http://poloclub.gatech.edu/cse6242

CSE6242 / CX4242: Data & Visual Analytics

MMap (Memory Mapping)

Simple, minimalist approach to scale up computation

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Partly based on materials by
Professors Guy Lebanon, Jeffrey Heer, John Stasko, Christos Faloutsos, Parishit Ram (GT PhD alum; SkyTree), Alex Gray

When should you use Spark/Hadoop, AWS, Azure?

And when should you not?

MMap

Fast Billion-Scale Graph Computation on a PC via Memory Mapping

Lead by

Zhiyuan (Jerry) Lin

Georgia Tech CS Undergrad

Now: Stanford PhD student

MMap: Fast Billion-Scale Graph Computation on a PC via Memory Mapping. Zhiyuan Lin, Minsuk Kahng, Kaeser Md. Sabrin, Duen Horng Chau, Ho Lee, and U Kang. *Proceedings of IEEE BigData 2014 conference.* Oct 27-30, Washington DC, USA.

Towards Scalable Graph Computation on Mobile Devices. Yiqi Chen, Zhiyuan Lin, Robert Pienta, Minsuk Kahng, Duen Horng (Polo) Chau. *IEEE BigData 2014 Workshop on Scalable Machine Learning: Theory and Applications.*

Graph Computation on Computer Cluster?

Steep learning curve

Cost

Overkill for smaller graphs

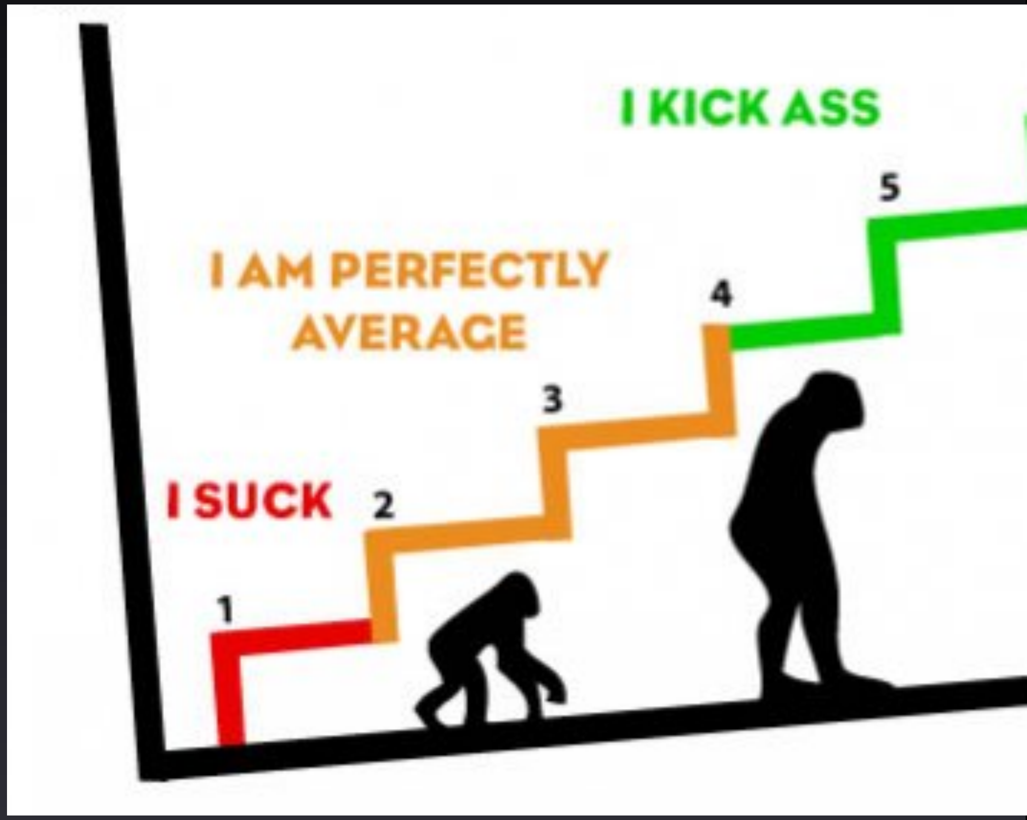


Image source: http://www.drupaltky.org/en/article/20

Best-of-breed Single-PC Approaches

- **GraphChi** – OSDI 2012
- **TurboGraph** – KDD 2013

What do they have in common?

- Sophisticated Data Structures
- Explicit Memory Management

Can We Do Less?

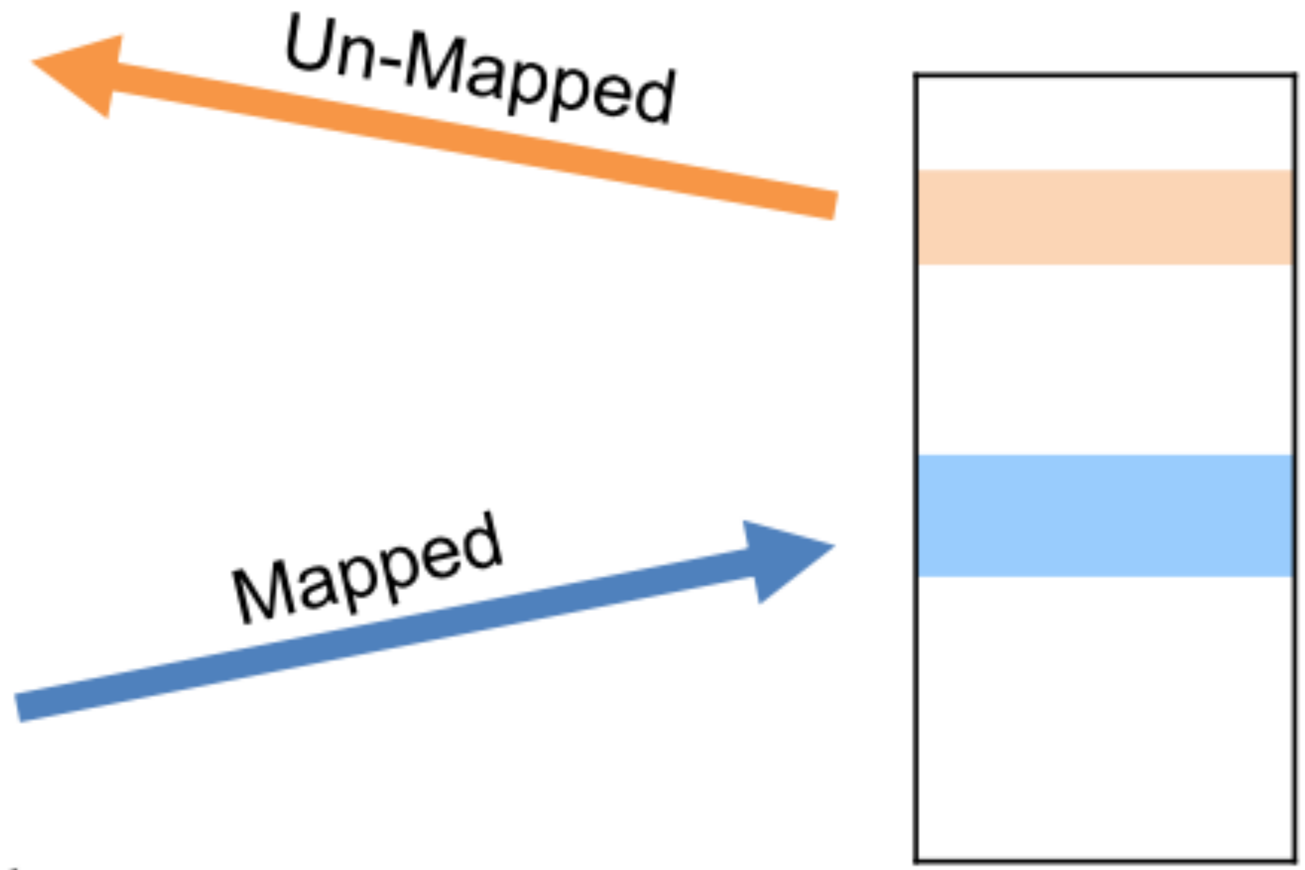
To get same or **better** performance?

e.g., auto memory management, faster, etc.

Main Idea: **Memory-mapped** the Graph

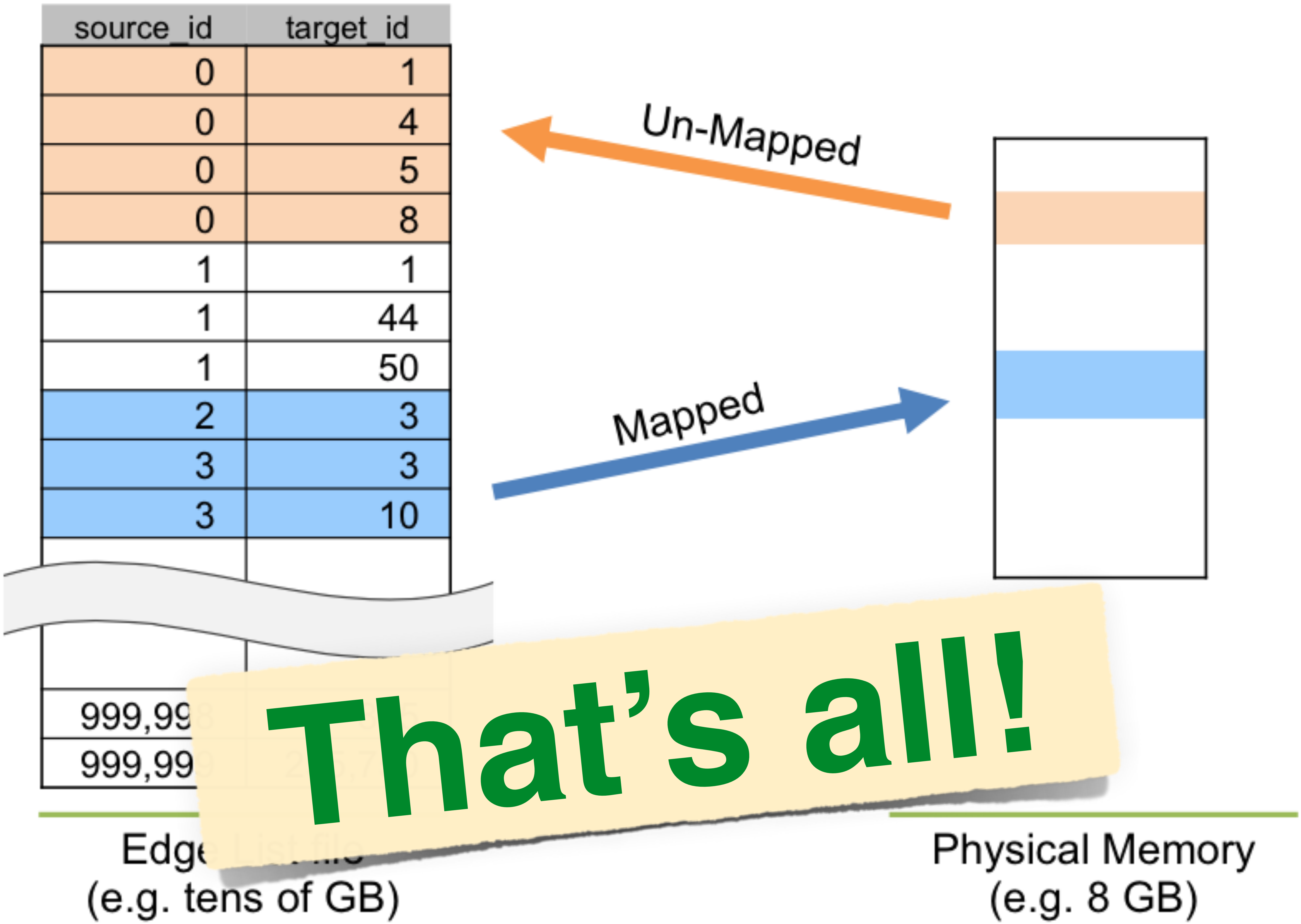
source_id	target_id
0	1
0	4
0	5
0	8
1	1
1	44
1	50
2	3
3	3
3	10
999,998	875
999,999	255,750

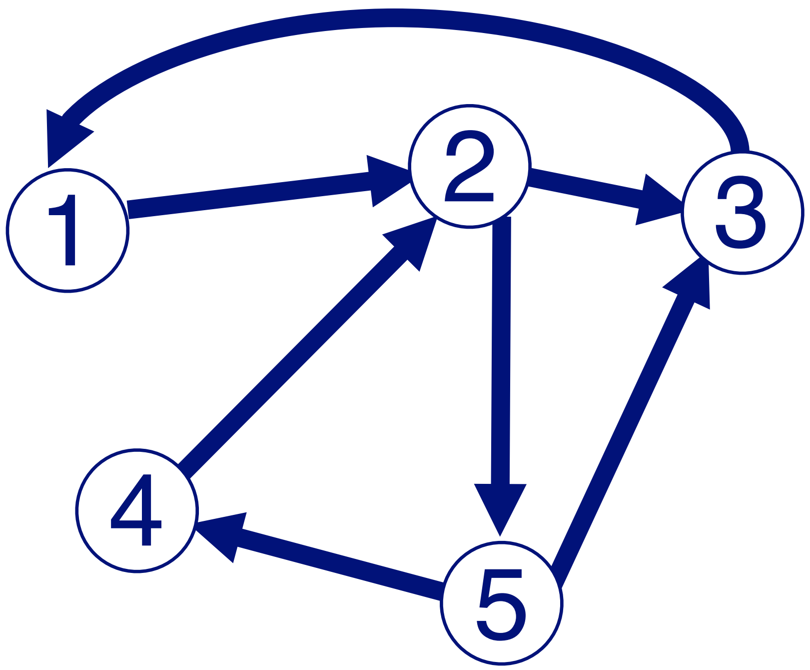
Edge List file
(e.g. tens of GB)



Physical Memory
(e.g. 8 GB)

Main Idea: **Memory-mapped** the Graph





How to compute PageRank for huge matrix?

Reminder

Use the power iteration method

http://en.wikipedia.org/wiki/Power_iteration

$$\mathbf{p} = c\,\mathbf{B}\,\mathbf{p} + \frac{(1-c)}{n}\,\mathbf{1}$$

p' = c **B** **p** + (1-c)/n [1, 1, ..., 1]

$$\begin{bmatrix} p1 \\ p2 \\ p3 \\ p4 \\ p5 \end{bmatrix} = c \begin{bmatrix} & & 1 & & \\ 1 & & & 1 & \\ & 1/2 & & & 1/2 \\ & & & & 1/2 \\ & 1/2 & & & \end{bmatrix} \begin{bmatrix} p1 \\ p2 \\ p3 \\ p4 \\ p5 \end{bmatrix} + \frac{(1-c)}{n} \begin{bmatrix} 1 \\ 1 \\ \cdots \\ 1 \end{bmatrix}$$

B

		1		
1			1	
	1/2			1/2
				1/2
	1/2			

Can initialize this vector to any non-zero vector, e.g., all "1"s

Example: PageRank (implemented using MMap)

http://www.cc.gatech.edu/~dchau/papers/14-bigdata-mmap.pdf

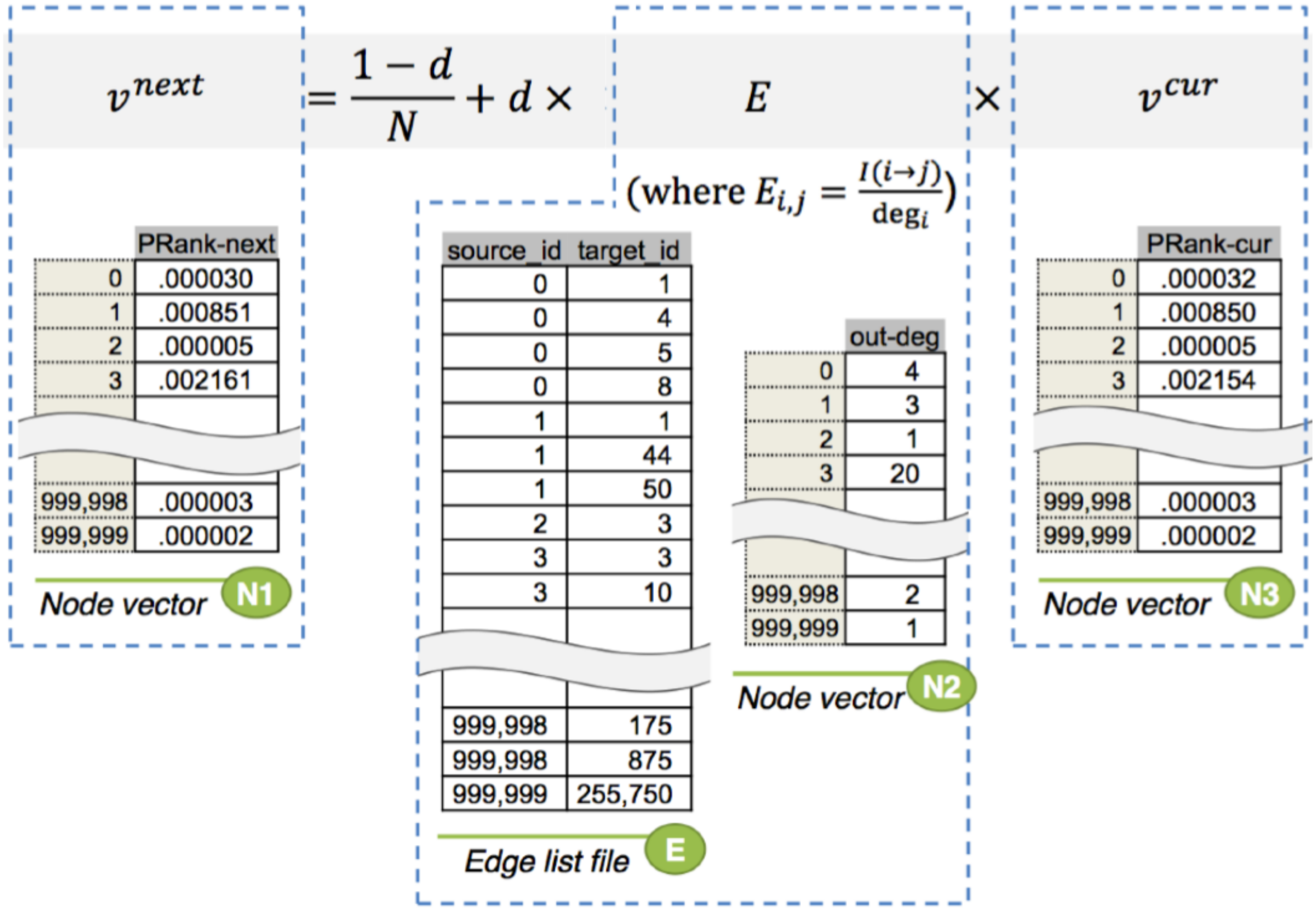
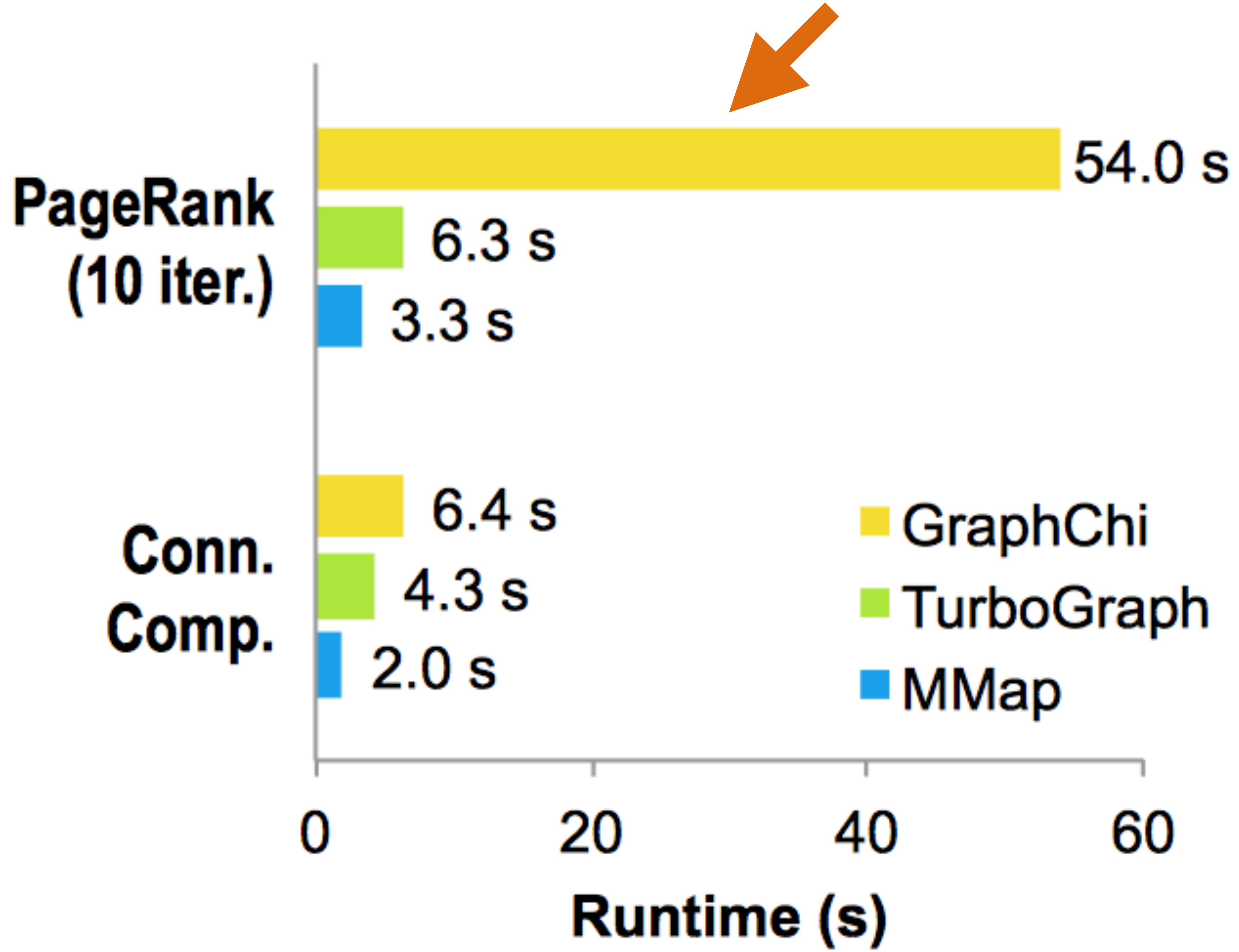
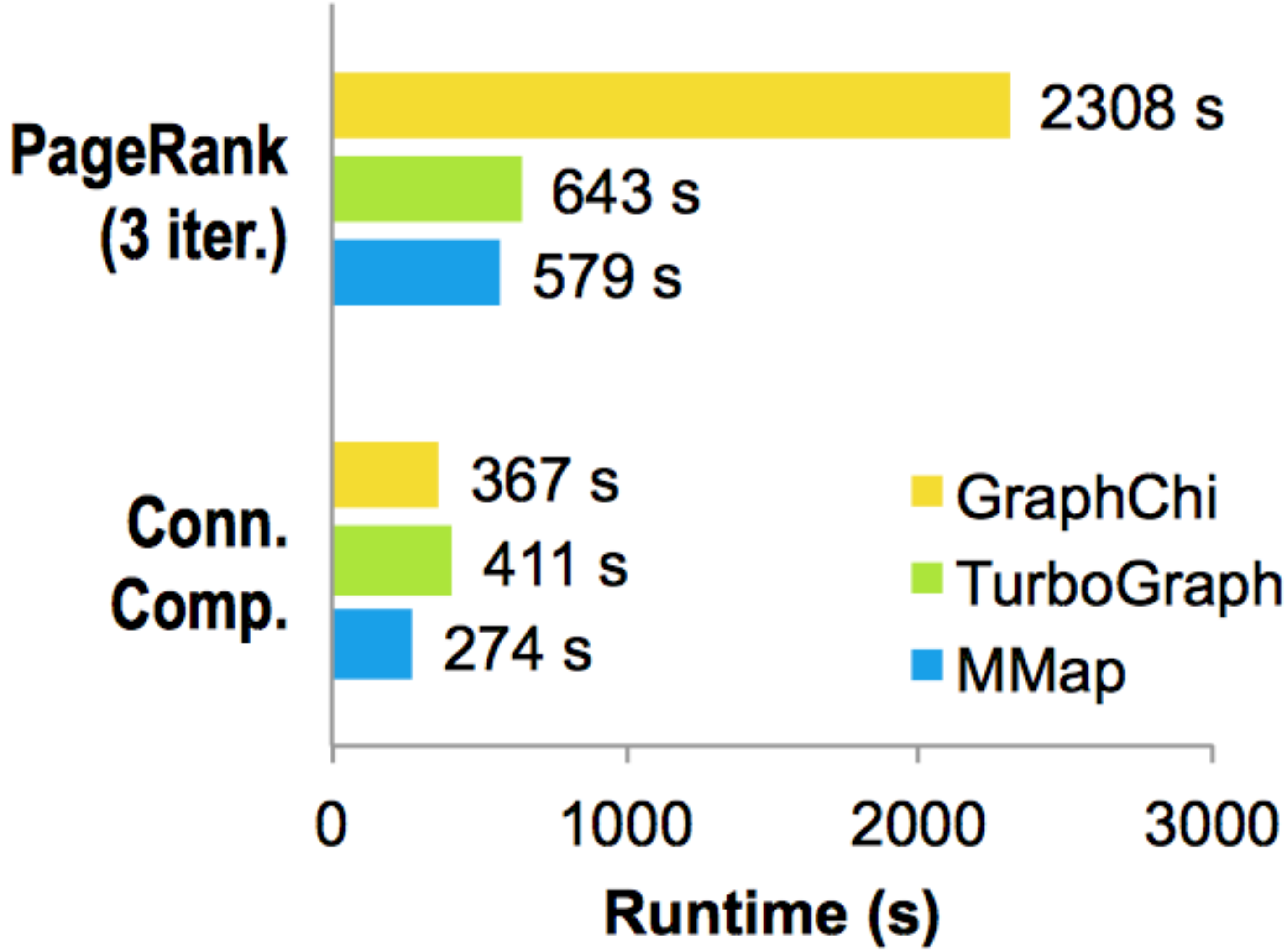


Fig. 3: **Data structures used for computing PageRank.** In

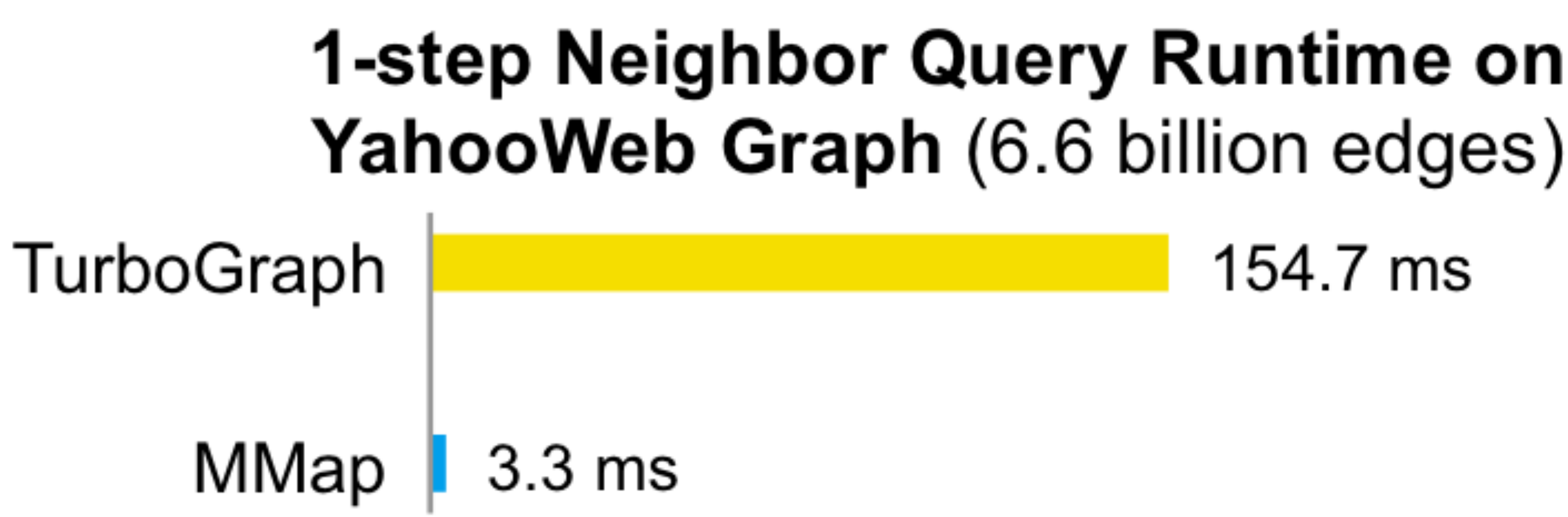
8000 lines of code



(a) LiveJournal graph (69M edges)



(c) YahooWeb graph (6.6B edges)



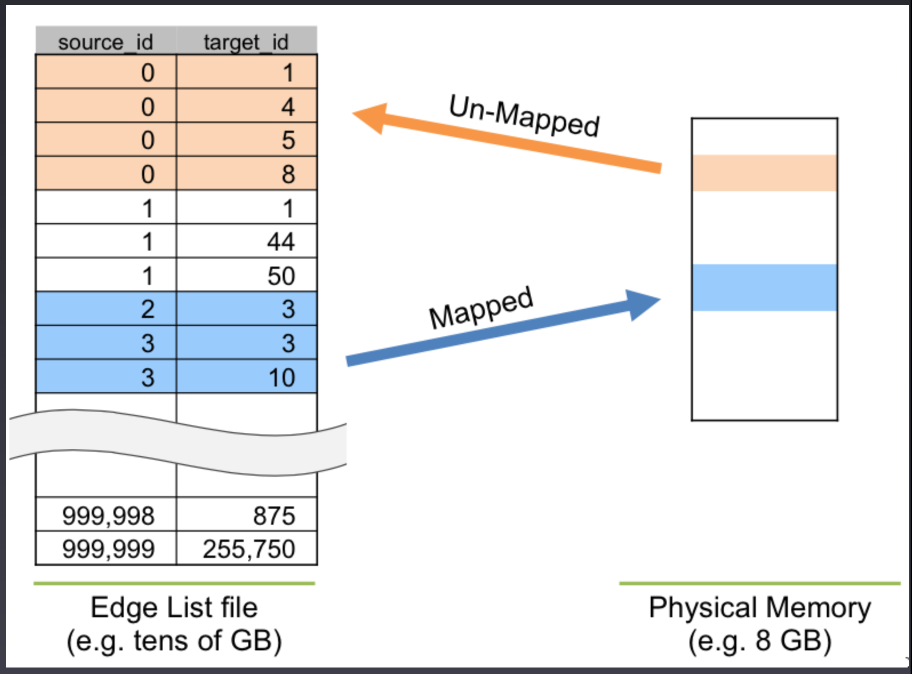
Why Memory Mapping Works?

High-degree nodes' info automatically cached/kept in memory for future frequent access

Read-ahead paging preemptively loads edges from disk.

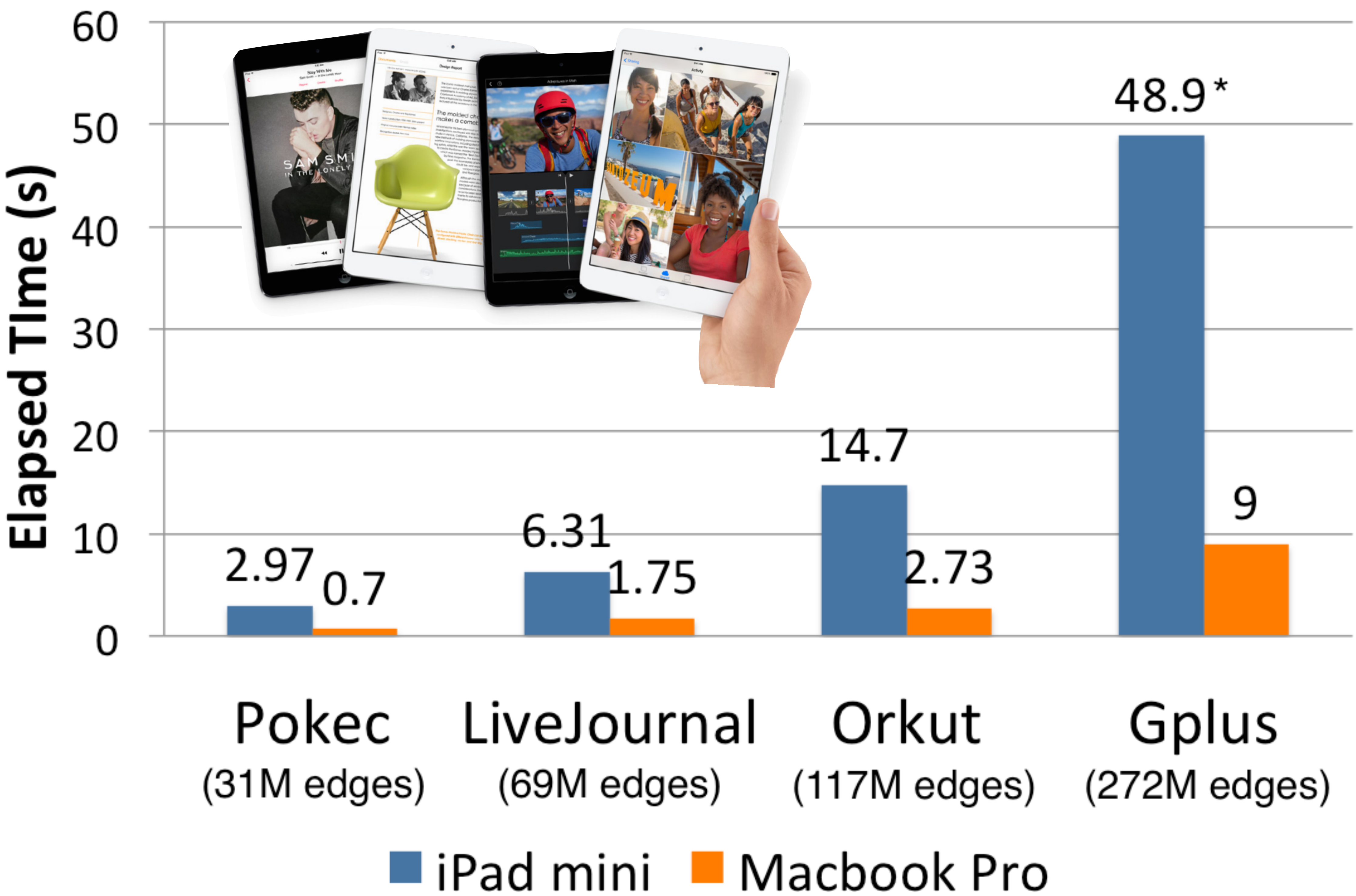
Highly-optimized by the OS

No need to explicitly manage memory (less book-keeping)



Also works on tablets! (If you want.)

Big Data on Small Devices (270M+ Edges)



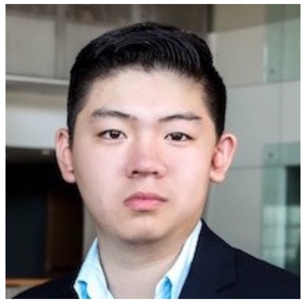
“Mobile” devices are now very powerful

Geekbench Results

	Chip	Single-Core Score	Multi-Core Score
2018 iPad Pro	A12X	5,025	18,106
iPhone XS / XS Max / XR	A12	4,795	11,167
2017 iPad Pro	A10X	3,913	9,327
2018 iPad	A10	3,474	5,914
2018 15” MacBook Pro	2.2GHz six-core Core i7	4,928	21,165
	2.6GHz six-core Core i7	5,053	21,351
	2.9GHz six-core Core i9	5,344	22,552

MacRumors

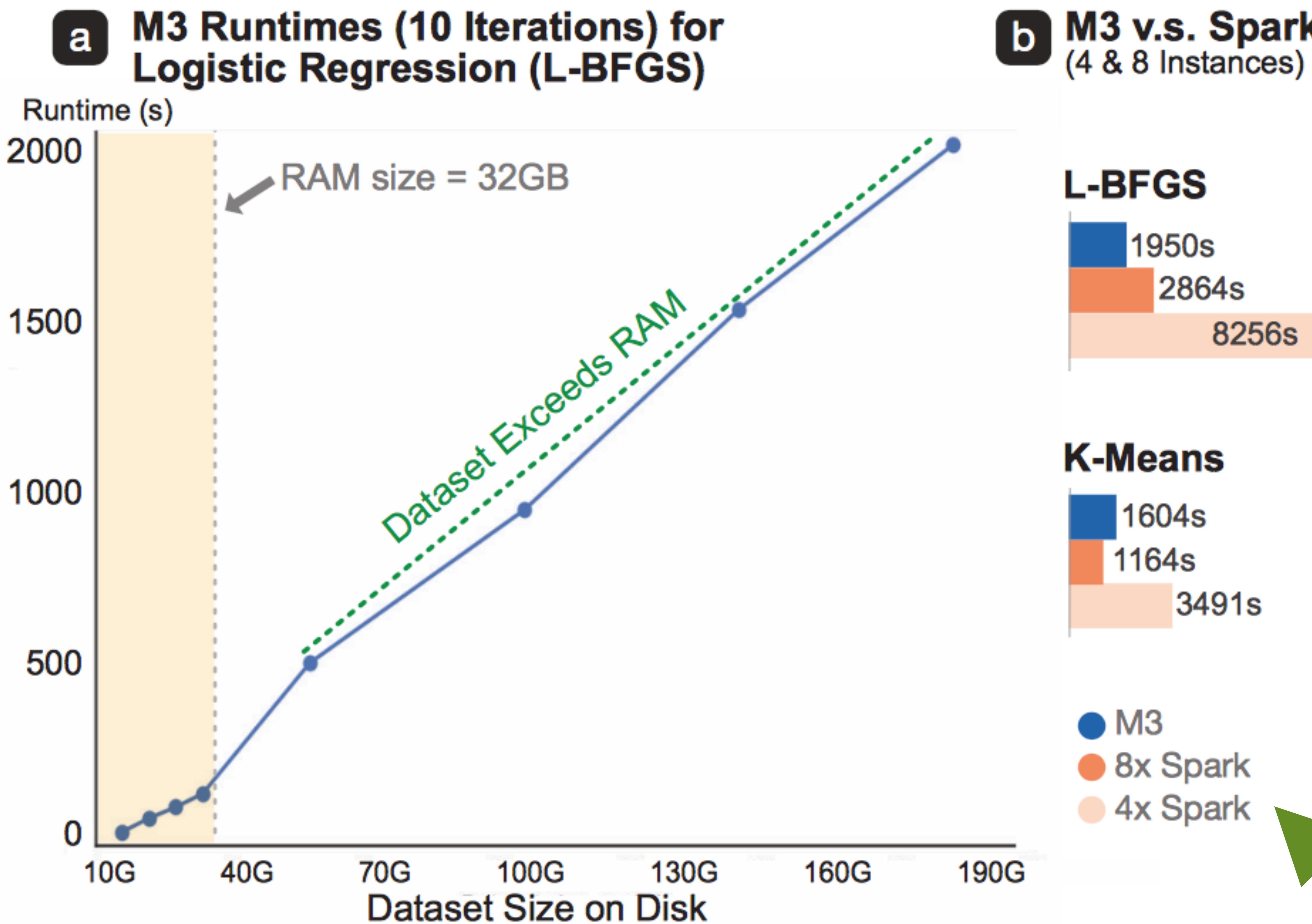
https://www.macrumors.com/2018/11/01/2018-ipad-pro-benchmarks-geekbench/



Lead by

Dezhi (Andy) Fang, Georgia Tech CS Undergrad.

Now: Airbnb software engineer



MMap project website http://poloclub.gatech.edu/mmap/

MMap Publications Code Datasets People

Scalable Machine Learning & Graph Mining via Virtual Memory

`Memory Mapping` based computation is a minimalist approach that forgoes sophisticated data structures, explicit memory management, and optimization techniques but still achieve high speed and scalability, by leveraging the fundamental memory mapping (MMap) capability found on operating systems.

Broader Impacts of this Project

Large datasets in terabytes or petabytes are increasingly common, calling for new kinds of scalable machine learning approaches. While state-of-the-art techniques often use complex designs, specialized methods to store and work with large datasets, this project proposes a minimalist approach that forgoes such complexities, by leveraging the fundamental virtual memory capability found on all modern operating systems, to load into the virtual memory space the large datasets

Faster I/O Operations

Less Overhead