Gunrock High-Performance Graph Analytics for the GPU

Muhammad Osama — University of California, Davis

UCDAVIS

Why use GPUs for graph processing?

GPUs and Graphs

Graphs

- Found **everywhere**
  - Road & social networks, web, etc.
- Require **fast processing**
  - Memory bandwidth, computing power and GOOD software
- Becoming **very large**
  - Billions of edges
- **Irregular data access pattern** and control flow
  - Limits performance and scalability

GPUs

- Found **everywhere**
  - Data center, desktops, mobiles, etc.
- Very **powerful**
  - High memory bandwidth (900 GBps) and computing power (15.7 TFlops)
- **Limited memory** size
  - 32 GB per NVIDIA V100
- **Difficult to program**
  - Harder to optimize

What is Gunrock?

A **CUDA**-based graph processing library, aims for

Performance

State-of-the-art graph processing library

A **CUDA**-based graph processing library, aims for

Generality

Covers a **broad range** of graph algorithms

A **CUDA**-based graph processing library, aims for

Programmability

Makes it easy to implement and extend graph algorithms from **1-GPU to multi-GPUs**

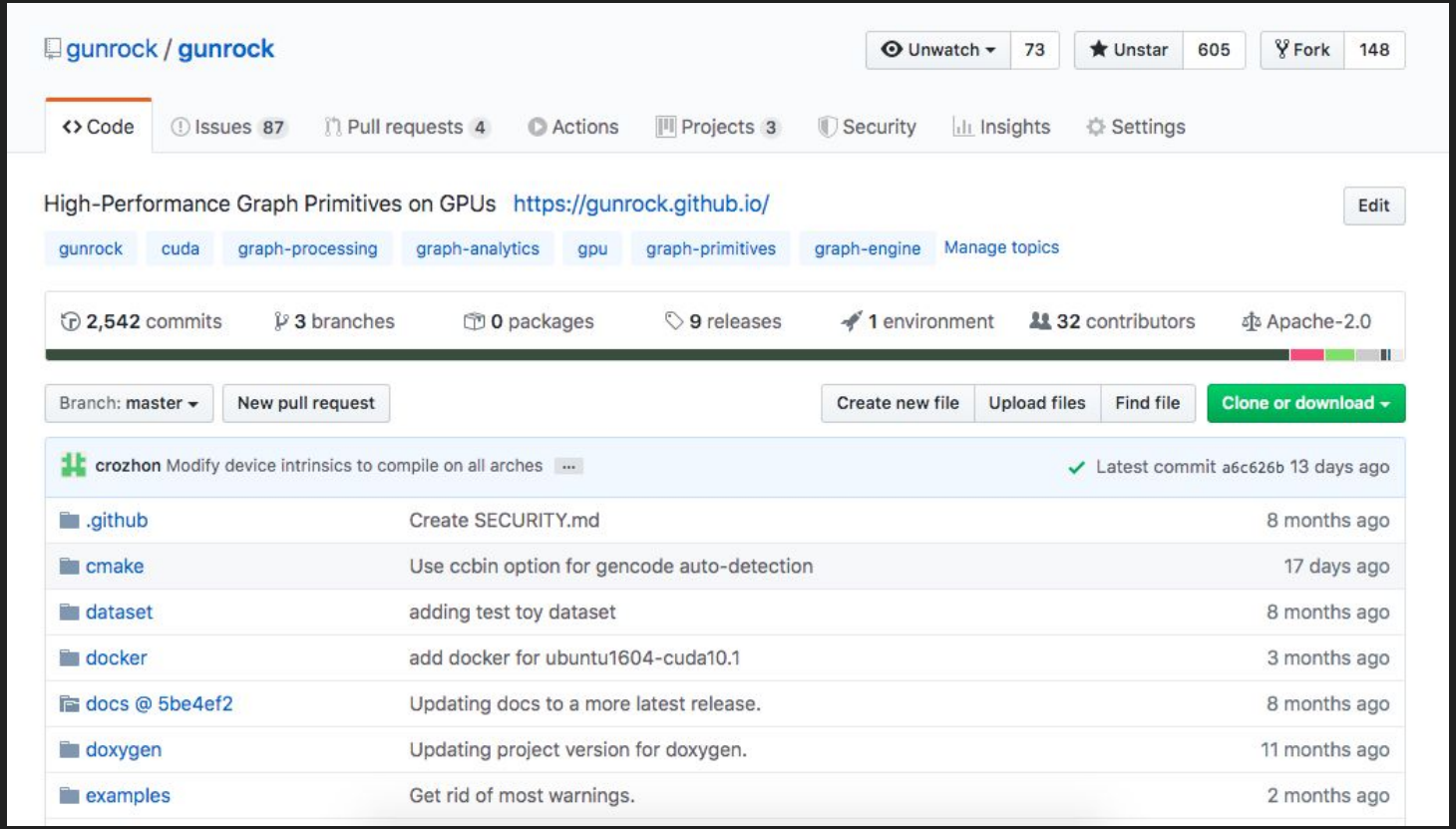
A **CUDA**-based graph processing library, aims for

Scalability

Fits in (very) limited GPU memory space

performance scales when using many GPUs

Where can you find Gunrock?



gunrock.github.io

Project's Workflow

Release (master) branch

Development (dev) branch

Git Forking Workflow

Contribute GitHub Issues & Pull Requests

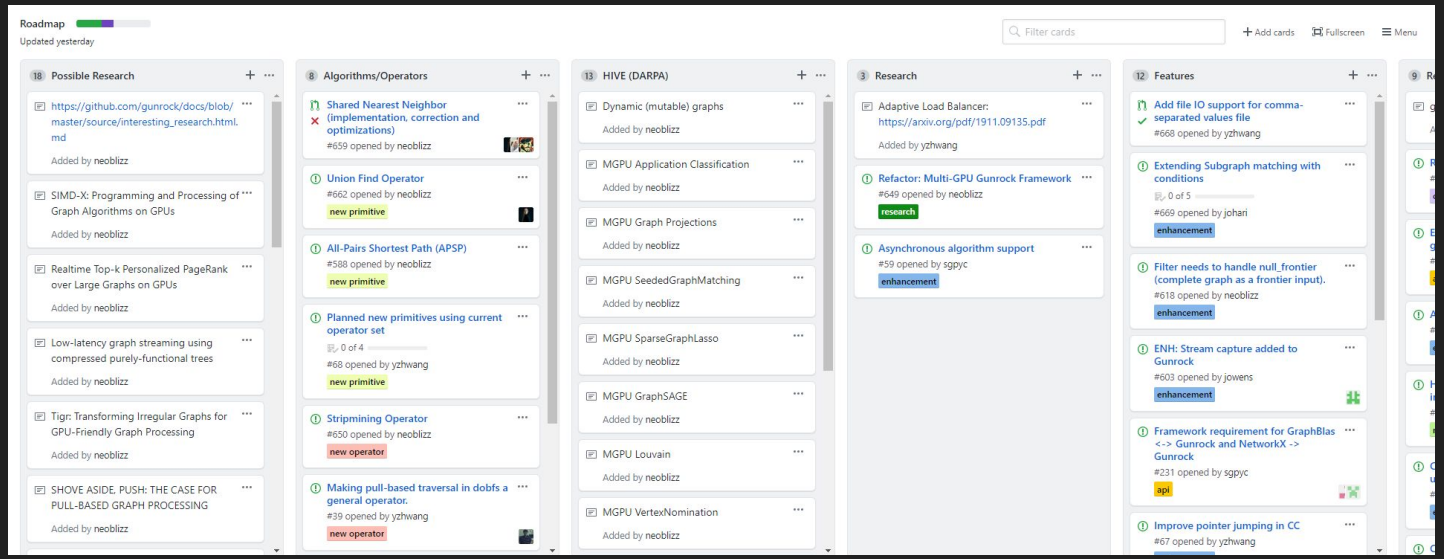
Apache 2.0 License

Code Coverage codecov.io

Central Integration jenkins.io

Documentation slate & doxygen

Project's Workflow (cont.)



Gunrock's **Roadmap**

Some Stats and Stuff! (as of 01/30/2020)

- 32 Contributors (over 2500 commits)
- ~600 stars 148 forks
- NVIDIA CUDA-X: GPU Accelerated Library
- RAPIDS

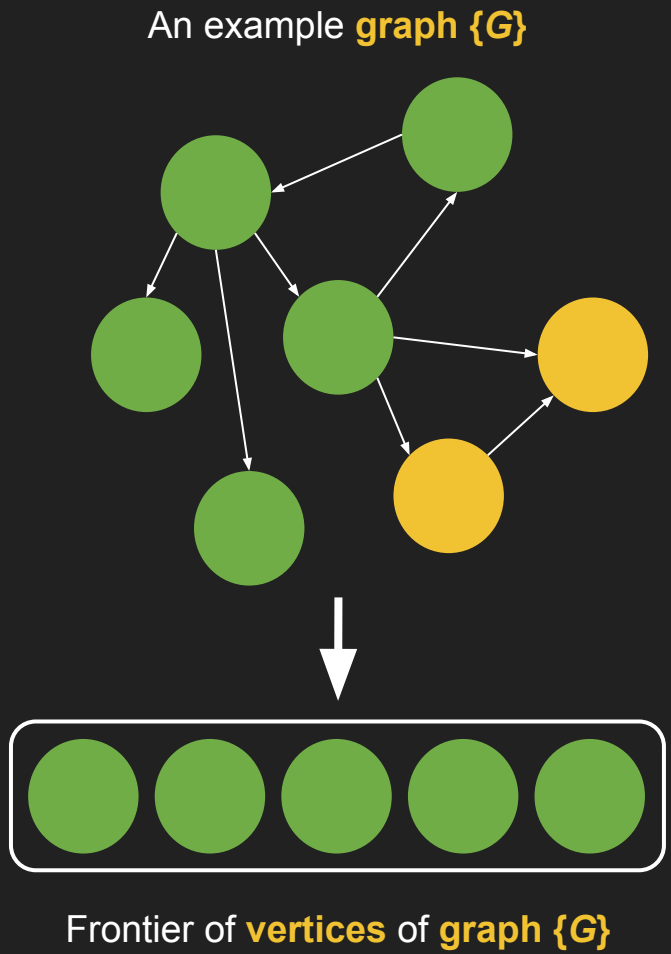
How does Gunrock work?

Programming Model

- **Data-centric** abstraction
- **Bulk-synchronous** programming

Frontier

A **frontier**; group of vertices or edges

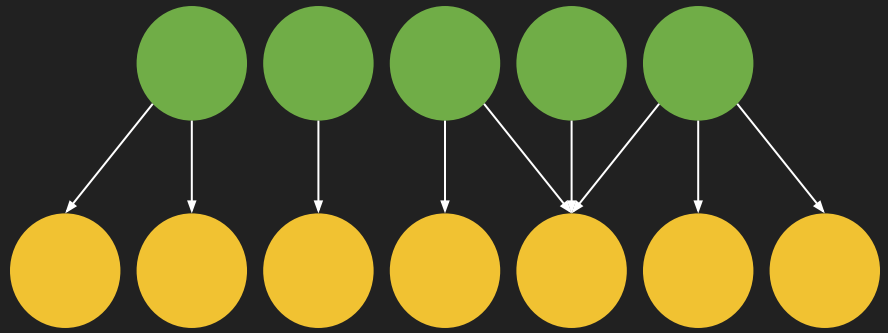


Parallel Operators

Manipulation of frontiers is an **operation**

- Advance
- Filter
- For
- Intersection
- Neighbor-Reduce
- … and more.

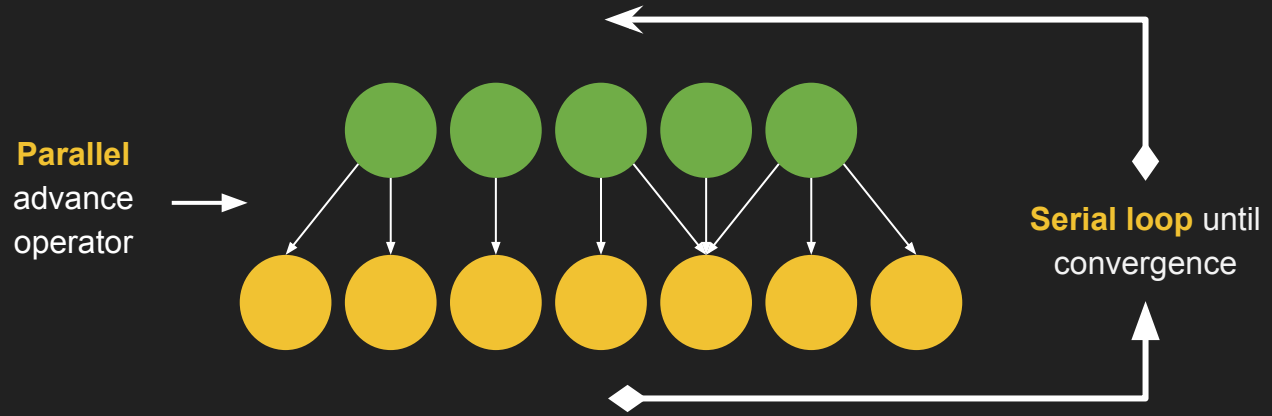
Illustration of **Advance** Operator



Generates new frontier by visiting the neighbors.

Bulk-Synchronous Programming

Series of **parallel operations** separated by **global barriers**



{Gunrock Algorithms}

A* Search

Betweenness Centrality

Breadth-First Search

Connected Components

Graph Coloring

Geolocation

RMAT Graph Generator

Graph Trend Filtering

Graph Projections

Random Walk

Hyperlink-Induced Topic Search

K-Nearest Neighbors

Louvain Modularity

Label Propagation

MaxFlow

Minimum Spanning Tree

PageRank

Local Graph Clustering

GraphSAGE

Stochastic Approach for Link-Structure Analysis

Subgraph Matching

Shared Nearest Neighbors

Scan Statistics

Single Source Shortest Path

Triangle Counting

Top K

Vertex Nomination

Who To Follow

Example application in Gunrock.

Single-Source Shortest Path

Implement the advance and filter C++ lambdas for SSSP

{complete code}

```
auto advance_op =
    [distances, weights] __host__ __device__ (...) -> bool {

  auto distance = distances[vertex_id] + weights[edge_id];
  auto old_distance = atomicMin(distances + neighbor_id, distance);

  if (distance < old_distance) return true;
  return false;
};

auto filter_op =
   [labels, iteration] __host__ __device__ (...) -> bool {
  if (!util::isValid(neighbor_id)) return false;
  return true;
};
```

Single-Source Shortest Path

Launch the lambdas within the operator call

{complete code}

```
while (!frontier.isEmpty()) {
      oprtr::Advance<oprtr::OprtrType_V2V>(
            graph.csr(), frontier, oprtr_parameters,
            advance_op, filter_op);
}
```

NVIDIA AI Laboratory. UC Davis Center for GPU Graph Analytics.

Department of Defense Advanced Research Projects Agency (DARPA). SYMPHONY: Orchestrating Sparse and Dense Data for Efficient Computation. Award HR0011-18-3-0007.

Department of Defense Advanced Research Projects Agency (DARPA). A Commodity Performance Baseline for HIVE Graph Applications. Award FA8650-18-2-7835.

Adobe Data Science Research Award. Scalability and Mutability for Large Streaming Graph Problems on the GPU.

National Science Foundation (Award OAC-1740333) SI\textln{2-SSE: Gunrock: High-Performance GPU Graph Analytics.

National Science Foundation (Award CCF-1637442) Theory and implementation of dynamic data structures for the GPU. Program: AitF---Algorithms in the Field.

National Science Foundation (Award CCF-1629657) PARAGRAPH: Parallel, Scalable Graph Analytics. XPS---Exploiting Parallelism & Scalability.

Department of Defense Advanced Research Projects Agency (DARPA) SBIR SB152-004. Many-Core Acceleration of Common Graph Programming Frameworks. Phase II: award W911NF-16-C-0020.

Department of Defense Advanced Research Projects Agency (DARPA) STTR ST13B-004 (“Data-Parallel Analytics on Graphics Processing Units (GPUs)”). A High-Level Operator Abstraction for GPU Graph Analytics. Awards D14PC00023 and D15PC00010.

Department of Defense (XDATA program). An XDATA Architecture for Federated Graph Models and Multi-Tier Asymmetric Computing. Oct. 2012--Sept. 2017. Prime contractor: Sotera Defense Solutions, Inc., US Army award W911QX-12-C-0059.

Acknowledgements & **Thanks!**