Reviewing:

CIEL

A universal execution engine for distributed data-flow computing

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Outline

1. Motivation
2. Goals
3. Design
4. Fault Tolerance
5. Performance
6. Related Work
7. Conclusion
Motivation

MapReduce

Dryad
Motivation

MapReduce/Dryad have shortcomings:

1. Designed to maximize throughput, not to minimize latency.
2. Perform scheduling before running the algorithm. The resulting schedule is static.

These makes MapReduce/Dryad inappropriate for iterative algorithms.
Goals

Design a distributed execution framework that can
1. efficiently run iterative algorithms
2. provide a simple interface
3. offer transparent fault tolerance
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CIEL’s Computation Model

The key feature of CIEL is a **dynamic task graph**.

Primitives of the model:

1. **Object**: An unstructured sequence of bytes (code, libraries, data, etc.)
2. **Reference**: The location where an object is stored
3. **Task**: A computation that executes completely on a single machine. Tasks can publish results and spawn other tasks.
An example task graph

Root task: A

Child tasks: B, C

Concrete object: W

Future object: x, y

Result (future): z
System Architecture

- Master maintains current state of task graph in the object and task tables.
- Master does scheduling by lazily evaluating output objects, and pairs runnable tasks with idle workers.
- Workers execute tasks and store objects.
Skywriting

- A simple programming interface to CIEL

```javascript
function process_chunk(chunk, prev_result) {
  // Execute native code for chunk processing.
  // Returns a reference to a partial result.
  return spawn_exec(...);
}

function is_converged(curr_result, prev_result) {
  // Execute native code for convergence test.
  // Returns a reference to a boolean.
  return spawn_exec(...)[0];
}

input_data = [ref("ciel://host137/chunk0"),
              ref("ciel://host223/chunk1"),
              ...];
curr = ...; // Initial guess at the result.

do {
  prev = curr;
  curr = [];
  for (chunk in input_data) {
    curr += process_chunk(chunk, prev);
  }
} while (!is_converged(curr, prev));

return curr;
```
Task Creation in Skywriting

Task creation is the distinctive feature that facilitates data-dependent control flow. Two essential ways to create tasks in Skywriting:

1. `spawn(f, args = [...])`
   spawns a child task that computes and returns a pointer to `f(args)`. Explicit task creation.

2. `*` (unary dereference operator that applies to a ref)
   Loads the referenced data and evaluates to the resulting data structure. Implicit task creation.
Implicit Task Creation with *

**Problem:** CIEL tasks are non-blocking, but dereferencing future objects will require waiting for tasks to complete.

**Solution:** Implicit creation of *continuation task*, which depends on dereferenced object and current execution stack.
Running a simple script

partitions = [...];
guess = ...

do {
    prev = guess;
    guess = mapreduce(partitions,
            lambda x: km_map(x, prev),
            km_reduce);
    done = spawn(is_converged, [guess, prev]);
} while (!*done);
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Fault Tolerance

- **Client**: Trivial since no driver program is required.
- **Worker**: Monitored by master (similar to Dryad)
- **Master**: Master state can be derived from the set of active jobs. This is accomplished with
  - persistent logging, and
  - object table reconstruction by workers
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Experiment I: Grep

- How does CIEL compare to Hadoop?
- Hadoop polls for tasks once every 5 seconds. [this has changed since 2011. See patch: MAPREDUCE-1906]
- Hadoop runs mandatory “setup” and “cleanup” for each job
- Note Hadoop’s weaker performance for small tasks.
Experiment II: k-means

- How does CIEL compare to Hadoop (Apache Mahout) for iterative algorithms?
- Hadoop does not perform cross-job optimisations. Each iteration is an independent job.
- CIEL prefers workers that have consumed the same data for previous iterations, which leads to better data-locality.

![Graph showing comparison between CIEL and Hadoop](image)
Experiment III: DP

- CIEL can distribute partially parallelizable tasks that do not cleanly fall into the MapReduce format.

(a) Smith-Waterman  (b) Binomial options pricing
Goals (revisited)

Design a distributed execution framework that can
1. efficiently run iterative algorithms [dynamic task graph]
2. provide a simple interface [Skywriting]
3. offer transparent fault tolerance [Master fault tolerance]
Related Work

- Pregel: Google’s distributed execution engine for graph algorithms [designed primarily for graph algorithms]
- HaLoop: task scheduler is made loop-aware by adding caching mechanisms [lacks fault tolerance]
- Apache Mahout: Uses Hadoop as its execution engine and a driver program runs iterative algorithms. [lacks master fault tolerance + requires driver program]
Conclusion

What are CIEL’s significant contributions?

- Iterative Algorithms can be a single job. Therefore, there is no driver program running outside of the cluster.
- Dynamic Task Graph: Task spawns Task
- Fault tolerance for Master