Pydoop: a Python MapReduce and HDFS API for Hadoop

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MAPREDUCE '10

Outline

1. Motivation
2. Architecture
3. Examples
4. Conclusions and Future Work

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1 Motivation

2 Architecture

3 Examples

4 Conclusions and Future Work

MapReduce Development

- Java: Hadoop is all you need
- C/C++: APIs for both MR and HDFS are supported by Hadoop Pipes and included in the Hadoop distribution
- Python: current solutions fail to meet all requirements of nontrivial apps
  - Reuse existing modules, including C/C++ extensions
  - NumPy / SciPy for numerical computation
  - Specialized components (RecordReader/Writer, Partitioner . . .)
  - HDFS access

Hadoop-Integrated Solutions

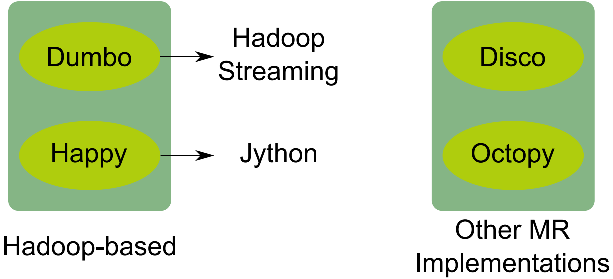
Hadoop Streaming

- text protocol: cannot process arbitrary data streams
- can only write mapper and reducer scripts (no RecordReader, etc.)
- awkward programming style (read key/value pairs from stdin, write them to stdout)

Jython

- incomplete standard library
- most third-party packages are only compatible with CPython
- cannot use C/C++ extensions
- typically one or more releases behind CPython

Third Party Solutions



- Hadoop-based: same limitations as Streaming (Dumbo) and Jython (Happy), except for ease of use
- Other implementations: good if you have your own cluster
  - Hadoop is the most widespread implementation

Our Solution: Pydoop

- Access to most MR components, including RecordReader, RecordWriter and Partitioner
- Get configuration, set counters and report status via context objects
- Framework is similar to the Java one: you define classes, framework instantiates them and calls their methods
- CPython: use any module
- HDFS API

Summary of Features

	Streaming	Jython	Pydoop
C/C++ Ext	Yes	No	Yes
Standard Lib	Full	Partial	Full
MR API	No*	Full	Partial
Java-like FW	No	Yes	Yes
HDFS	No	Yes	Yes

(*) you can only write the map and reduce parts as executable scripts.

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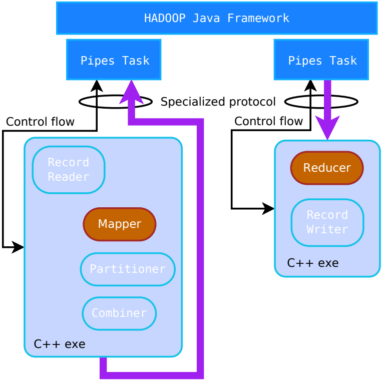
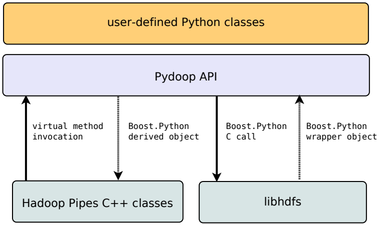
Hadoop Pipes



- Communication with Java framework via persistent sockets
- The C++ app provides a factory used by the framework to create MR components
- Providing Mapper and Reducer is mandatory

Integration of Pydoop with C++


user-defined Python classes
Pydoop API
virtual method invocation
Boost.Python derived object
Boost.Python C call
Boost.Python wrapper object
Hadoop Pipes C++ classes
libhdfs

- Integration with Pipes:
    - Method calls flow from the framework through the C++ and the Pydoop API, ultimately reaching user-defined methods
    - Results are wrapped by Boost and returned to the framework
- Integration with HDFS:
    - Function calls initiated by Pydoop
    - Results wrapped and returned as Python objects to the app

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HDFS: Command Line Examples

```
>>> import os
>>> from pydoop.hdfs import hdfs
>>> fs = hdfs("localhost", 9000)
>>> fs.open_file("f",os.O_WRONLY).write(open("f").read())
```

```
>>> from pydoop.hdfs import hdfs
>>> for f in fs.list_directory("temp"):
...     print f["name"].rsplit("/",1)[-1],
...     if f["kind"] == "file":
...             print f["size"]
...     else:
...             print "(%d)" % len(fs.list_directory(f["name"]))
...
dir (0)
file1 512000
file2 614400
file3 455680
```

HDFS: Usage by Block Size

```python
from pydoop.hdfs import hdfs

def treewalker(fs, root_info):
  yield root_info
  if root_info["kind"] == "directory":
    for info in fs.list_directory(root_info["name"]):
      for item in treewalker(fs, info): yield item

def usage_by_bs(fs, root):
  stats = {}
  root_info = fs.get_path_info(root)
  for info in treewalker(fs, root_info):
    if info["kind"] == "directory": continue
    bs = int(info["block_size"])
    size = int(info["size"])
    stats[bs] = stats.get(bs, 0) + size
  return stats

def main(argv):
  fs = hdfs("localhost", 9000)
  root = fs.working_directory()
  for k, v in usage_by_bs(fs, root).iteritems():
    print "%.1f %d" % (k/float(2**20), v)
  fs.close()
```

Minimal Python WordCount

```python
from pydoop.pipes import Mapper, Reducer, Factory, runTask

class WordCountMapper(Mapper):

  def map(self, context):
    words = context.getInputValue().split()
    for w in words:
      context.emit(w, "1")

class WordCountReducer(Reducer):

  def reduce(self, context):
    s = 0
    while context.nextValue():
      s += int(context.getInputValue())
    context.emit(context.getInputKey(), str(s))

runTask(Factory(WordCountMapper, WordCountReducer))
```

- All communication happens through the context
  - Mapper/Reducer: get/emit key/value pairs
  - All components: get jobconf, update status and counters

Python WordCount: Counter and Status Updates

```
class WordCountMapper(Mapper):

  def __init__(self, context):
    super(WordCountMapper, self).__init__(context)
    context.setStatus("initializing")
    self.inputWords = context.getCounter(WC, INPUT_WORDS)

  def map(self, context):
    words = context.getInputValue().split()
    for w in words:
      context.emit(w, "1")
    context.incrementCounter(self.inputWords, len(words))

class WordCountReducer(Reducer):

  def __init__(self, context):
    super(WordCountReducer, self).__init__(context)
    self.outputWords = context.getCounter(WC, OUTPUT_WORDS)

  def reduce(self, context):
    s = 0
    while context.nextValue():
      s += int(context.getInputValue())
    context.emit(context.getInputKey(), str(s))
    context.incrementCounter(self.outputWords, 1)
```

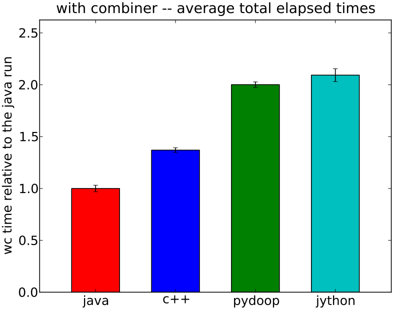
Python WordCount: RecordReader

```
class WordCountReader(RecordReader):

  def __init__(self, context):
    super(WordCountReader, self).__init__()
    self.isplit = InputSplit(context.getInputSplit())
    self.host, self.port, self.fpath = split_hdfs_path(self.isplit.filename)
    self.fs = hdfs(self.host, self.port)
    self.file = self.fs.open_file(self.fpath, os.O_RDONLY)
    self.file.seek(self.isplit.offset)
    self.bytes_read = 0
    if self.isplit.offset > 0:
      discarded = self.file.readline()  # read by previous reader
      self.bytes_read += len(discarded)

  def next(self):  # @return: (got_record, key, value)
    if self.bytes_read > self.isplit.length: return (False, "", "")
    key = struct.pack(">q", self.isplit.offset+self.bytes_read)
    record = self.file.readline()
    if record == "": return (False, "", "")
    self.bytes_read += len(record)
    return (True, key, record)

  def getProgress(self):
    return min(float(self.bytes_read)/self.isplit.length, 1.0)
```

Python WordCount: RecordWriter, Partitioner

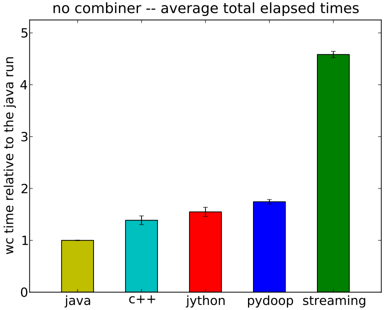
```
class WordCountWriter(RecordWriter):

  def __init__(self, context):
    super(WordCountWriter, self).__init__(context)
    jc = context.getJobConf()
    jc_configure_int(self, jc, "mapred.task.partition", "part")
    jc_configure(self, jc, "mapred.work.output.dir", "outdir")
    jc_configure(self, jc, "mapred.textoutputformat.separator",
                 "sep", "\t")
    outfn = "%s/part-%05d" % (self.outdir, self.part)
    host, port, fpath = split_hdfs_path(outfn)
    self.fs = hdfs(host, port)
    self.file = self.fs.open_file(fpath, os.O_WRONLY)

  def emit(self, key, value):
    self.file.write("%s%s%s\n" % (key, self.sep, value))

class WordCountPartitioner(Partitioner):

  def partition(self, key, numOfReduces):
    reducer_id = (hash(key) & sys.maxint) % numOfReduces
    return reducer_id
```

Comparison: slower than Java/C++, as expected



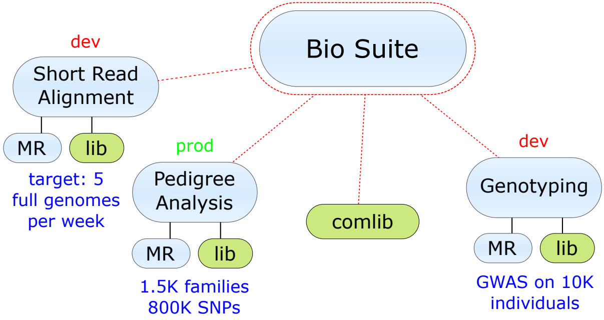
- Cluster: 48 nodes with 2 dual core 1.8 GHz Opterons, 4 GB RAM
- App: WordCount on 20 GB of random English text
  - Dataset: uniform sampling from a spell checker list
  - Each run: 192 mappers, 90 reducers; 5 iterations
  - Combiner = Reducer

Comparison: much better than Streaming



- Cluster: 48 nodes with 2 dual core 1.8 GHz Opterons, 4 GB RAM
- App: WordCount on 20 GB of random English text
  - Dataset: uniform sampling from a spell checker list
  - Each run: 192 mappers, 90 reducers; 5 iterations
  - No Combiner

Pydoop Usage at CRS4



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Conclusions

- Pydoop vs Jython:
    - Pydoop is CPython
    - No significant performance difference
- Pydoop vs Streaming:
    - Java-like API
    - Access to most MR components
    - Process any data type
    - HDFS access
    - Better performance

Current/future Work

- Pydoop is under active development
    - Continuous improvements are made, often arising from production application needs
- We are planning to add a more “pythonic” interface
    - Property access for keys/values
    - Python-style iterators

```
class WordCountReducer(Reducer):

  def reduce(self, context):
    context.emit(context.input_key, str(sum(context.itervalues())))
```

Thank you for your time!

http://pydoop.sourceforge.net