uSAP: An Ultra-Fast Stochastic Graph Partitioner

2023 MIT/IEEE/Amazon HPEC Graph Challenge

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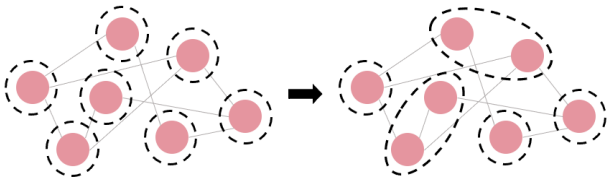
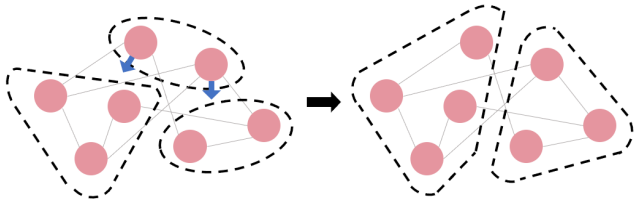
Challenges

- **Time-consuming** baseline sequential partitioner (PEIXOTO[1])

(1) Bottom-up block merging



(2) Iterative MCMC nodal block assignment



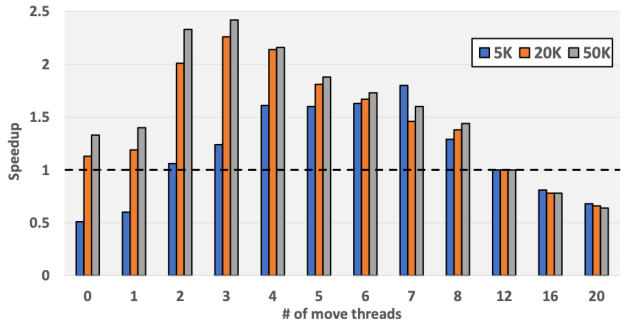
- The 2021 Champion's results can be improved (FSBP[2])

(1) Aggressive initial merging

$\|V\|$	Default Initial Reduction 0.5	0.75 Initial Reduction	0.90 Initial Reduction
500	1	1	0.9528
1k	1	1	1
5k	0.9743	0.9738	1
20k	1	1	0.9543
50k	1	1	0.9169
100k	0.9816	0.9129	0.6849
200k	0.9317	0.9054	0.8284

Recall decrease!

(2) Parallelism control strategy



Not scalable!

[1] T. P. Peixoto, "Efficient monte carlo and greedy heuristic for the inference of stochastic block models," in 2014

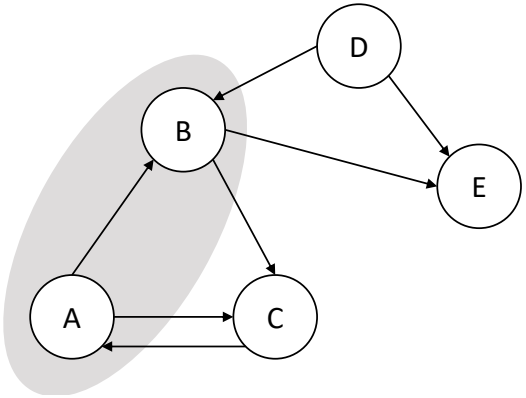
[2] A. J. Uppal, J. Choi, T. B. Rolinger, and H. H. Huang, "Faster stochastic block partition using aggressive initial merging, compressed representation, a parallelism control," in 2021

Solutions

- **Strongly Connected Components**-based initial block merging

  $\Longrightarrow$ try to find the blocks with more interactions

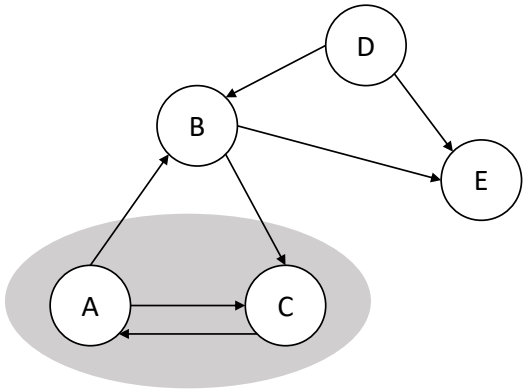
(1) Merge the block B



$$M_1^+ = \begin{array}{c} \begin{matrix} A & B & C & D & E \end{matrix} \\ \begin{pmatrix} 1 & 0 & 2 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{matrix} A \\ B \\ C \\ D \\ E \end{matrix} \end{array}$$

$\Longrightarrow \Delta E = 0.35$

(2) Merge the block C



$$M_2^+ = \begin{array}{c} \begin{matrix} A & B & C & D & E \end{matrix} \\ \begin{pmatrix} 2 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{matrix} A \\ B \\ C \\ D \\ E \end{matrix} \end{array}$$

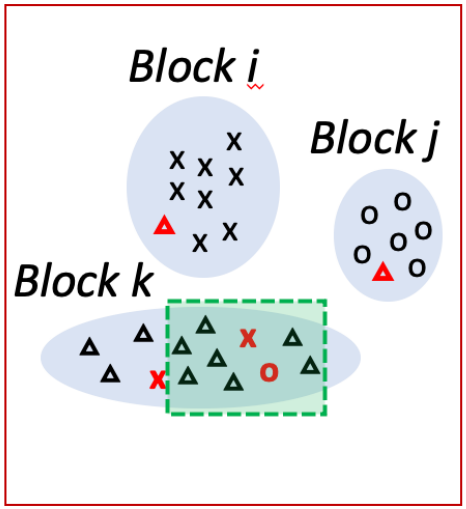
$\Longrightarrow \Delta E = -0.43$

We use a tunable threshold t_{SCC} to determine when to stop.

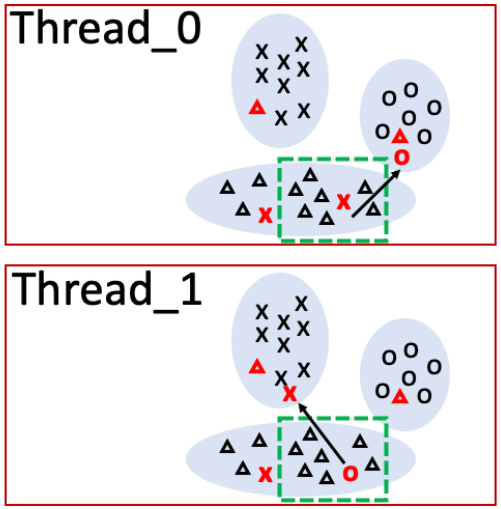
Solutions

- **Batch Parallel** Nodal Block Assignment

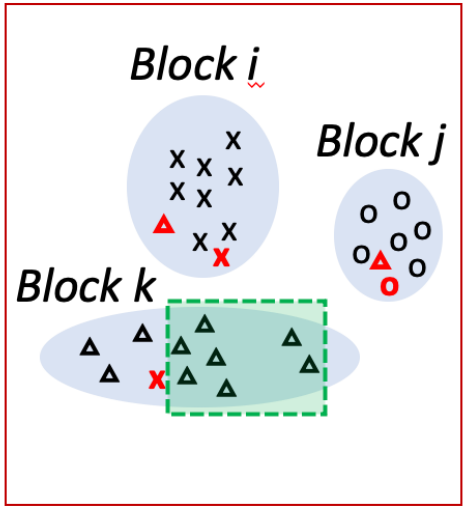
(1) Randomly select a batch



(2) Nodal block assignment in parallel



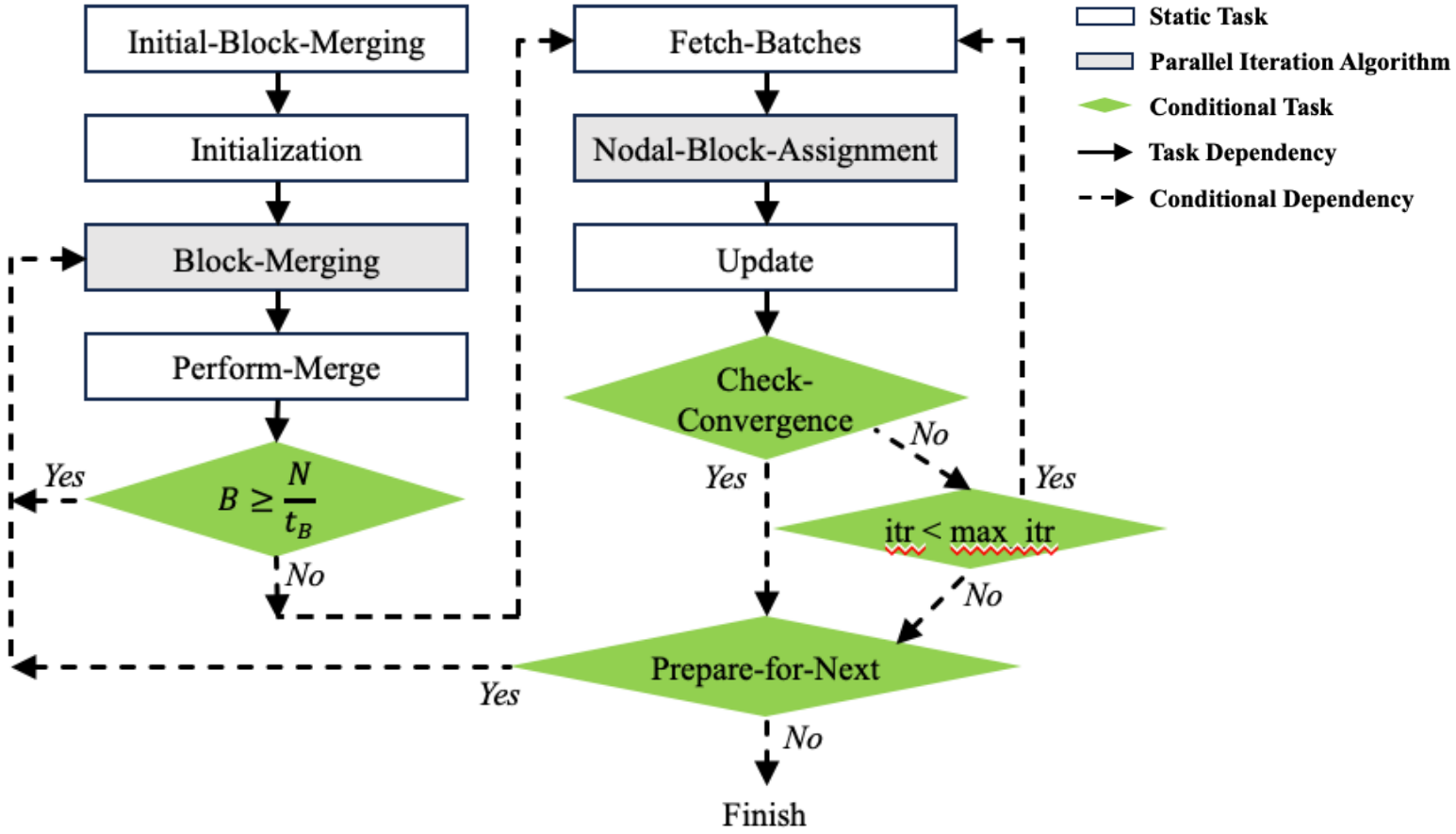
(3) Update the shared state



The results of (2) are saved in a **shared vector**.

Solutions

- **Task Graph Parallelism**



T.-W. Huang, D.-L. Lin, C.-X. Lin, and Y. Lin, "Taskflow: A lightweight parallel and heterogeneous task graph computing system," IEEE Transactions on Parallel and Distributed Systems, in 2021

Experimental Setup

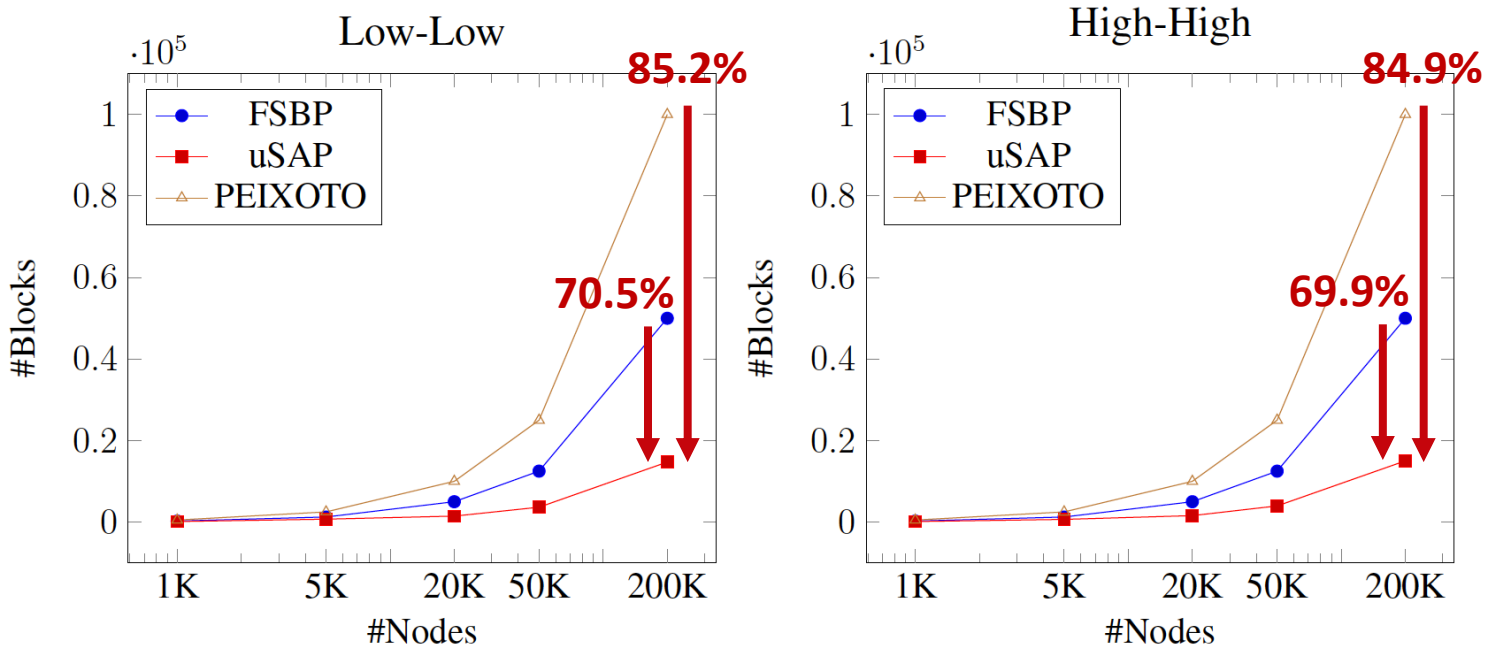
- **Baseline**
  - Example code provided by Graph Challenge (PEIXOTO[1])
  - Faster Stochastic Block Partition (FSBP[2])
- **Dataset**
  - 2022 Streaming Graph Partition Dataset provided by Graph Challenge
- **Software**
  - Ubuntu 20.04 Linux 5.15.0-58-generic x86_64 machine
  - GNU GCC-11.3.0 with C++17
- **Hardware**
  - 12-core Intel® Core(TM) i7-12700 processor
  - 32GB RAM

[1] T. P. Peixoto, “Efficient monte carlo and greedy heuristic for the inference of stochastic block models,” in 2014

[2] A. J. Uppal, J. Choi, T. B. Rolinger, and H. H. Huang, “Faster stochastic block partition using aggressive initial merging, compressed representation, a
parallelism control,” in 2021

Experimental Result

- Our SCC-based initial block merging strategy significantly reduces the number of initial blocks to speed up the algorithm. (t_{scc} = 10)



Overall Runtime

- uSAP significantly outperforms PEIXOTO and FSBP in the static graph categories.
  - 1,700x for 1K-node, 80.2x for 5K-node, 103.3x for 20K-node, and 129.4x for 50K-node faster than FSBP.

	Static Graph Categories											
	Low-Low			Low-High			High-Low			High-High		
Nodes	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP
	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB
1K	47.3 86.6	8.5 49.1	**0.005** **6.9**	46.8 86.4	8.6 48.0	**0.006** **7.3**	59.9 86.7	9.9 49.3	**0.007** **7.4**	58.9 86.6	10.1 48.8	**0.007** **7.2**
5K	470.0 244.6	56.2 78.9	**0.7** **13.6**	522.8 244.7	70.5 78.5	**0.6** **15.7**	596.5 249.9	75.8 78.6	**1.2** **14.3**	550.7 239.1	71.3 79.3	**1.1** **16.7**
20K	5305.5 2074.4	640.6 378.2	**6.2** **126.1**	5450.9 1951.7	641.2 386.4	**7.0** **136.1**	5681.6 2073.3	689.2 385.3	**10.4** **136.1**	5176.6 2033.6	607.7 382.0	**10.1** **132.6**
50K	>36000 -	3558.6 942.6	**27.5** **318.9**	>36000 -	3462.6 981.5	**27.4** **310.5**	>36000 -	3381.4 947.3	**53.5** **310.5**	>36000 -	3419.2 970.8	**41.4** **322.5**
200K	>36000 -	>36000 -	**299.8** **1222.6**	>36000 -	>36000 -	**338.8** **1228.8**	>36000 -	>36000 -	**1243.8** **1228.8**	>36000 -	>36000 -	**1381.2** **1334.5**

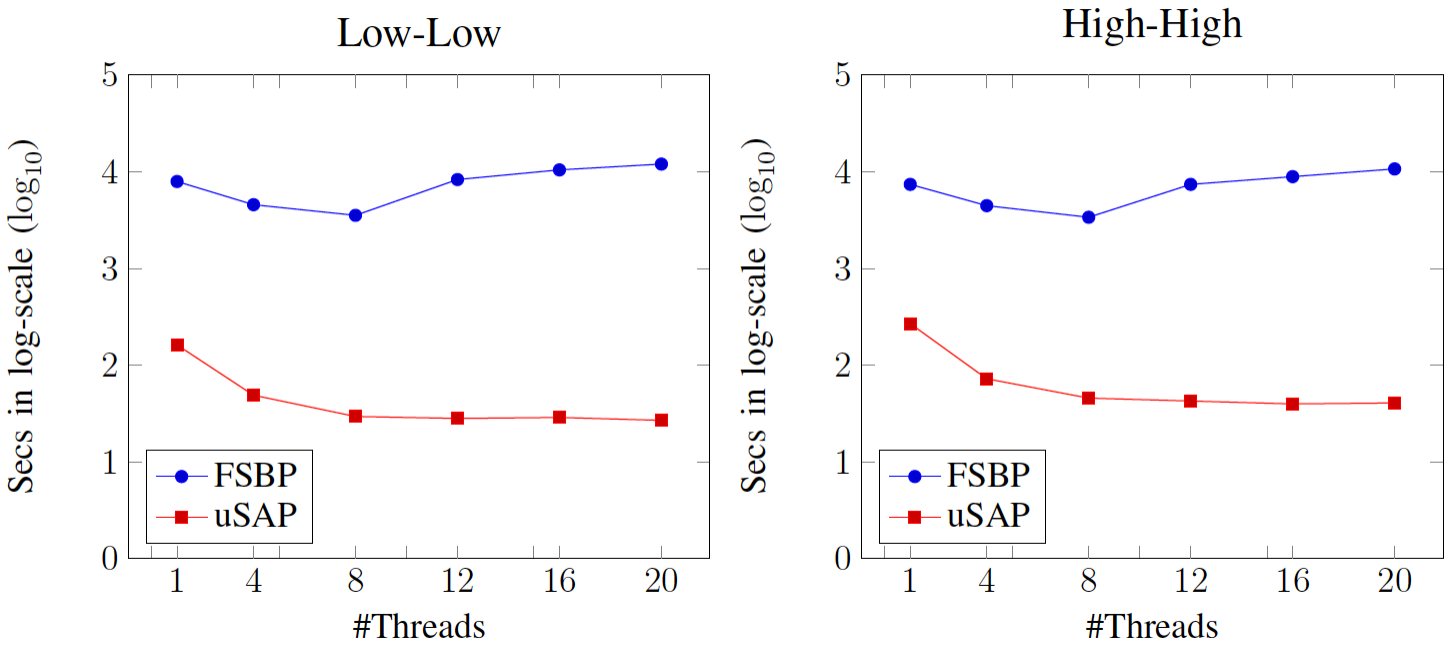
Pairwise Precision and Recall

- The quality of the partition results is better than PEIXOTO and FSBP with our SCC-based initial merging strategy.

	Static Graph Categories											
	Low-Low			Low-High			High-Low			High-High		
Nodes	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP
	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR
1K	0.994 0.996	0.994 0.996	**0.998** **0.998**	0.939 0.990	0.811 **0.995**	**0.952** 0.993	0.717 0.883	0.719 0.878	**0.747** **0.971**	0.686 **0.972**	0.710 0.653	**0.843** 0.954
5K	0.940 **1.000**	**1.000** **1.000**	**1.000** **1.000**	0.976 0.769	0.970 0.850	**0.987** **0.998**	0.861 0.816	0.641 0.666	**0.983** **0.997**	0.676 0.789	0.689 0.721	**0.861** **0.801**
20K	0.984 **1.000**	**1.000** **1.000**	**1.000** **1.000**	0.721 0.671	0.921 0.479	**0.948** **0.999**	0.950 0.740	0.875 0.705	**0.982** **0.999**	**0.889** **0.995**	0.789 0.943	0.803 0.778
50K	- -	0.988 0.855	**1.000** **1.000**	- -	0.849 0.997	**0.921** **0.998**	- -	0.757 0.862	**0.946** **0.994**	- -	**0.766** 0.64	0.456 **0.981**
200K	- -	- -	**0.983** **1.000**	- -	- -	**0.768** **0.922**	- -	- -	**0.832** **0.314**	- -	- -	**0.386** **0.885**

Scalability (Runtime v.s. #Threads)

- uSAP outperforms FSBP regardless of the number of threads. FSBP achieves its best performance when utilizing 8 threads.



Conclusion

- **SCC-based Initial block merging**
- **Batch parallel nodal block assignment**
- **Task graph parallelism**
- **Experimental Result**
  - Better runtime (129.4x faster than FSBP on 50K-node graph)
  - Better pairwise precision and recall
  - Better scalability compared to FSBP

Thank you!

uSAP: An Ultra-Fast Stochastic Graph Partitioner

https://github.com/gary30404/uSAP.git

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