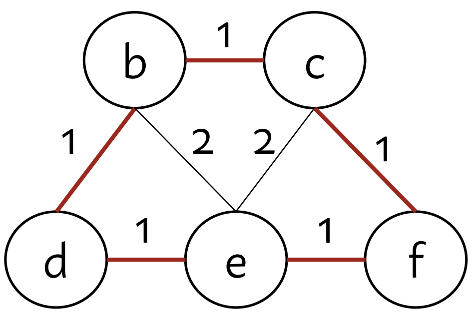
k = 2: identify edges with support 0



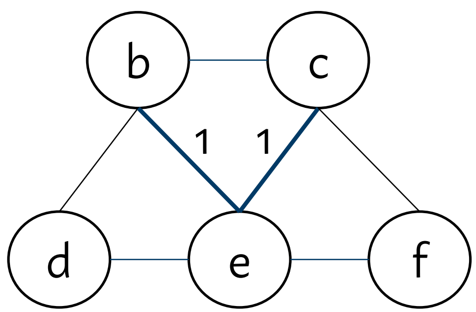
k = 2: update support of other edges



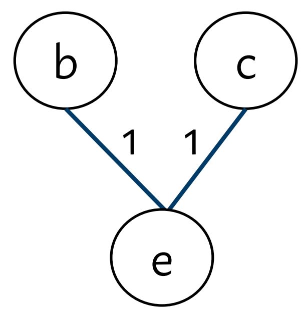
k = 3: identify edges with support 1



k = 3: update support of other edges



k = 3: identify edges with support 1



Support update step in PKT

The trickiest part of the algorithm.

We do not explicitly list triangles when updating support. We use atomics instead.

See Algorithm 5 and “Concurrent triangle processing” subsection in paper.

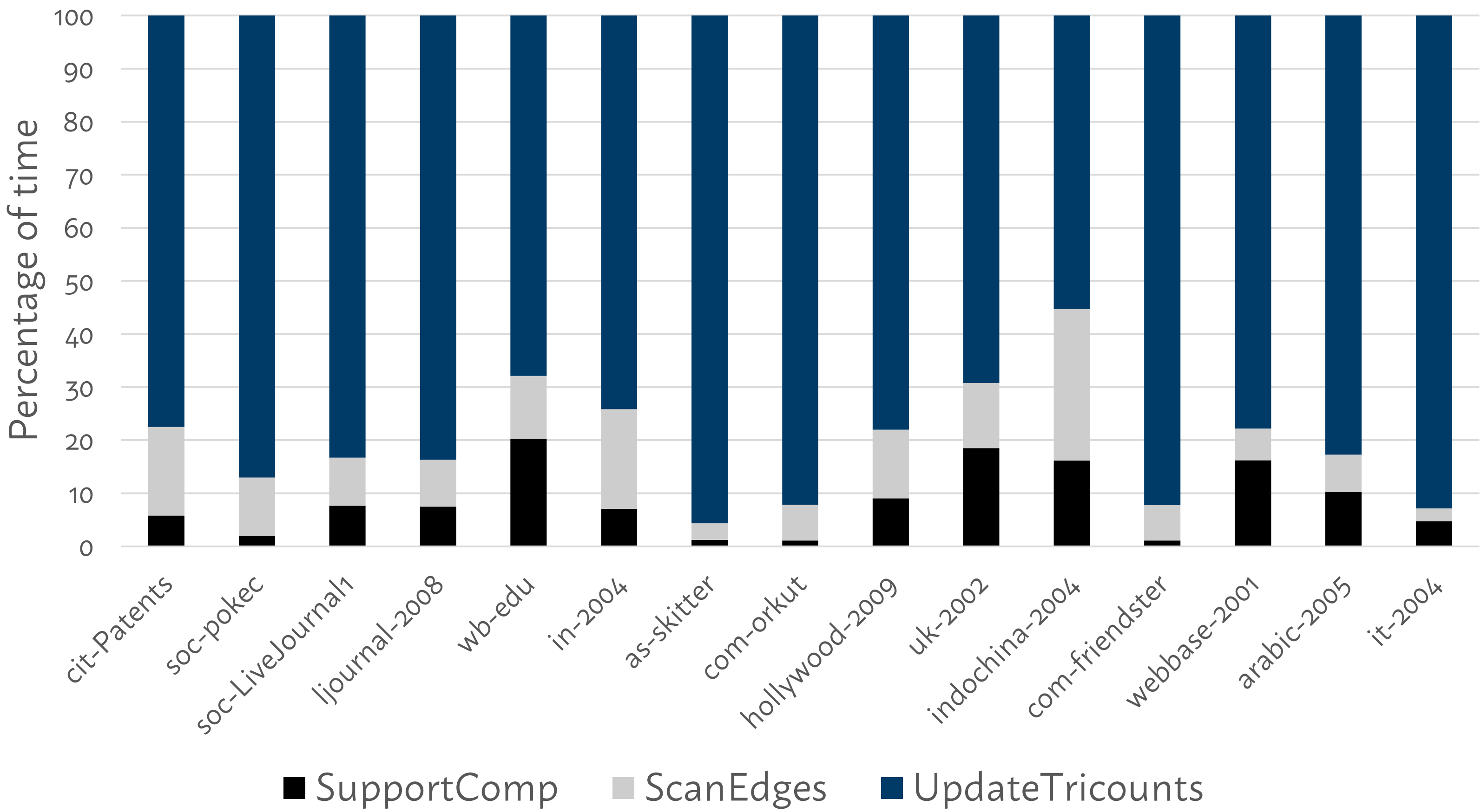
Empirical evaluation

15 large sparse graphs with triangle counts varying from 10 million to 48 billion

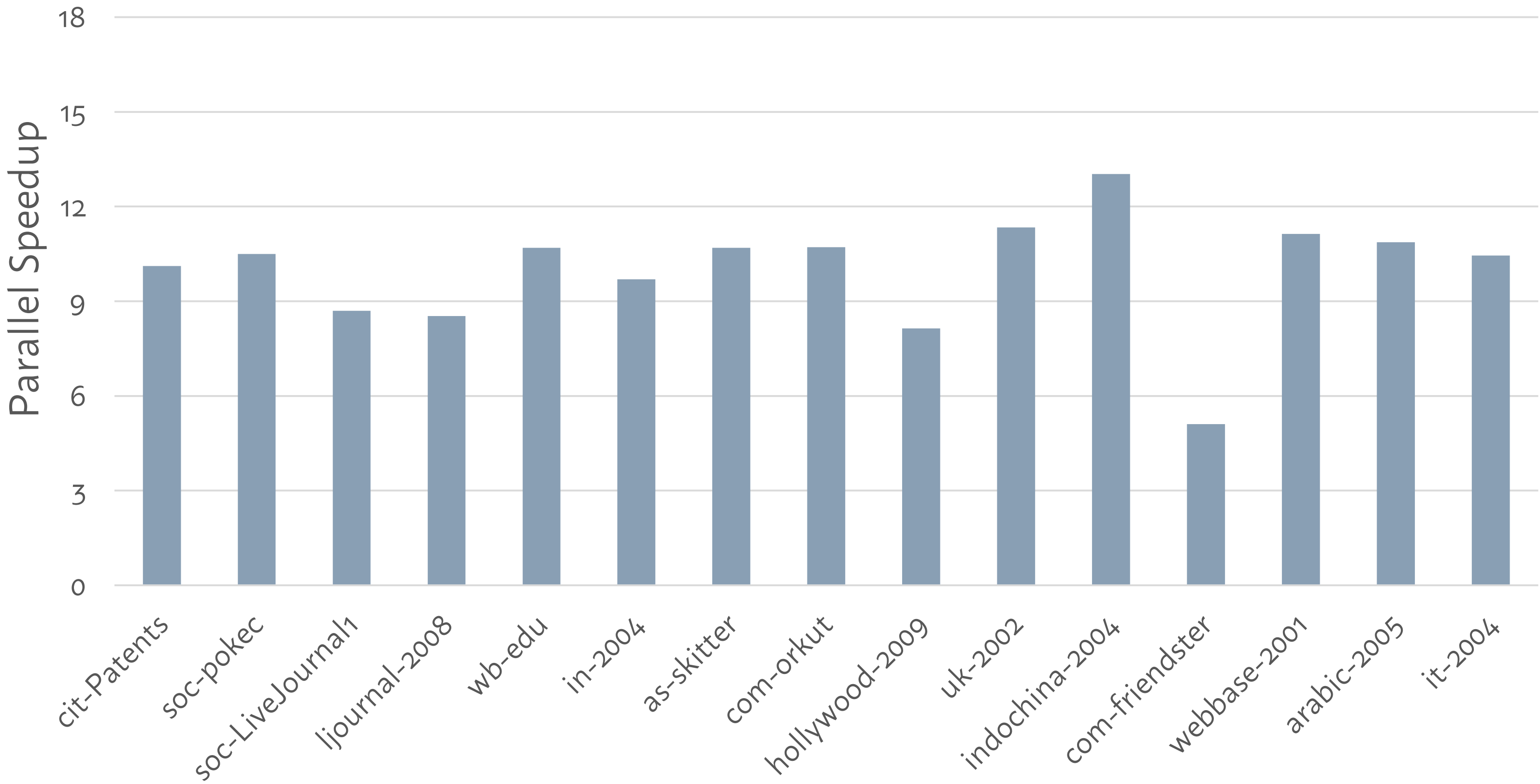
Dual-socket Intel system with 128 GB memory. 12-core 2.2 GHz Xeon E5-2650 v4 (Broadwell) processors.

Source code available on GitHub: humayunk1/PKT

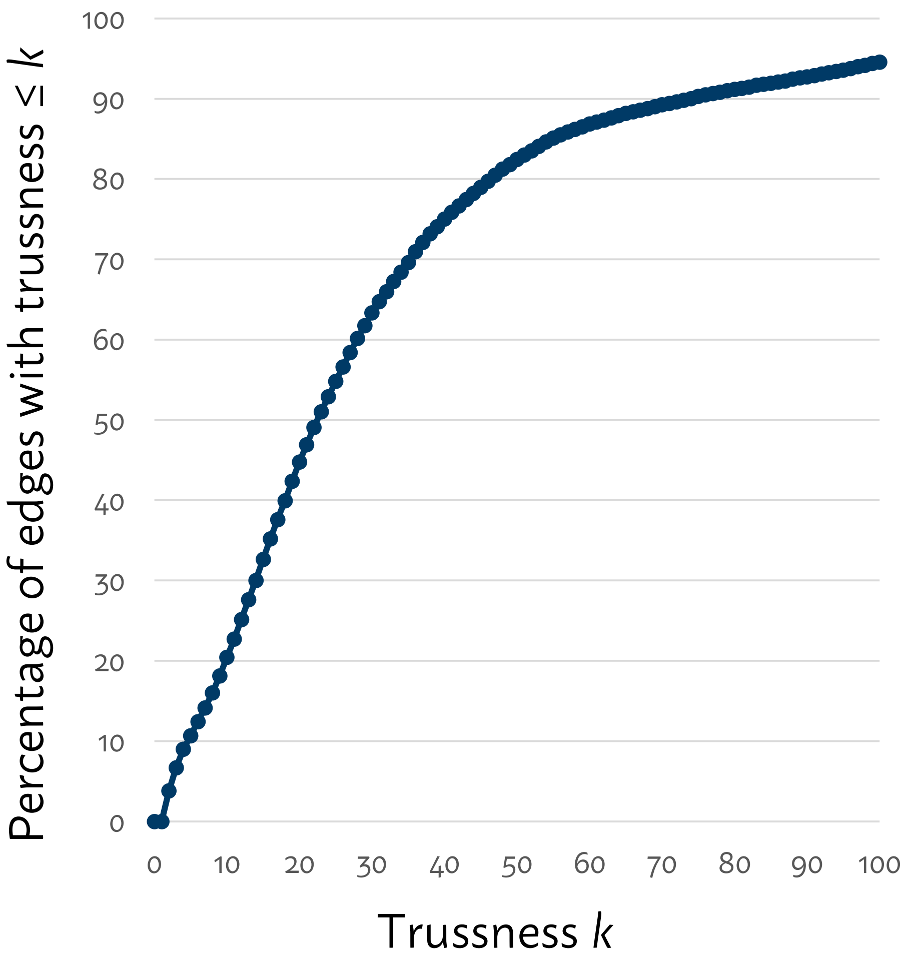
Breakdown of execution time

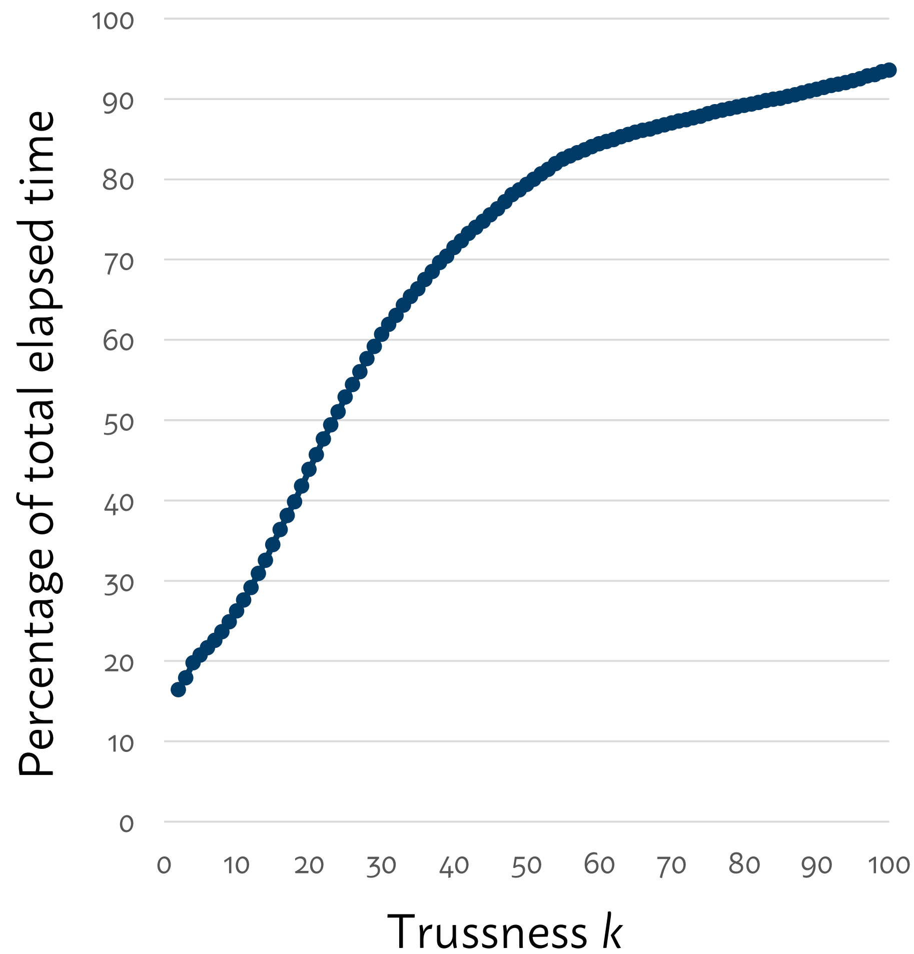


24-core parallel speedup



Trussness and execution time distribution (uk-2002 graph)





GraphChallenge

New parallel graph analysis competition (http://graphchallenge.mit.edu/, 2017)

Two challenge problems

Static: triangle counting, truss decomposition

Streaming: stochastic block partition clustering

6 parallel truss decomposition-related submissions

Please see HPEC 2017 proceedings for more details

Conclusions

We present PKT, a new shared-memory parallel algorithm for truss decomposition of graphs

On a 24-core Intel system, PKT achieves a 10X parallel speedup (average, 15 test graphs)

PKT uses a bottom-up, peeling-based approach and is memory-efficient

Possible Improvements

Explore memory use-synchronization tradeoffs

On-the-fly triangle counting instead of precomputing support

For higher values of k, extract k-cores and then search for trusses

Thank you!

Questions?