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TriBIT: Triangle Counting Using Binary Tensor Core Operations

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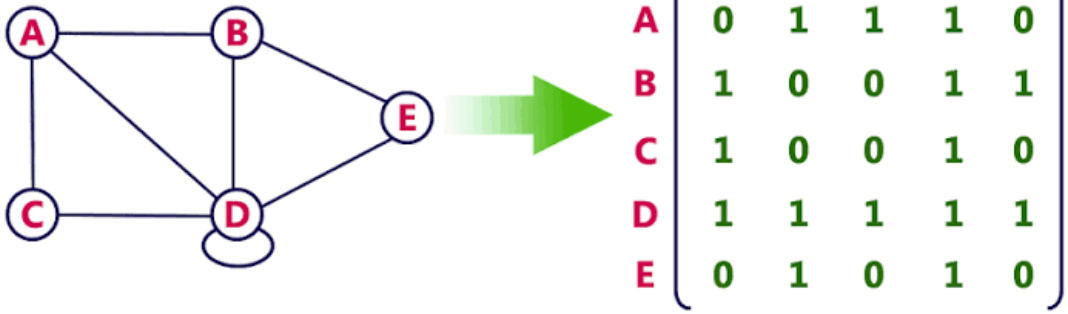


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1. **What is the TC problem?**
2. *What application is impacted?*
3. *What is the main innovation?*
4. *What is TriBIT's performance?*

Triangle counting (TC)

- **Goal:** The task is to count the triangles in a graph, i.e., triplets of vertices {i, j, k} that are mutually connected.
- **Representation:** The graph is encoded as an adjacency matrix A, where the entry A[i,j] equals 1 if vertices i and j are connected, and 0 otherwise.





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Where Triangle Counting (TC) shows up

- **Web & networks:** Any network can be represented by a graph. Large-graph scale Triangle Counting can help identify spam detection and link recommendation.

- **Bioinformatics:** Triangle Counting helps identify dense clusters in protein-protein interaction networks, which indicate biological significance.

- **Social networks**: Triangle Counting helps with community detection and measuring social cohesion.

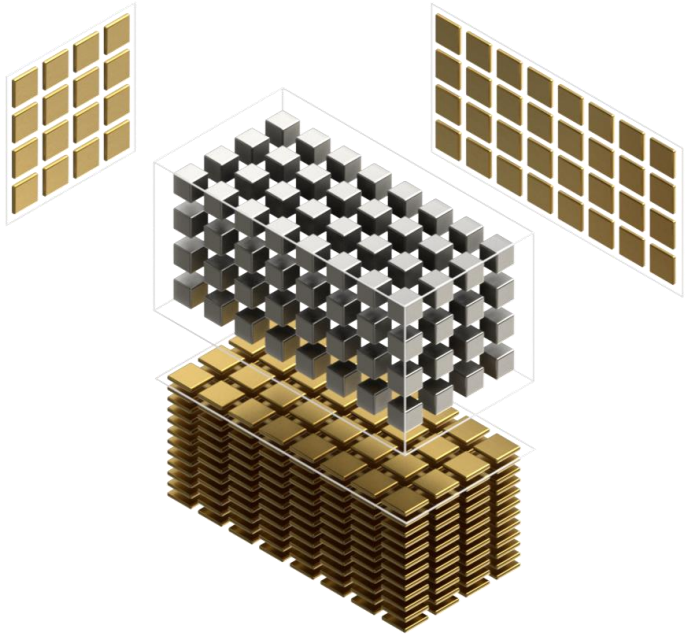


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Innovation

- **Hardware**: TriBIT is the first TC algorithm to use *bitwise tensor core units* (TCUs), i.e. specialized GPU hardware units that multiply bit matrices in a single instruction.
- **Data layout:** TriBIT uses specialized bitmap-compressed data structures that cut memory and are fast to build on the GPU.
- **Together**: exact counts, low preprocessing, balanced end-to-end time. Multi-GPU is supported.



Idea 2: Compressed data structures

- **Goal:** A specialized graph representation that is easy to build and lets TriBIT retrieve data efficiently.
- **Preprocessing**: Runs entirely on the GPU, using the Thrust and CUB libraries. By contrast, bbTC and WeTriC preprocess on the CPU.
- Built from standard parallel primitives: radix sort, reduce-by-key, run-length encoding, and prefix sums.

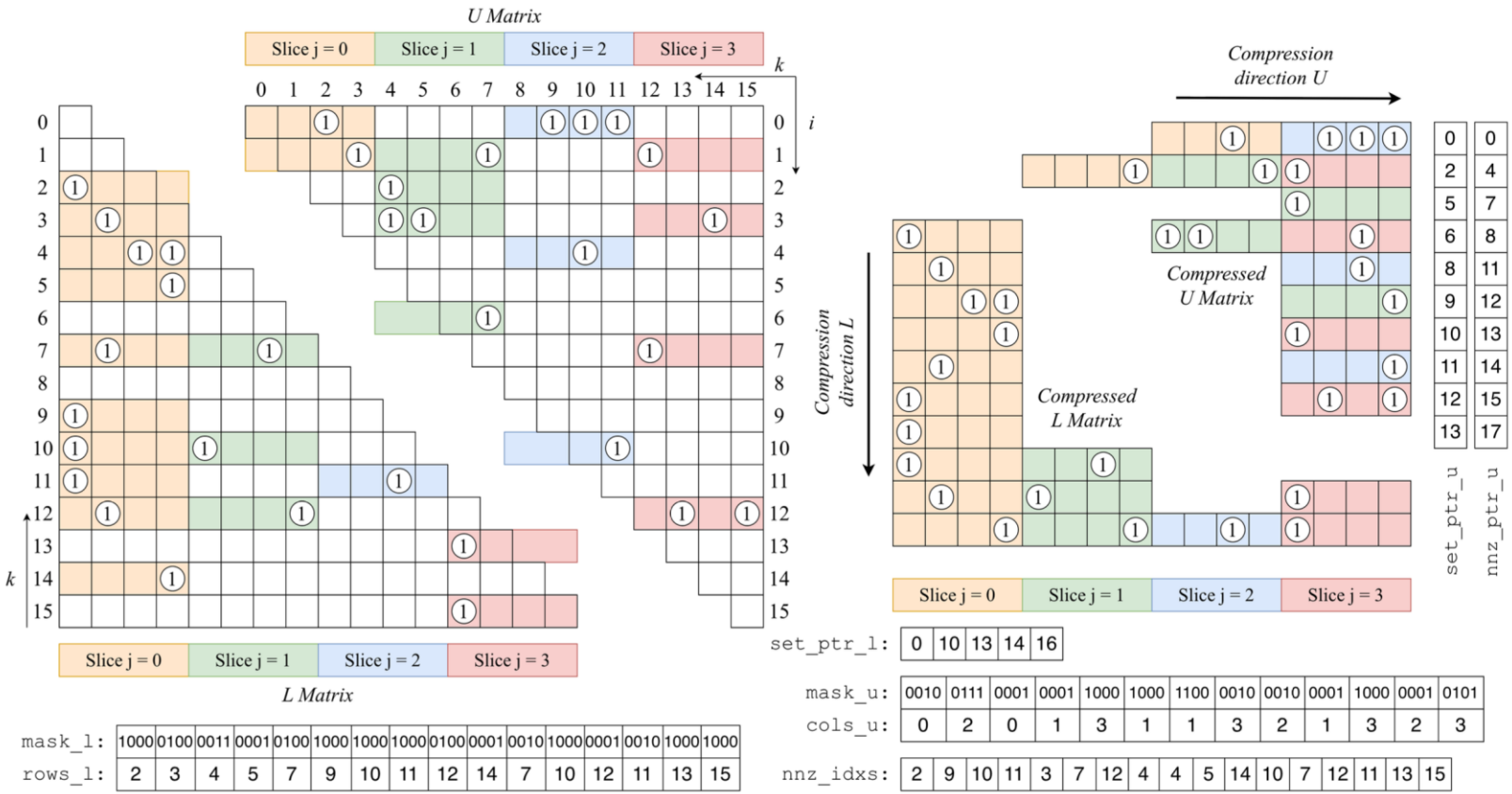


Fig. 1. Illustration of the compressed data structures (see Section III-B).



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Speedup

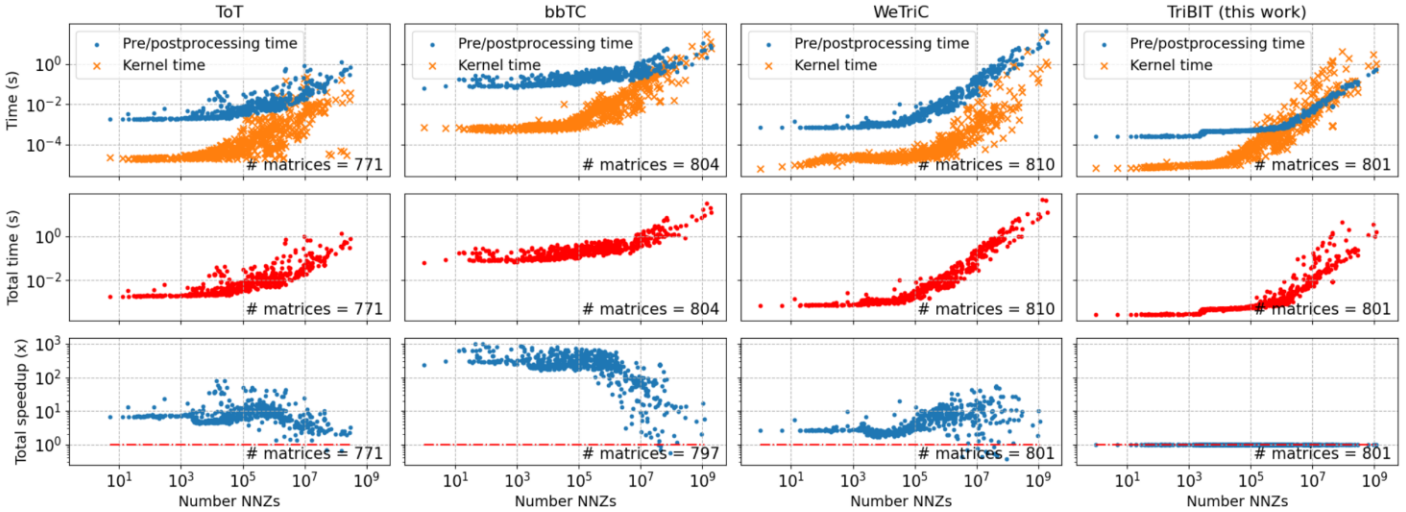


Fig. 4. Performance comparison of ToT, bbTC, WeTriC, and TriBIT (this work).

Method	Kernel	Pre/postproc.	Total
ToT	0.151 ms	6.735 ms	6.974 ms
bbTC	2.637 ms	200.394 ms	207.628 ms
WeTriC	0.055 ms	4.428 ms	4.507 ms
TriBIT	0.098 ms	0.755 ms	0.972 ms

Baseline	TriBIT speedup
ToT	7.17×
bbTC	213.61×
WeTriC	4.63×

Multi-GPU: graphs with over 128 billion edges

Dataset	$\|V\|$	$\|E\|$	GB	# Triangles	Time (s)	GPUs	Triangles / s
Hyperlink-2012	3 563 602 789	128 736 914 167	959.16	9 648 842 110 027	3126.27	32	3.09×10^9
eu-2015	1 070 557 254	91 792 261 600	683.91	15 338 196 409 949	51.16	32	3.00×10^{11}
Hyperlink-2014	1 724 573 718	64 422 807 961	479.99	4 587 563 913 535	435.00	32	1.05×10^{10}
uk-2014	787 801 471	47 614 527 250	354.75	7 872 561 225 874	35.10	32	2.24×10^{11}
gsh-2015	988 490 691	33 877 399 152	252.41	910 140 734 636	30.23	32	3.01×10^{10}
uk-union-2006-06-2007-05	133 633 040	5 507 679 822	41.04	453 830 915 910	4.97	32	9.13×10^{10}
uk-2007-02	110 123 614	3 944 932 566	29.39	663 713 224 270	1.74	32	3.81×10^{11}
uk-2007-01	108 563 230	3 929 837 236	29.28	668 826 533 027	1.98	32	3.38×10^{11}
uk-2006-09	106 288 541	3 871 625 613	28.85	518 989 781 579	13.95	32	3.72×10^{10}
gsh-2015-host	68 660 142	1 802 747 600	13.43	520 901 310 734	5.05	32	1.02×10^{11}
twitter-2010	41 652 230	1 468 365 182	10.94	34 824 916 864	27.42	32	1.27×10^9

- **Scale:** Hyperlink-2012 has 3.6 B vertices and 128.7 B edges (~1 TB raw).
- **Peak throughput:** 381 B triangles/s on uk-2007-02, which finishes in only 1.74 s.
- **Huge triangle counts:** eu-2015 has 15.3 trillion triangles and is counted in 51 s. uk-2014 has 7.9 trillion in 35 s.



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Thank you.