CS 744: MAPREDUCE

Shivaram Venkataraman
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ANNOUNCEMENTS

• Assignment 1 deliverables
  – Code (comments, formatting)
  – Report
    • Partitioning analysis (graphs, tables, figures etc.)
    • Persistence analysis (graphs, tables, figures etc.)
    • Fault-tolerance analysis (graphs, tables, figures etc.)

• See Piazza for Tutorial
Scalable Storage Systems

Datacenter Architecture

Resource Management

Computational Engines

Applications

Machine Learning  SQL  Streaming  Graph
BACKGROUND: PTHREADS

void *myThreadFun(void *vargp)
{
    sleep(1);
    printf("Hello World\n");
    return NULL;
}

int main()
{
    pthread_t thread_id_1, thread_id_2;
    pthread_create(&thread_id_1, NULL, myThreadFun, NULL);
    pthread_create(&thread_id_2, NULL, myThreadFun, NULL);
    pthread_join(thread_id_1, NULL);
    pthread_join(thread_id_2, NULL);
    exit(0);
}
int main(int argc, char** argv) {
    MPI_Init(NULL, NULL);

    // Get the number of processes
    int world_size;
    MPI_Comm_size(MPI_COMM_WORLD, &world_size);

    // Get the rank of the process
    int world_rank;
    MPI_Comm_rank(MPI_COMM_WORLD, &world_rank);

    // Print off a hello world message
    printf("Hello world from rank %d out of %d processors\n",
            world_rank, world_size);

    // Finalize the MPI environment.
    MPI_Finalize();
}
MOTIVATION

Build Google Web Search
  - Crawl documents, build inverted indexes etc.

Need for
  - automatic parallelization
  - network, disk optimization
  - handling of machine failures
OUTLINE

- Programming Model
- Execution Overview
- Fault Tolerance
- Optimizations
PROGRAMMING MODEL

Data type: Each record is (key, value)

**Map function:**

\[(K_{in}, V_{in}) \rightarrow \text{list}(K_{inter}, V_{inter})\]

**Reduce function:**

\[(K_{inter}, \text{list}(V_{inter})) \rightarrow \text{list}(K_{out}, V_{out})\]
def mapper(line):
    for word in line.split():
        output(word, 1)

def reducer(key, values):
    output(key, sum(values))
WORD COUNT EXECUTION: PART 1

Input
- the quick brown fox
- the fox ate the mouse
- how now brown cow

Map
- the quick brown fox
- the fox ate the mouse
- how now brown cow

Shuffle & Sort

Reduce
- Reduce
- Reduce
- Reduce

Output
WORD COUNT EXECUTION: PART2

Input
- the quick brown fox
- the fox ate the mouse
- how now brown cow

Map
- Map
- Map
- Map

Shuffle & Sort
- the, 1
- brown, 1
- fox, 1
- how, 1
- now, 1
- brown, 1
- the, 1
- fox, 1
- the, 1
- quick, 1
- ate, 1
- mouse, 1
- cow, 1

Reduce
- Reduce
- Reduce

Output
- brown, 2
- fox, 2
- how, 1
- now, 1
- the, 3
- ate, 1
- cow, 1
- mouse, 1
- quick, 1
ASSUMPTIONS

1. Commodity networking, less bisection bandwidth
2. Failures are common
3. Local storage is cheap
4. Replicated FS
5. Input is splittable
WORD COUNT EXECUTION

Submit a Job

Automatically split work

MR Master

Schedule tasks with locality

Map

the quick brown fox

Map

the fox ate the mouse

Map

how now brown cow

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Map

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Map

how now brown cow
If a task crashes:

- Retry on another node
- If the same task repeatedly fails, end the job
If a node crashes:

– Relaunch its current tasks on other nodes

What about task inputs? File system replication
FAULT RECOVERY

If a task is going slowly (straggler):

- Launch second copy of task on another node
- Take the output of whichever finishes first
MORE DESIGN

Master failure

Locality
MAPREDUCE: SUMMARY

- Simplify programming on large clusters with frequent failures

- Limited but general functional API
  - Map, Reduce, Sort
  - No other synchronization / communication

- Fault recovery, straggler mitigation through retries
DISCUSSION

https://forms.gle/prXWmR97A3xozHkH9
Indexing pipeline where you start with HTML documents. You want to index the documents after removing the most commonly occurring words.

1. Compute most common words.
2. Remove them and build the index.

What are the main shortcomings of using MapReduce to do this?
(a) Normal execution

(b) No backup tasks
### MapReduce Usage Statistics Over Time

<table>
<thead>
<tr>
<th></th>
<th>Aug, '04</th>
<th>Mar, '06</th>
<th>Sep, '07</th>
<th>Sep, '09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of jobs</td>
<td>29K</td>
<td>171K</td>
<td>2,217K</td>
<td>3,467K</td>
</tr>
<tr>
<td>Average completion time (secs)</td>
<td>634</td>
<td>874</td>
<td>395</td>
<td>475</td>
</tr>
<tr>
<td>Machine years used</td>
<td>217</td>
<td>2,002</td>
<td>11,081</td>
<td>25,562</td>
</tr>
<tr>
<td>Input data read (TB)</td>
<td>3,288</td>
<td>52,254</td>
<td>403,152</td>
<td>544,130</td>
</tr>
<tr>
<td>Intermediate data (TB)</td>
<td>758</td>
<td>6,743</td>
<td>34,774</td>
<td>90,120</td>
</tr>
<tr>
<td>Output data written (TB)</td>
<td>193</td>
<td>2,970</td>
<td>14,018</td>
<td>57,520</td>
</tr>
<tr>
<td>Average worker machines</td>
<td>157</td>
<td>268</td>
<td>394</td>
<td>488</td>
</tr>
</tbody>
</table>

Jeff Dean, LADIS 2009
NEXT STEPS

• Next lecture: Spark
• Assignment 1: Use Piazza!