Pregel: A System for Large-Scale Graph Processing

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Why Pregel?

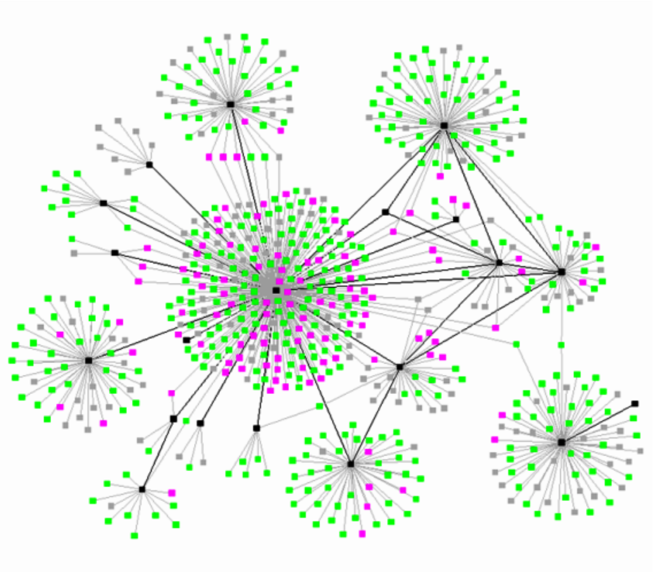
Need to process large-scale graphs.

- Option 1: Implement distributed infrastructure per algorithm?
  Too much repeated effort
- Option 2: Exsiting distribtued computing platform:
  MapReduce? Parallel databases?
  Not suitable for graph processing
- Option 3: Single-computer graph algorithm library?
  Limited scale
- Option 4: Existing parallel graph systems?
  Fault tolerance and other issues

Main Features

- Vertex program
- Message passing
- Synchronous parallel

Example: PageRank

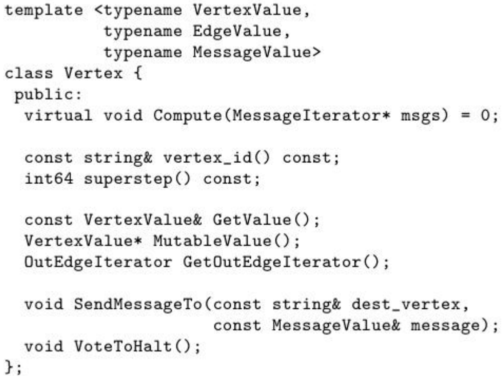


Example: PageRank as a vertex program

Iteratively run the following steps:

- Read messages from adjacent vertices (their ranks)
- Update my rank
- Send my rank to adjacent vertices

Vertex program in Pregel



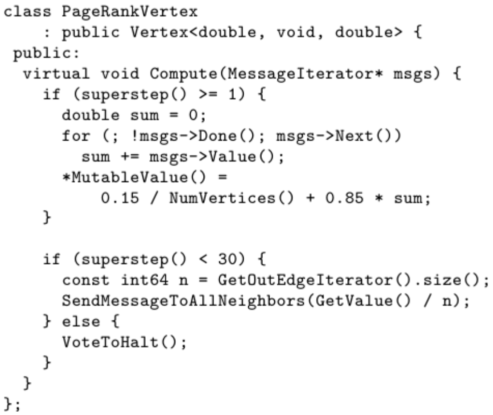
```
template <typename VertexValue,
          typename EdgeValue,
          typename MessageValue>
class Vertex {
 public:
  virtual void Compute(MessageIterator* msgs) = 0;

  const string& vertex_id() const;
  int64 superstep() const;

  const VertexValue& GetValue();
  VertexValue* MutableValue();
  OutEdgeIterator GetOutEdgeIterator();

  void SendMessageTo(const string& dest_vertex,
                     const MessageValue& message);
  void VoteToHalt();
};
```

PageRank in Pregel



```
class PageRankVertex
    : public Vertex<double, void, double> {
 public:
  virtual void Compute(MessageIterator* msgs) {
    if (superstep() >= 1) {
      double sum = 0;
      for (; !msgs->Done(); msgs->Next())
        sum += msgs->Value();
      *MutableValue() =
          0.15 / NumVertices() + 0.85 * sum;
    }

    if (superstep() < 30) {
      const int64 n = GetOutEdgeIterator().size();
      SendMessageToAllNeighbors(GetValue() / n);
    } else {
      VoteToHalt();
    }
  }
};
```

Message passing

- Message passing vs. Distributed Shared Memory (DSM)
- Communication between vertex programs is done via explicit message sending and receiving.
- Simple to implement
- No shared resource - no need for consistency model or concurrency control
- Disadvantages?

Bulk Synchronous Parallel

- A superstep: local computation + communicaiton + sychronization barrier
- All vertex programs must reach the barrier before starting the next superstep.
- Messages sent won't be seen by other until the next iteration.

Combiners

- Messages may be combined to reduce communication overhead.
- User-defined function to combine messages.

Aggregators

- Enables restricted global communication.
- Each vertex supplies a value. All values are combined by a reduction operator. The aggregated value is avaiable for all vertices to read at the next iteration.
- Inherited by Distributed GraphLab.

Topology Mutation

- Add or remove vertices and edges.
- How to handle conflicts, e.g. two requests to add one vertex with different values?
- Partial ordering
  - Additions follow removals.
  - Edge removals before vertex removals.
- User-defined handler

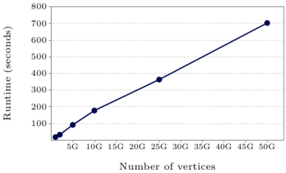
Implementation

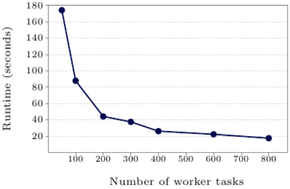
- The graph is partitioned and distributed among worker machines.
- Default is hash partioning. Allows custom assignment function.
- The master instructs workers to perform a superstep.
- Workers run Compute() on each vertex

Fault Tolerance

- Check pointing.
- Confined check pointing - under development.
  Only recover lost partition.

Evaluation


Runtime (seconds)
800
700
600
500
400
300
200
100
5G
10G
15G
20G
25G
30G
35G
40G
45G
50G
Number of vertices


Runtime (seconds)
180
160
140
120
100
80
60
40
20
100
200
300
400
500
600
700
800
Number of worker tasks

Look back from 2013

- The first widely-known distributed graph processing system.
- Influntial to many graph processing systems: Giraph, GraphLab, GraphChi...

Problems with message passing

- A vertex program must keep running to send out messages. Otherwise, its adjacent vertices won't know that vertex's value.
- In real applications, some vertices may converge earlier than others.
- Wasted CPU resource.
- What about DSM?

Other problems with Pregel

- BSP: well-known straggler problem
- Load balancing - power-law graph