SIMD-X: Programming and Processing of Graph Algorithms on GPUs

Hang Liu        H. Howie Huang
University of Massachusetts Lowell  George Washington University
Graphs are Everywhere ...
Graph Algorithms are Insightful

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Functionality</th>
<th>Graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangle completing</td>
<td>Friend recommendation</td>
<td></td>
</tr>
<tr>
<td>Shortest path</td>
<td>Navigation</td>
<td></td>
</tr>
<tr>
<td>PageRank</td>
<td>Webpage searching</td>
<td></td>
</tr>
<tr>
<td>Matrix factorization</td>
<td>Product recommendation</td>
<td></td>
</tr>
</tbody>
</table>
Graph computation is NOT easy

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Complexity</th>
<th>Runtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangle completing</td>
<td>$</td>
<td>E</td>
</tr>
<tr>
<td>Shortest path</td>
<td>$</td>
<td>E</td>
</tr>
<tr>
<td>PageRank</td>
<td>$n \cdot</td>
<td>E</td>
</tr>
<tr>
<td>Matrix factorization</td>
<td>$n \cdot L \cdot</td>
<td>E</td>
</tr>
</tbody>
</table>

* V and E: vertex and edge count
* n: #iterations to converge
* L: #latent factors

* PowerGraph [OSDI ‘12] on Twitter dataset
  - 53M vertices
  - 2B edges
General Purpose GPUs (Tesla V100)

- **Massive parallelism and high bandwidth**
  - 22.5/120 TFLOPS and 900 GB/s.
  - 5,120 cores, supporting ~millions of threads.

- **Thread granularity**
  - **Warp**: consecutive 32 threads, executed in **SIMD**.
  - Lack of inter-SMX communication support.

- **Memory access pattern**
  - 900 GB/s: **consecutive** threads access **adjacent** data.
  - Random/stride access is ~10x slower.

[Ref]. NVIDIA TESLA V100 GPU ACCELERATOR. 2018.
Mapping Graph Computing on GPUs

- GPU: **SIMD**
- Graph: CompleX

**SIMD-X** bridges the gap!
SIMD-X Approaches

❖ SIMD-X — up to 10x faster than state-of-the-art “Gunrock" [PPoPP ‘16]
❖ Data-parallel ACC programming abstraction
❖ Just-in-time task management
❖ Push-pull based kernel fusion
SIMD-X: Programming and Processing of Graph Algorithms on GPUs

Hang Liu          H. Howie Huang
University of Massachusetts Lowell   George Washington University