Pregel

A SYSTEM FOR LARGE-SCALE GRAPH PROCESSING
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What is it

Efficient, scalable, fault tolerant, graph processing

Small amount of programming effort for scalable graph analysis

Distribution details hidden from user

Think like a vertex
Challenges

Little work per vertex

Changing parallelism over the course of the algorithm

Poor locality
Other options

Make your own infrastructure
  ◦ Substantial implementation effort

MapReduce
  ◦ Suboptimal performance
  ◦ Entire state is transmitted between steps

Single node compute
  ◦ Limits scale

Existing graph systems
  ◦ Not fault tolerant
Compute model

Think like a vertex

Directed edges associated with source vertex

Supersteps
- Modify its own state
- Modify its edges
- Review and send messages

Edges do not have associated compute
API

Have to write a new compute function for the vertex class

Each vertex has a single value associated with it
  ◦ The value can be a large complex type if needed

No remote reads

Message Passing
  ◦ Any number can be sent
  ◦ Viewable in the next superstep
  ◦ Can send to any node, not just neighbors
Combiners

Messages can be combined
  ◦ Reduce number of messages
  ◦ Reduce size of buffers
  ◦ Examples
    ◦ Sum
    ◦ Min
    ◦ Max
Aggregators

For global communication

Each vertex provides a value that are globally combined

Can be used for information about the graph and statistics
- Finding the number of edges
  - Each vertex outputs its out degree and sum them
- Can also make histograms

Global coordination
- When a condition is satisfied and can start the next phase
Topology Mutation

Vertices can add and remove edges

This can cause conflicts
  ◦ Two different vertices trying to add the same new vertex

Conflict resolution
  ◦ Removals before additions
  ◦ Edge removals before vertex removals
  ◦ Vertex additions before edge additions
  ◦ User-defined handlers deal with the rest
Examples

PageRank

Shortest Paths
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();
      }
   }
class ShortestPathVertex
    : public Vertex<int, int, int> {
  
    void Compute(MessageIterator* msgs) {
        int mindist = IsSource(vertex_id()) ? 0 : INF;
        for (; !msgs->Done(); msgs->Next())
            mindist = min(mindist, msgs->Value());
        if (mindist < GetValue()) {
            *MutableValue() = mindist;
            OutEdgeIterator iter = GetOutEdgeIterator();
            for (; !iter.Done(); iter.Next())
                SendMessageTo(iter.Target(),
                               mindist + iter.GetValue());
        }
        VoteToHalt();
    }
};
class MinIntCombiner : public Combiner<int> {
    virtual void Combine(MessageIterator* msgs) {
        int mindist = INF;
        for (; !msgs->Done(); msgs->Next())
            mindist = min(mindist, msgs->Value());
        Output("combined_source", mindist);
    }
};
Disadvantages

All computation are synchronous
- Asynchronous operations can lead to faster convergence

Does not take into account known information on graphs
- Such as small world or power law.

Lost single node performance
- GraphChi found they could get ¼ the performance with 1/30th of the cores
References


Implementation

On top of Google cluster architecture
- 1000s of commodity machines
- Name service
  - Instances are described by name independent of hardware
- Distributed storage system
  - GFS
  - BigTable

Partitions
- Either just hash(node ID) or user defined function
  - It is known where every vertex is stored by every machine
Worker

Maintains state of its partitions in memory

Queues for incoming messages and outgoing messages
  ◦ Buffering messages limits internode traffic

Calls compute for each superstep

Combiners are called in all queues
Master

Determines how many partitions the graph has
  ◦ Assigns one or more to each node

Maintains a list of active workers

Ensures everything proceeds in lockstep
  ◦ When a node fails goes to failure recover mode
Fault Tolerance

Uses a persistent distributed storage system

Check pointing

Failure detection via pings

Outgoing messages are logged