i²MapReduce: Incremental Iterative MapReduce

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Iterative Computation

• Use the same computation logic (update function) to process the data many times

• The previous iteration’s output is the next iteration’s input

• Stop when the iterated result converges to a fixed point
Iterative Cloud Intelligence Apps

Collaborative filtering recommendation

PageRank

Shortest path

Earthquake/hurricane prediction

Non negative matrix factorization

Data clustering
Iterative Computation

\[ v^k = F(v^{k-1}, D) \]

- \( v \): state data (updated every iteration)
- \( D \): structure data (static during iterative computation)
- \( F() \): iterative update function

\[ R^{(k)} = dW R^{(k-1)} + (1 - d)E \]

\( v \): PageRank scores \( R \)

\( D \): web graph matrix \( W \)
Structure Data is Changing
Structure Data is Changing
Structure Data is Changing

- Need to update the result to timely reflect the changing dataset
- Start from scratch? – heavy weighted
- Incremental processing

Changing social graph

Changing web graph
Incremental Processing

Utilize the previous iterative computation’s result:

1. Reduce the number of iterations
   - Structure data is slightly changed <-> the result is slightly changed
   - Start from the previously converged state rather than from a random start point
     \[ F(v, D) \]
     \[ F(v, D + \Delta D) \]

2. Reduce the workload of each iteration

\[ O(|D + \Delta D|) \rightarrow O(|\Delta D|) \]

Restart computation \hspace{1cm} Incremental processing
Related Works & Our Focus

• Incoop [SOCC 2011] (MPI-SWS)
• Naiad [CIDR 2013] (Microsoft)

• Our Focus: Incremental Iterative MapReduce
  – MapReduce is the most widely used big data processing tool
  – Compatible with existing MapReduce apps
Map-Reduce Bipartite Graph

Iterative processing
Throw a Pebble into Still Water
Map-Reduce Bipartite Graph

Iterative processing

Incremental processing
Map-Reduce Bipartite Graph

Iterative processing

Incremental processing
Map-Reduce Bipartite Graph

Iterative processing

Incremental processing
i²MapReduce: Incremental Processing

1. Start from the previously converged state data
   - Reduce the number of iterations

2. Only execute the changed mappers/reducers and utilize the converged MR-Edge/RM-Edge state
   - Reduce the workload of each iteration

3. Filter the converged reducers
   - Avoid changes propagation
i²MapReduce: Implementation

- Hadoop extension
i²MapReduce vs. MapReduce compute

- 20-node cluster
- App: PageRank
- Synthetic power-law graph
  - Degree: log-normal dist.
  - Avg. degree 5.18
- Fixed change size
  - Randomly change 10K edges
- Varying input size
  - From 10M nodes to 50 nodes

The time of incremental processing does not change much as input size grows
Conclusions & Future Work

• Conclusions
  – Incremental processing with MRBGraph
  – $i^2$MapReduce: a MapReduce based framework for incremental iterative computations in the cloud

• Future work
  – Indexing mechanism for querying MRBGraph file
  – Cost-aware execution plan
Thank You!