

How to Implement MapReduce Using **Gearman**

*Presented By
Jamie Pitts*

A Problem Seeking A Solution

Given a corpus of html-stripped financial filings:
Identify and count unique subjects.

Possible Solutions:

1. Use the unix toolbox.
2. Create a set of unwieldy perl scripts.
3. Solve it with MapReduce, perl, and Gearman!

What is MapReduce?

A programming model for processing
and generating large datasets.

The original 2004 paper by Dean and Ghemawat

MapReduce: Simplified Data Processing on Large Clusters

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Abstract

MapReduce is a programming model and an associated implementation for processing and generating large data sets. Users specify a *map* function that processes a key/value pair to generate a set of intermediate key/value pairs, and a *reduce* function that merges all intermediate values associated with the same intermediate key. Many real world tasks are expressible in this model, as shown in the paper.

Programs written in this functional style are automatically parallelized and executed on a large cluster of commodity machines. The run-time system takes care of the details of partitioning the input data, scheduling the program's execution across a set of machines, handling machine failures, and managing the required inter-machine communication. This allows programmers without any experience with parallel and distributed systems to eas-

given day, etc. Most such computations are conceptually straightforward. However, the input data is usually large and the computations have to be distributed across hundreds or thousands of machines in order to finish in a reasonable amount of time. The issues of how to parallelize the computation, distribute the data, and handle failures conspire to obscure the original simple computation with large amounts of complex code to deal with these issues.

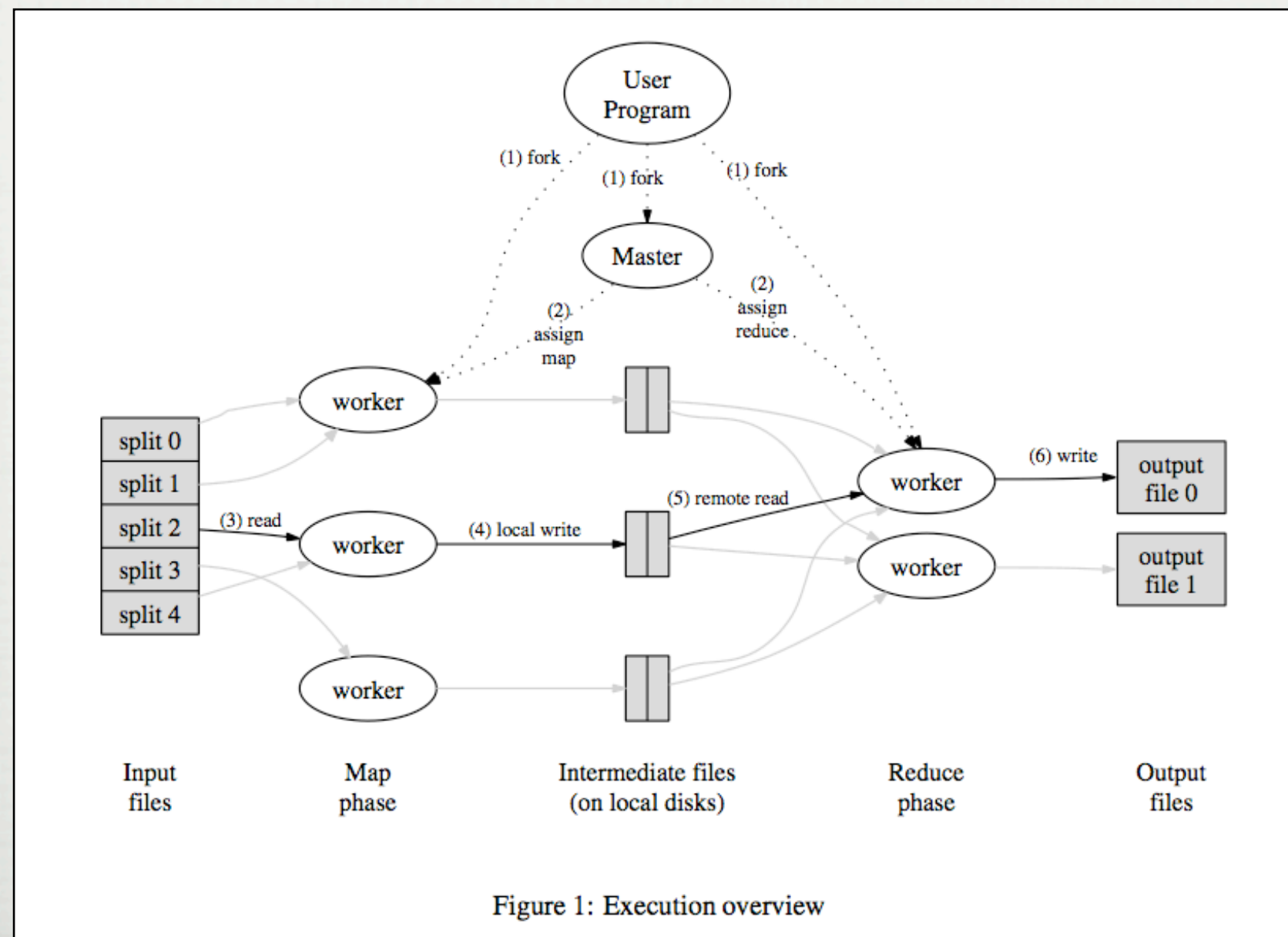
As a reaction to this complexity, we designed a new abstraction that allows us to express the simple computations we were trying to perform but hides the messy details of parallelization, fault-tolerance, data distribution and load balancing in a library. Our abstraction is inspired by the *map* and *reduce* primitives present in Lisp and many other functional languages. We realized that most of our computations involved applying a *map* operation to each logical "record" in our input in order to

M.R. Execution Model

A large set of Input key/value pairs is reduced into a smaller set of Output key/value pairs

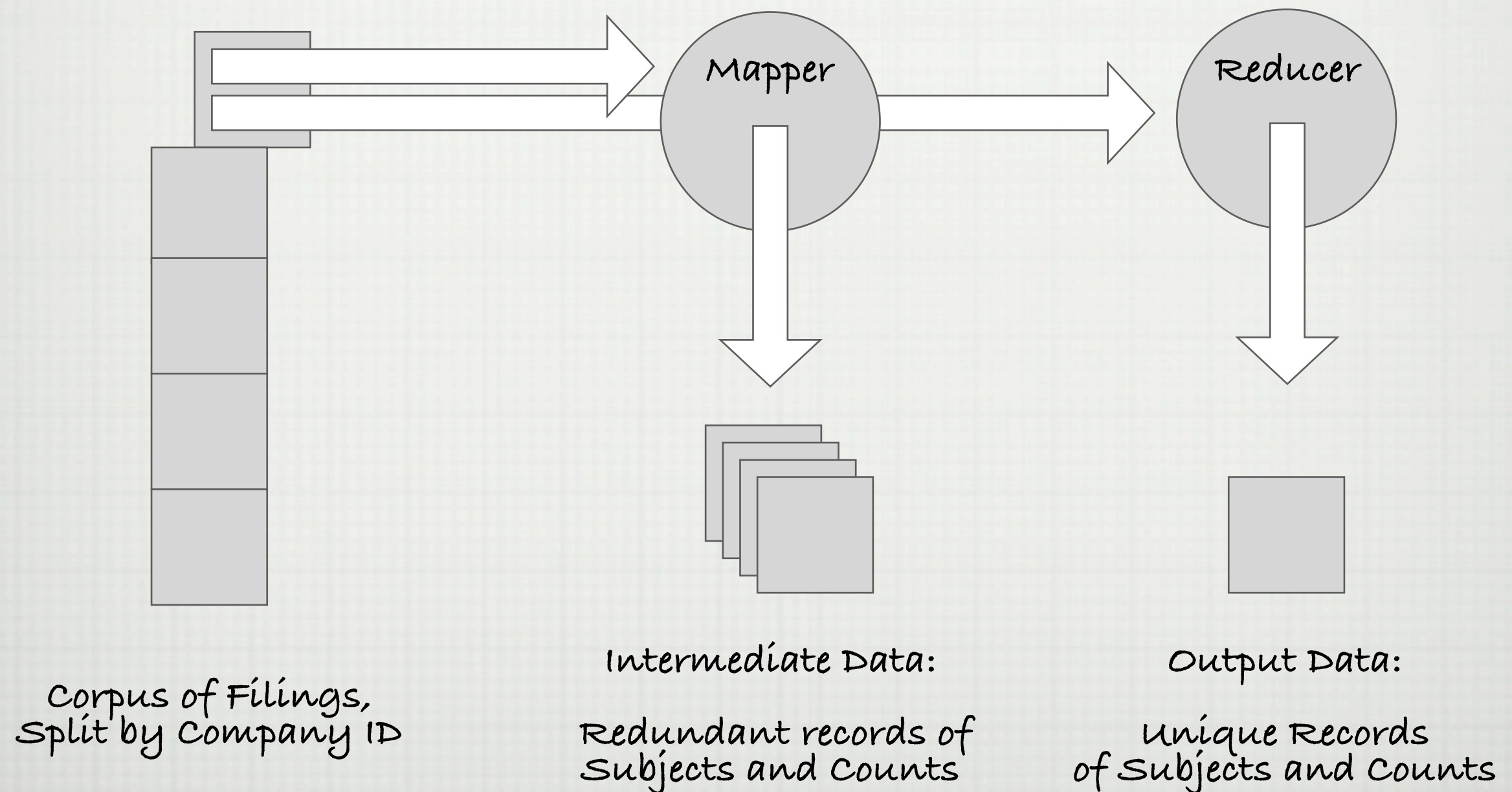
1. A Master process splits a corpus of documents into sets. Each is assigned to a separate Mapper worker.
2. A Mapper worker iterates over the contents of the split. A Map function processes each. Keys are extracted and key/value pairs are stored as intermediate data.
3. When the mapping for a split is complete, the Master process assigns a Reducer worker to process the intermediate data for that split.
4. A Reducer worker iterates over the intermediate data. A Reduce function accepts a key and a set of values and returns a value. Unique key/value pairs are stored as output data.

M.R. Execution Model Diagram



Applying MapReduce

Counting Unique Subjects in a Corpus of Financial Filings



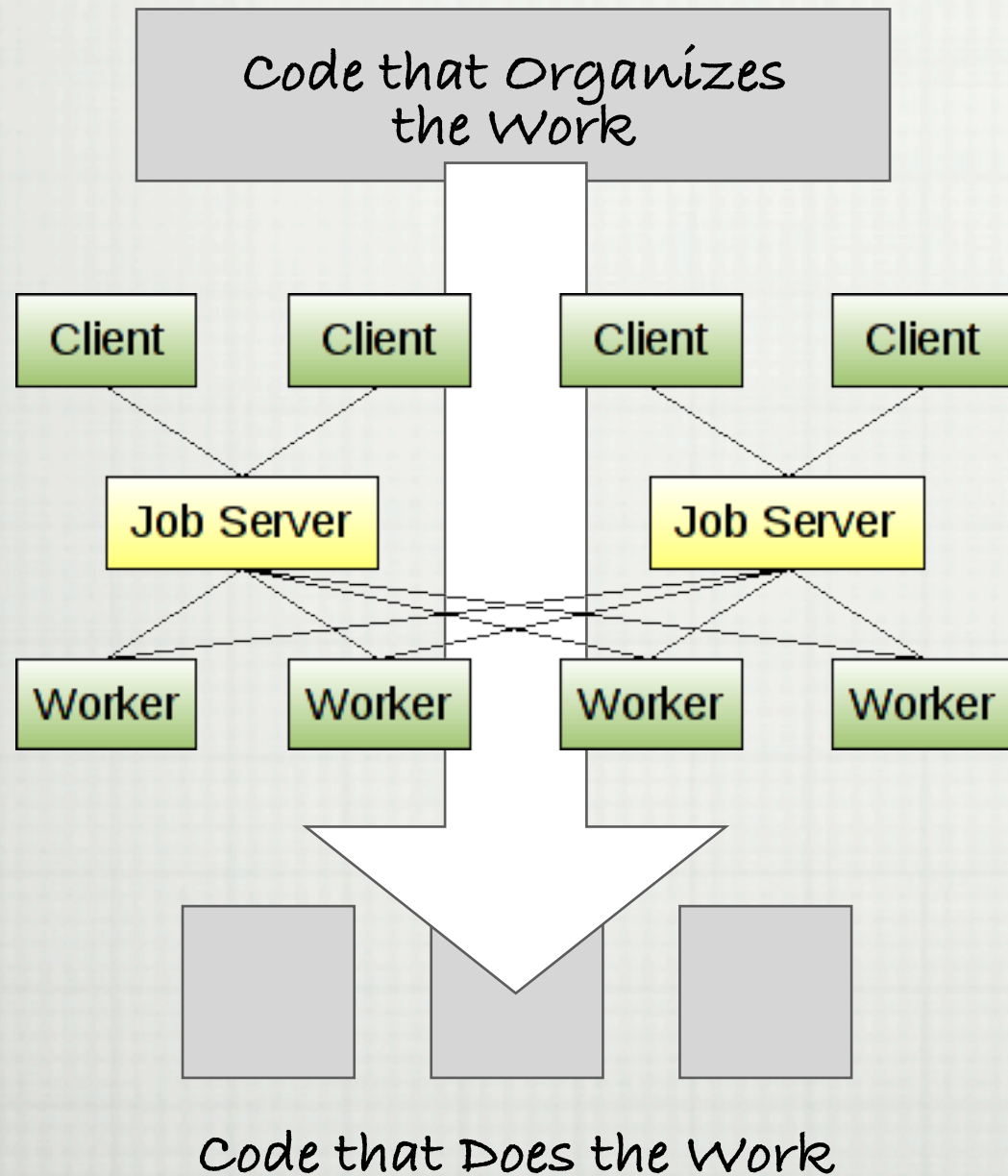
What is Gearman?

A protocol and server for distributing work across multiple servers.

- ☐ Job Server implemented in pure perl and in C
- ☐ Client and Workers can be implemented in any language
- ☐ Not tied to any particular processing model
- ☐ No single point of failure

Current Maintainers: Brian Aker and Eric Day


Gearman Architecture



- ☐ Job Server is the intermediary between Clients and Workers
- ☐ Clients organize the work
- ☐ Workers define and register work functions with Job Servers.
- ☐ Servers are aware of all available Workers.
- ☐ Clients and Workers are aware of all available Servers.
- ☐ Multiple Servers can be run on one machine.

Perl and Gearman

Use Gearman::XS to Create a Pipeline Process



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Modules

Gearman::XS	Perl front end for the Gearman C library.	0.11
Gearman::XS::Client	Perl client for gearman using libgearman	0.11
Gearman::XS::Job	Perl job for gearman using libgearman	0.11
Gearman::XS::Task	Perl task for gearman using libgearman	0.11
Gearman::XS::Worker	Perl worker for gearman using libgearman	0.11

<http://search.cpan.org/~dschoen/Gearman-XS/>

Perl and Gearman

Client-Server-Worker Architecture

Gearman Job Servers

```
bash-3.2$ ./sbin/gearmand -v --port=4730 --log-file=logs/4730.log &  
[1] 81764  
bash-3.2$ ./sbin/gearmand -v --port=4731 --log-file=logs/4731.log &  
[2] 81765
```

Each computer has two Gearman Job Servers running:
one each for handling mapping and reducing jobs to available workers.

Gearman::XS::Client

Split > Do Mapping > Do Reducing

The Master uses Gearman clients to
control the MapReduce pipeline.

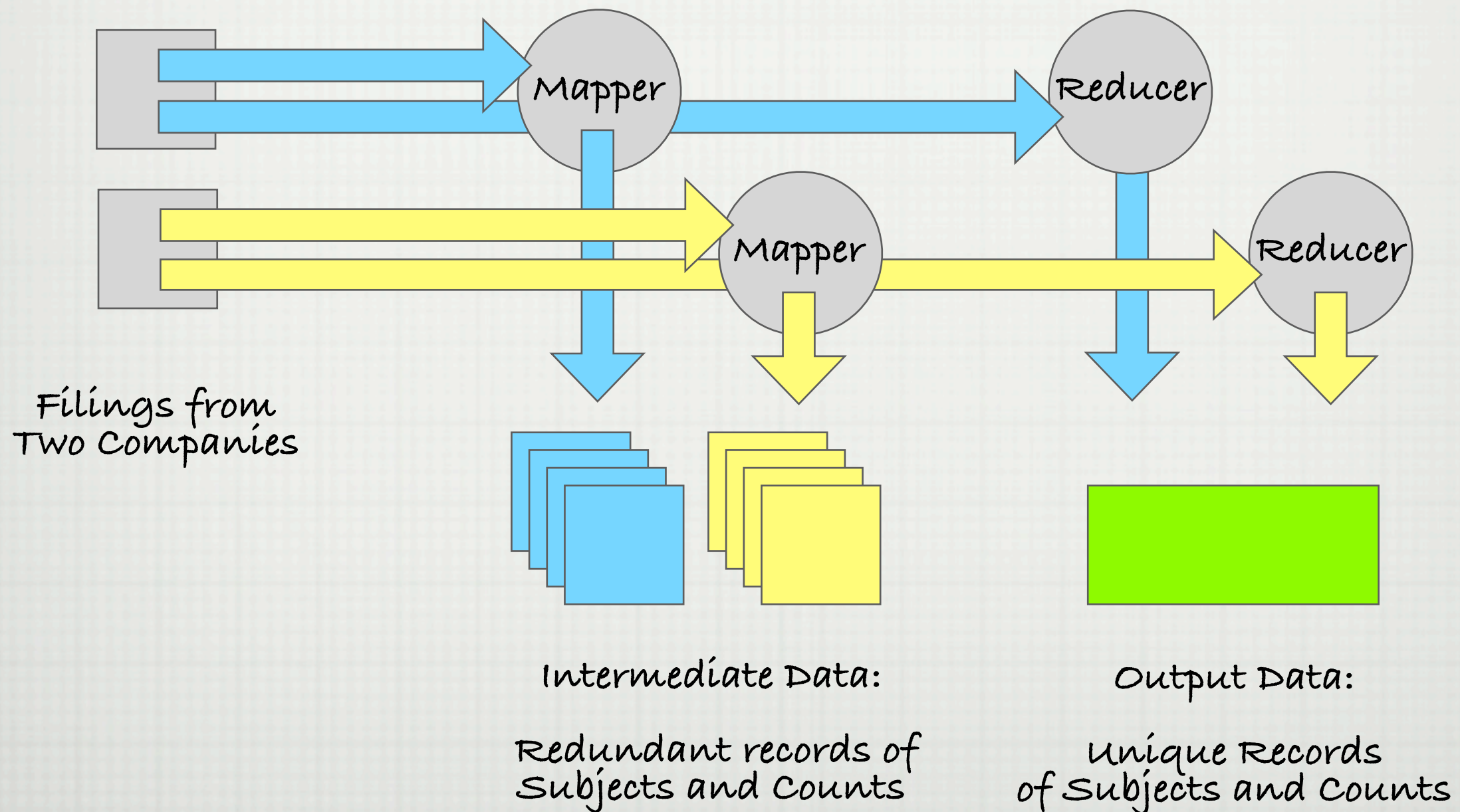
Gearman::XS::Worker



Mapper and Reducer workers are
perl processes, ready to accept jobs.

Example

Processing Filings from Two Companies



Example: The Master Process

Setting Up the Mapper and Reducer Gearman Clients

```
use Gearman::XS qw(:constants);
use Gearman::XS::Client;
use FreezeThaw qw(freeze thaw cmpStr safeFreeze cmpStrHard);

# set up the mapper
my $mapper = new Gearman::XS::Client;
if ($mapper->add_server('localhost', 4730) != GEARMAN_SUCCESS) {
    printf(STDERR "%s\n", $mapper->error());
    exit(1);
}

# set up the reducer, generate a sortable unique id
my $reducer = new Gearman::XS::Client;
if ($reducer->add_server('localhost', 4731) != GEARMAN_SUCCESS) {
    printf(STDERR "%s\n", $reducer->error());
    exit(1);
}
my $reducer_id = time . '_' . join "", map { ("a".."z", 0..9)[rand 36] } (1..4);
```

- ☐ Connect the mapper client to the gearman server listening on 4730. More than one can be defined here.
- ☐ Connect the reducer client to the gearman server listening on 4731. More than one can be defined here.
- ☐ A unique reducer id is generated for each reducer client. This is used to identify the output.

Example: The Master Process

Submitting a Mapper Job For Each Split

```
# submit jobs with each split to the mappers
my ($ret, $job_handle);
my $jobs = {};
foreach my $split (@splits) {

    # submit a mapper job to be performed by gearman workers
    ($ret, $job_handle) = $mapper->do_background( 'mapper',
        freeze ({ # workload
                    'split' => int($split)
                })
    );

    # add this to the jobs to be monitored
    if ($ret == GEARMAN_SUCCESS) {
        print "> Begin mapping $split with job_handle=$job_handle.\n";
        $jobs->{$job_handle} = {
            mapper => 1, split => int($split), gearman_client => $mapper
        };
    } else {
        printf(STDERR "%s\n", $mapper->error()) and die;
    }

    # sleep for a tenth of a sec
    select(undef, undef, undef, 0.10);
}
```

- ☐ The company IDs are pushed into an array of splits. A jobs hash for both mappers and reducers is defined.
- ☐ A background mapper job for each split is submitted to gearman.
- ☐ The job handle is a unique ID generated by gearman when the job is submitted. This is used to identify the job in the jobs hash.
- ☐ The split is passed to the job as frozen workload data.

Example: The Master Process

Job Monitoring: Submitting Reducer Jobs When Mapper Jobs Are Done

```
# watch the mapper processing...
# when one is complete, submit a job to the reducers
while (1) {

    # stop if there are no more jobs
    last unless (keys %$jobs);

    # check each job, run reducer when a mapper is done
    foreach $job_handle (sort keys %$jobs) {

        # get the job status from this job's gearman client
        my ($return_val, $is_status_known, $status, $status_num, $status_denom) =
            $jobs->{$job_handle}->{gearman_client}->job_status($job_handle);

        # this job is done
        unless ($running_status) {

            # this is a complete mapper job... run its reducer
            if ($jobs->{$job_handle}->{mapper}) {
                ...
            }

            # delete the done job
            delete $jobs->{$job_handle};
        }

        # sleep for a tenth of a sec
        select(undef, undef, undef, 0.10);
    }
}
```

- ☐ Mapper and Reducer jobs are monitored inside of a loop.
- ☐ The job status is queried from the client using the job handle.
- ☐ If the job is completed and if it is a mapper job, a reducer is now run (detailed in the next slide).
- ☐ Completed jobs are deleted from the jobs hash.

Example: The Master Process

Detail on Submitting the Reducer Job

```
# this is a complete mapper job... run its reducer
if ($jobs->{$job_handle}->{mapper}) {

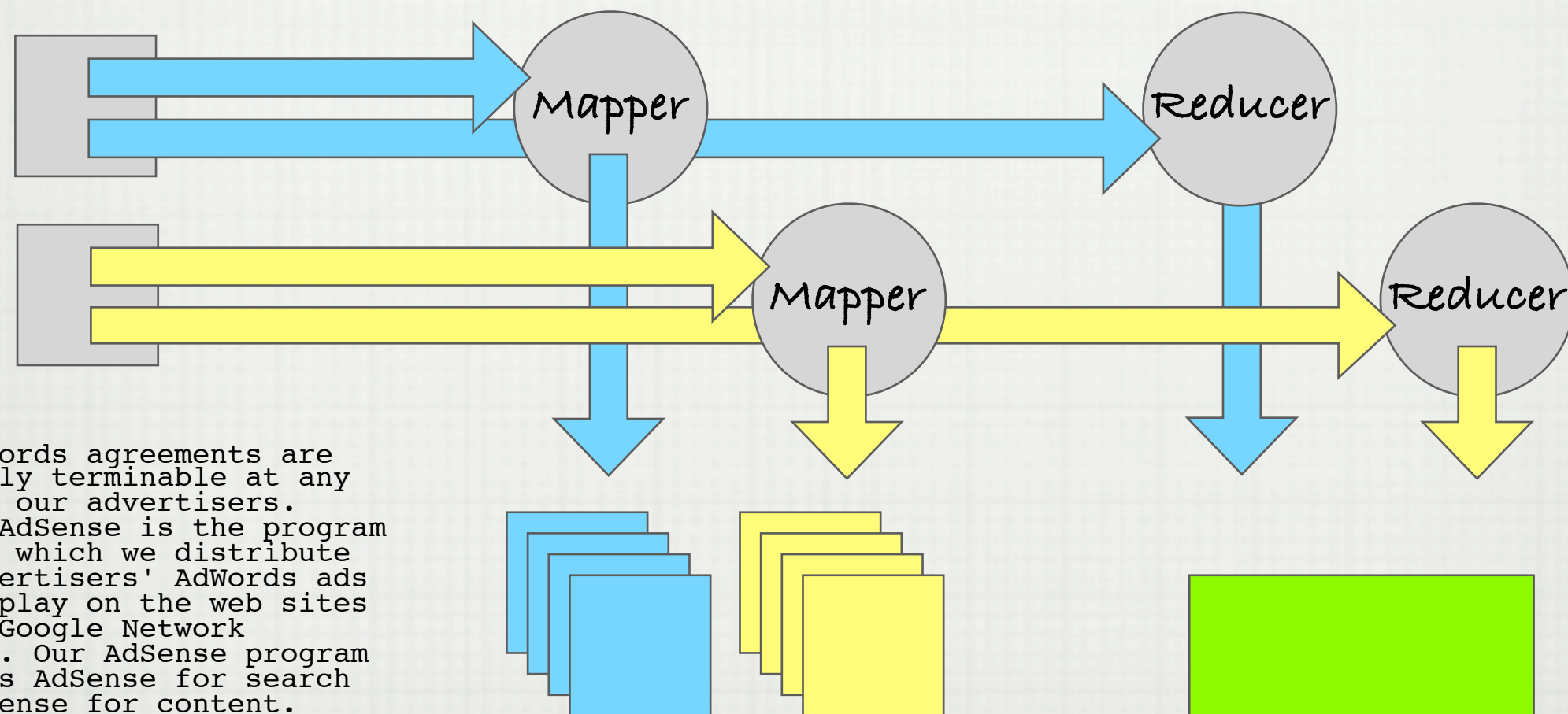
    # submit a reducer job to be performed by gearman workers
    ($ret, $re_job_handle) = $reducer->do_background( 'reducer',
        freeze ({ # workload
            'split' => int($jobs->{$job_handle}->{split}),
            'reducer_id' => $reducer_id
        })
    );

    # add this to the jobs to be monitored
    if ($ret == GEARMAN_SUCCESS) {
        $jobs->{$re_job_handle} = {
            reducer => 1,
            split => $jobs->{$job_handle}->{split},
            gearman_client => $reducer
        };
    }
}
```

- ☐ A background reducer job is submitted to gearman.
- ☐ The job handle is a unique ID generated by gearman when the job is submitted. This is used to identify the job in the jobs hash.
- ☐ The split and reducer_id is passed to the job as frozen workload data.

Example

The Result of Processing Filings from Two Companies



Our AdWords agreements are generally terminable at any time by our advertisers. Google AdSense is the program through which we distribute our advertisers' AdWords ads for display on the web sites of our Google Network members. Our AdSense program includes AdSense for search and AdSense for content. AdSense for search is our service for distributing relevant ads from our advertisers for display with search results on our Google Network members' sites.

... Filings Text ...

1 AdWords
1 Google Adsense
1 Adwords
1 Google Network
1 AdSense
1 AdSense
1 AdSense
1 Google Network

... Redundant Counts ...

1 Ad Words
14 AdMob
299 AdSense
152 AdWords

... Aggregated Counts ...

That's It For Now
To Be Continued...

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Credits

Diagrams and other content were used
from the following sources:

MapReduce: Simplified Data Processing on Large Clusters
Jeffrey Dean and Sanjay Ghemawat

Gearman (<http://gearman.org>)
Brian Aker and Eric Day