Gunrock: GPU Graph Analytics

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Overview

Gunrock is a CUDA library for graph-processing designed specifically for the GPU. Gunrock offers:

- a high-level, bulk-synchronous, data-centric programming model with
- best-in-class and scalable performance on single-GPU and multi-GPU-single-node configurations.

What is Gunrock's Data-centric Programming Model?

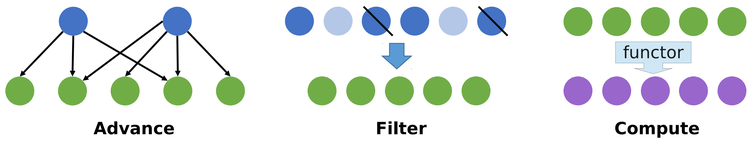
A **frontier** is a compact set of vertices or edges. Gunrock is built around **operators** that manipulate frontiers, including:

advance: generate a new frontier from the edges or vertices of the current frontier

filter: generate a new frontier from a current frontier using a user-specified predicate

compute: run a user-specified computation in parallel on each element in the current frontier

segmented-intersection: input two input frontiers; output each element that is in both input frontiers



How does Gunrock express graph algorithms?

```
### import libraries
from ctypes import *
gunrock = cdll.LoadLibrary('../../build/lib/libgunrock.so')

### read in input CSR arrays from files
row_list = [int(x.strip())
for x in open('path/to/rowoffsets/r_file')]
col_list = [int(x.strip())
for x in open('path/to/columnindices/c_file')]

### convert CSR graph inputs for gunrock input
row = pointer((c_int * len(row_list))(*row_list))
col = pointer((c_int * len(col_list))(*col_list))
nodes = len(row_list) - 1
edges = len(col_list)

### output array
scores = pointer((c_float * nodes)())

### call gunrock function on device
gunrock.bc(scores, nodes, edges, row, col, 0)

### sample results
print '\nnode\tbc\tscores:',
for idx in range(nodes): print scores[0][idx],
```

(a) Compute BC in Python.

```
BCProblem::Init(); // Initialization
// Accumulate sigma values
while (frontier_queue_length > 0) {
forward_queue_offsets.push(new_offsets);
  // Get neighbors and update scores
  BCEnactor::gunrock::oprtr::
  advance<BCProblem, ForwardEnactor>();
  // Cenerate new vertex frontier
  BCEnactor::gunrock::oprtr::
  filter<BCProblem, ForwardEnactor>();
}

// Compute delta values
while (!forward_queue_offsets.empty()) {
  // Compute delta values
  BCEnactor::gunrock::oprtr::
  advance<BCProblem, BackwardEnactor>();
}

BFSProblem::Extract(); // Get result
```

(b) Call Gunrock's BC in Python.

Figure: Code snapshots of programming a Gunrock primitive and using Gunrock.

Current primitives in Gunrock:

traversal-based: (direction-optimized) breadth-first search, single-source shortest path;

node-ranking: HITS, SALSA, PageRank, betweenness centrality;

global: connected component, minimum spanning tree, triangle counting, subgraph matching.

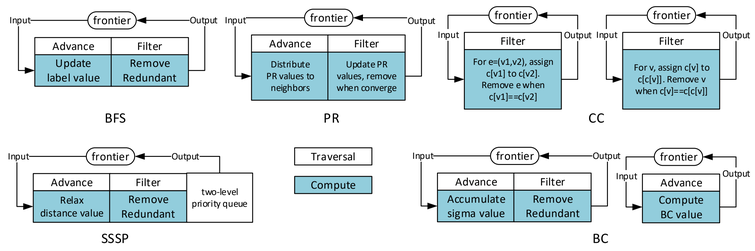


Figure: Operation flow chart for selected primitives in Gunrock (a black line with an arrow at one end indicates a while loop that runs until the frontier is empty).

Multi-GPU Framework

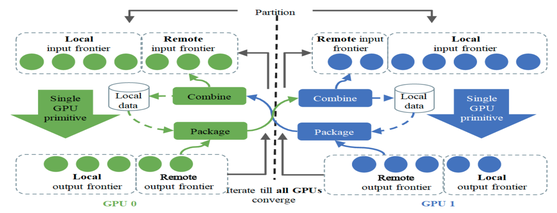


Figure: Single-node multiple-GPU communication flow.

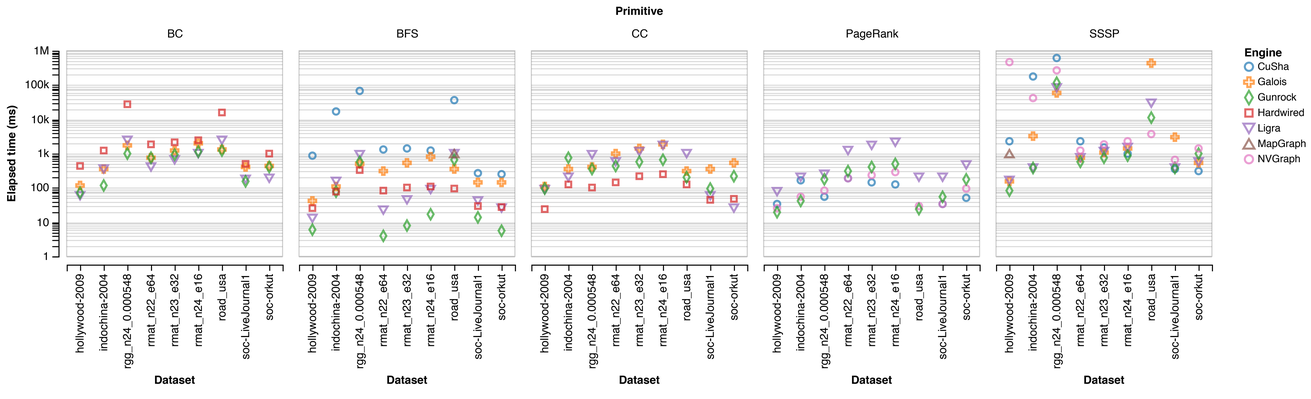
Optimization Strategies

- Static/dynamic workload mapping and load-balancing strategy;
- Enable idempotent operations;
- Pull vs. push traversal;
- Priority Queue, reorganizing frontier items into "near" and "far" slices;
- Kernel fusion;
- Efficient and effective coalesced-memory access.

Future Work

- Enhanced scalability (scale-up, scale-out);
- Support dynamic/streaming graphs;
- Expand core operators and add new primitives;
- Support higher-level programming models.

Gunrock Performance (lower is better)



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Contact Information

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