CSinParallel: Using Map-Reduce to Teach Parallel Programming Concepts Across the CS Curriculum
Part 1

SC13

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Workshop site

CSinParallel.org:

- Workshops tab on left
- SC13 Map-Reduce Workshop

See also workshop handout

Goals

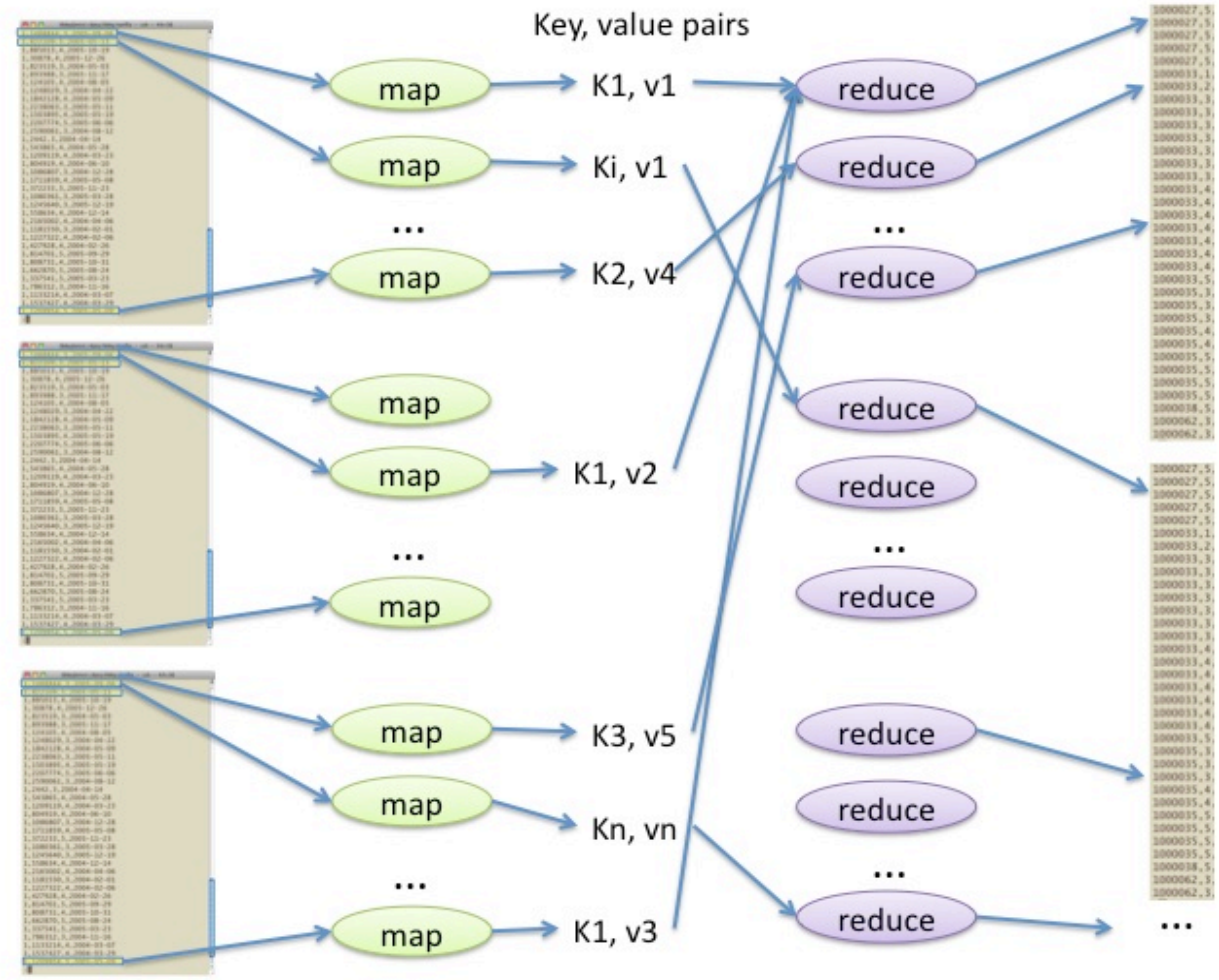
- Introduce map-reduce computing, using the *WebMapReduce (WMR)* simplified interface to Hadoop
  - Why use map-reduce in the curriculum?
- Hands-on exercises with WMR for foundation courses
- Use of WMR for intermediate and advanced courses
  - What's under the hood with WMR
  - A peek at Hadoop…
- Hands-on exercises for more advanced use

Introduction to Map-Reduce Computing

History

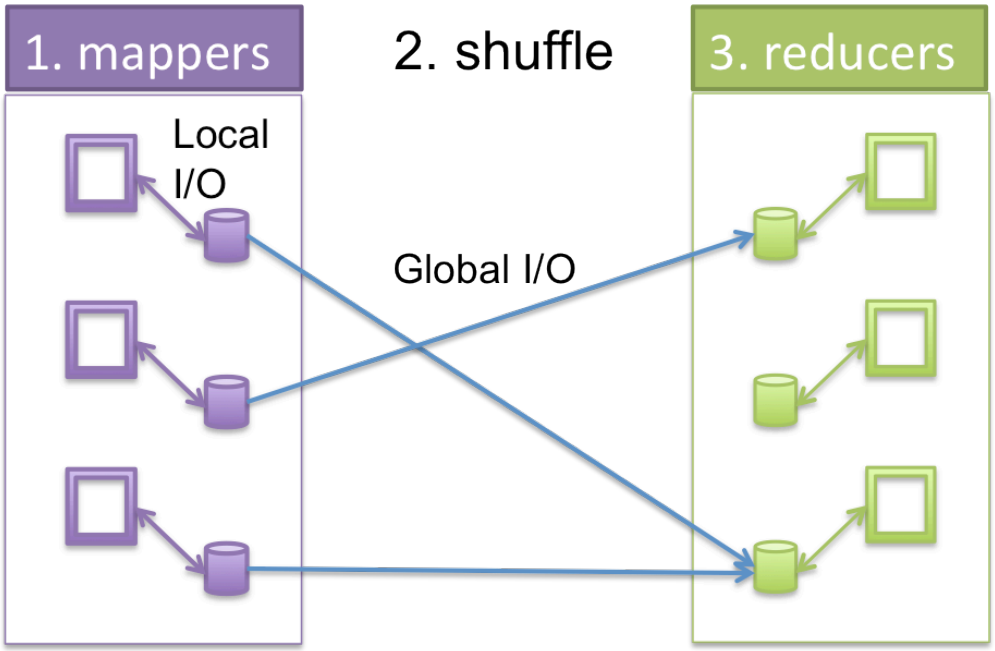
- The computational model of using map and reduce operations was developed decades ago, for LISP
- Google developed MapReduce system for search engine, published (Dean and Ghemawat, 2004)
- Yahoo! created Hadoop, an open-source implementation (under Apache); Java mappers and reducers

Map-Reduce Concept



The map-reduce computational model

- Map-reduce is a two-stage process with a "shuffle twist" between the stages.



- Stages are controlled by functions: mapper() , reducer()

The map-reduce computational model

- mapper() function:
  - Argument is one line of input from a file
  - Produces (key, value) pairs

- Example: word-count mapper()

  "the cat in the hat" --> [mapper for this line]

  ("the", "1"), ("cat", "1"), ("in", "1"),

  ("the", "1"), ("hat", "1")

The map-reduce computational model

- Shuffle stage:
  - group all mappers' (key, value) pairs together that have the same key, and feed each group to its own call of reduce()
  - Input: all (key,value) pairs from all mappers
  - Output: Those pairs rearranged, sent to calls of reduce() according to key

- Note: Shuffle also sorts (optimization)

The map-reduce computational model

- reducer() function:
  - Receives all key-value pairs for one key
  - Produces an aggregate result

- Example: word-count reducer()

("the", "1"), ("the", "1")

-->

("the", "2")

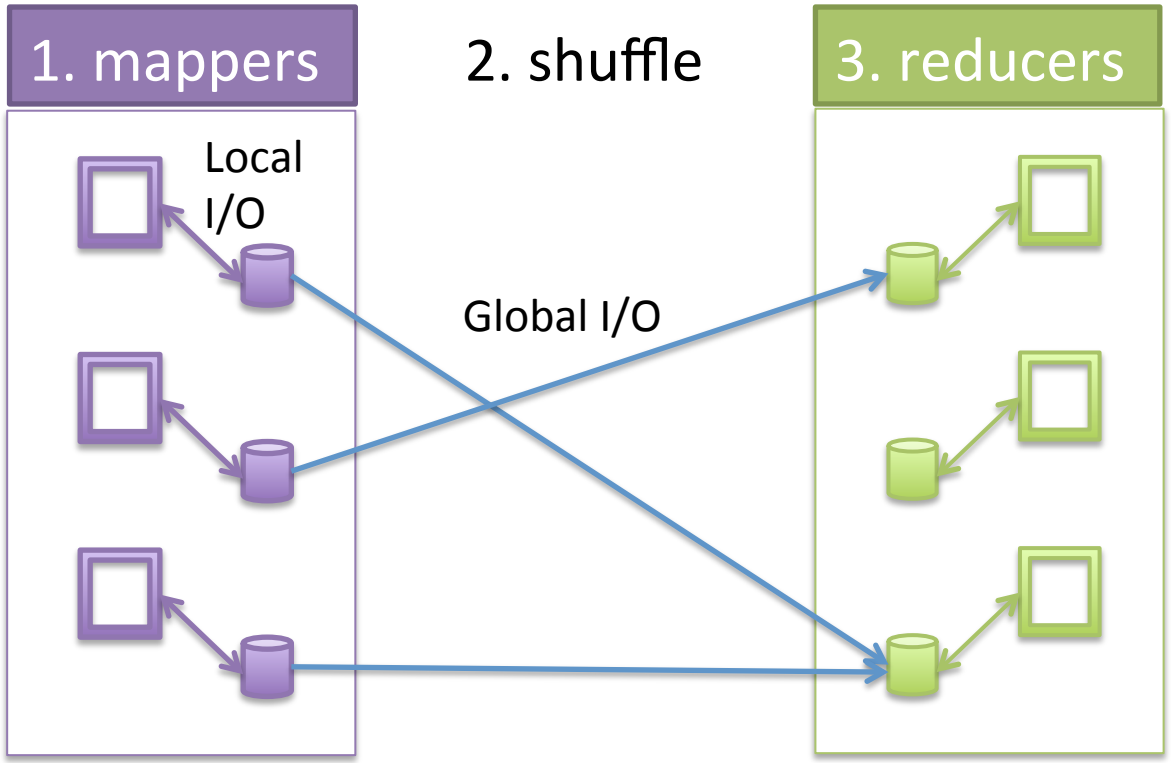
[reducer for "the"]

The map-reduce computational model

- In map-reduce, a programmer codes only two functions (plus config information)
  - A model for future parallel-programming frameworks
- Underlying map-reduce system reuses code for
  - Partitioning the data into chunks and lines,
  - Moving data between mappers and reducers
  - Auto-recovering from any crashes that may occur
  - …
- Optimized, Distributed, Fault-tolerant, Scalable

The map-reduce computational model

- Optimized, Distributed, Fault-tolerant, Scalable



Demo of WMR

Why teach map-reduce?

Why map-reduce for teaching notions of parallelism/concurrency?

– Concepts:

- data parallelism;
- task parallelism;
- locality;
- effects of scale;
- example effective parallel programming model;
- distributed data with redundancy for fault tolerance; ...

Why map-reduce for teaching notions of parallelism/concurrency?

- Real-World: Hadoop widely used
- Exciting: The appeal of Google, etc.
- Useful: for appropriate applications
- Powerful: scalability to large clusters, large data

Why WMR?

- Introduce concepts of parallelism
- Low bar for entry, feasible for CS1 (and beyond)
- Capture the imaginations of students

- Supports rapid introduction of concepts of parallelism for every CS student

WebMapReduce (WMR)

- Simplified web interface to Hadoop computations
- Goals:
  - Strategically Simple
    suitable for CS1, but not a toy
  - Configurable
    write mappers/reducers in any language
  - Accessible web application
  - Multi-platform, front-end and back-end

WMR Features (Briefly)

- Testing interface
  - Error feedback
  - Bypasses Hadoop -- small data only!
- Students enter the following information:
  - **choice of language**
  - data to process
  - definition of mapper in that language
  - definition of reducer in that language

WMR system information

- Languages currently supported:
  Java, C++, Python, Scheme, C, C#
- Back ends to date:
  local cluster, Amazon EC2 cloud images

More details about the system in Part 2 of the workshop

Teaching map-reduce with WMR in the introductory sequence

Macalester College
Calvin
Minds in the Making
St. Olaf College

Teaching materials for WMR at an introductory level

- CSinParallel module: *Map-reduce Computing for Introductory Students using WebMapReduce*
  - See `csinparallel.org`

Experience

- Opportunity to informally introduce a host of PDC concepts
- Don't expect speedup from our "tiny" problems
  - Hadoop is designed for terascale to petascale, and the overhead of I/O operations is dominant for mere megascale or less

Teaching with frameworks

- The syntax of Python mapper/reducer is familiar to any CS1 student with Python

But, programming with a framework:

- They are used to writing entire programs
- Challenge to understand how values come/ go when it's not standard input/output.

Make a toy framework? Little success…

Off-line exercise for students

- Manual map-reduce for students in-class
  - Makes the process concrete, which informs better understanding of the framework
- Let's demonstrate by counting occurrences from a paper book
  - program, programmer, programming
  - design
  - code
  - technical
  - people
  - system, systems

Overview of suggested exercises

Available on the csinparallel.org site

- Run word count (provided), with small and large data
- Modify, run variations on word count: strip punctuation; case insensitive; etc.

- Alternative exercises

Quick questions/comments so far?

Hands-on

Module exercises

Data sets available

/shared/MovieLens2/movieRatings

/shared/gutenberg/WarAndPeace.txt

/shared/gutenberg/CompleteShakespeare.txt

/shared/gutenberg/all/group8
/shared/gutenberg/all_nonl/group8/