https://images.techhive.com/images/article/2016/08/thinkstockphotos-462205183-100677632-large.jpg

Lecture 1: Introduction to Spark and HPC

Haiping Lu

COM6012: Scalable ML

YouTube Playlist:
https://www.youtube.com/c/HaipingLu/

Week 1 Contents / Objectives

- The Big Data Problem: Why Spark?
- What is Spark?: The Essentials
- An Example of Spark: Log Mining
- How to Use Spark: PySpark, HPC, Resources

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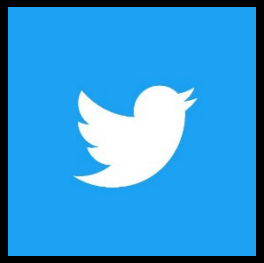
Where Does Big Data Come From?

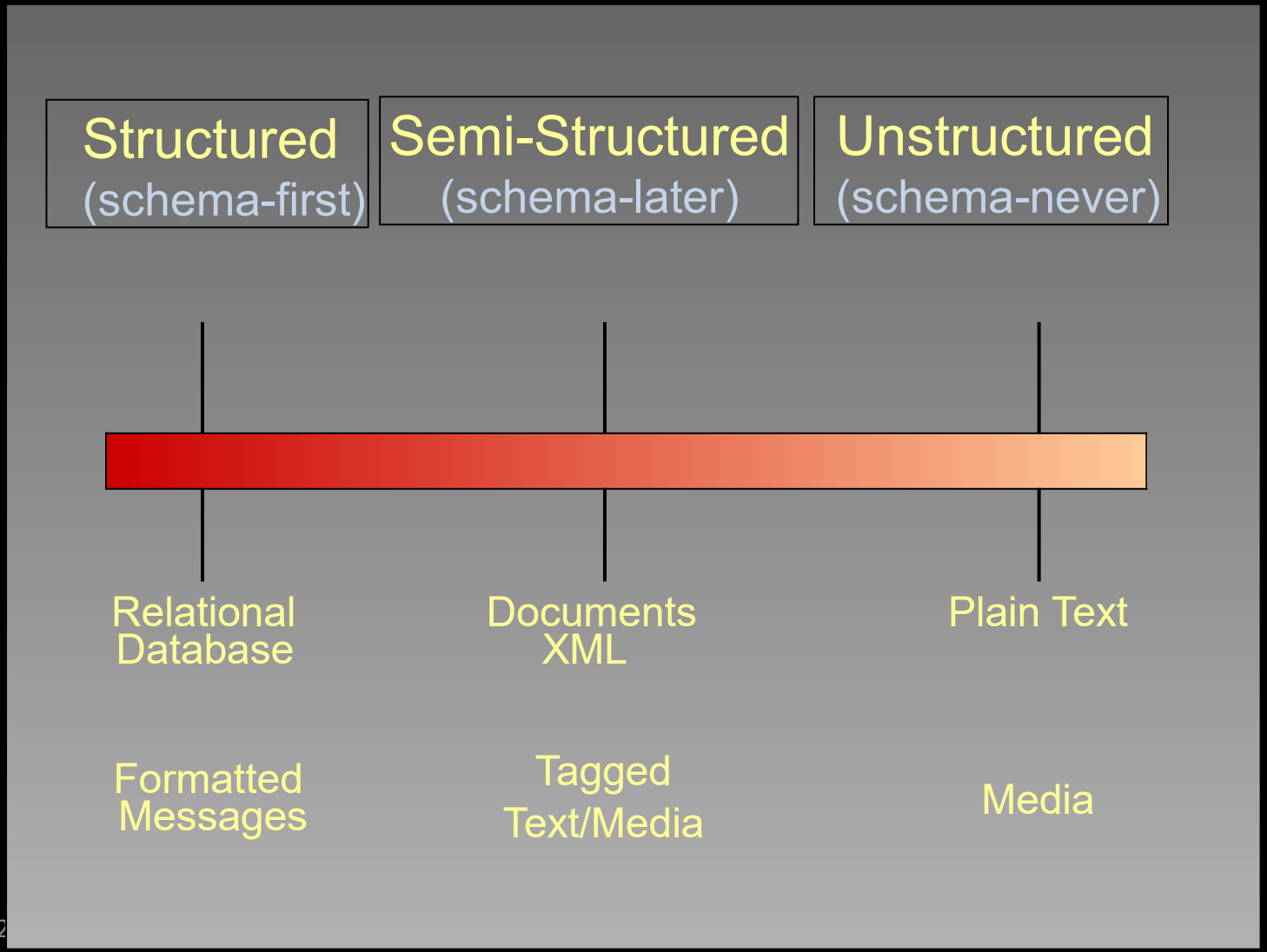
- All happening online, e.g. tracking of:
  - Clicks
  - Billing events
  - Server requests
  - Transactions
  - Network messages
  - Faults
  - …

Where Does Big Data Come From?

- User generated content: web + mobile

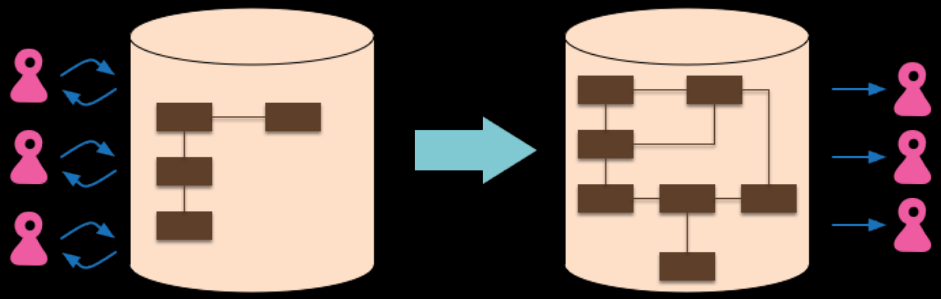


Data Structure Spectrum



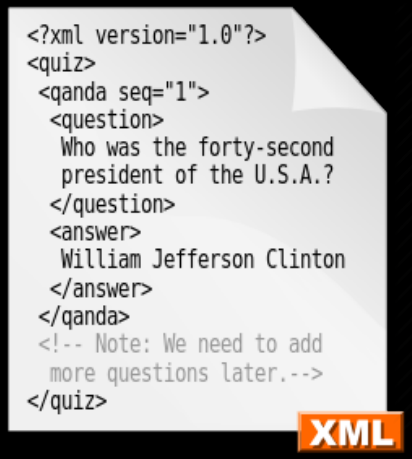
Structured Data

- Database: relational data model → how a database is structured and used (hottest job 20 years ago)
- Schema: the organisation of data as a blueprint of how the database is constructed
  - The programmer must statically specify the schema
  - Decreasing ← consumer/media app, enterprise search
- SQL: Structured Query Language



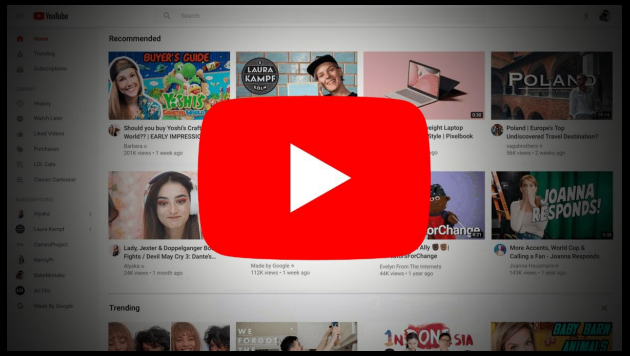
Semi-Structured Data

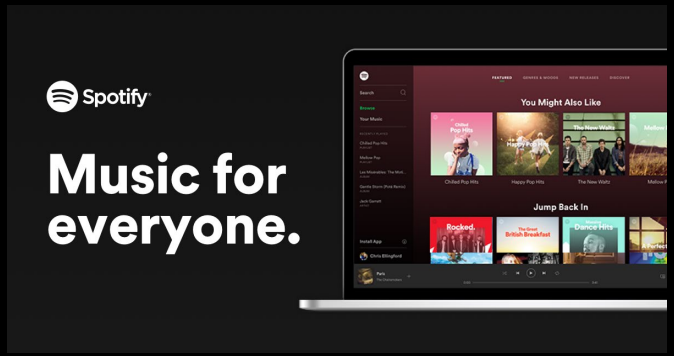
- Self-describing rather than formal structures, tags/markers to separate semantic elements
- The column types → the schema for the data
  - Spark dynamically infers the schema while reading each row
  - Programmer statically specifies the schema
- Examples:

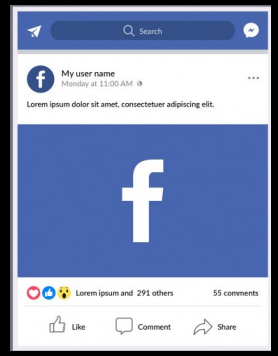


Unstructured Data

- Only one column with string or binary type
- Examples

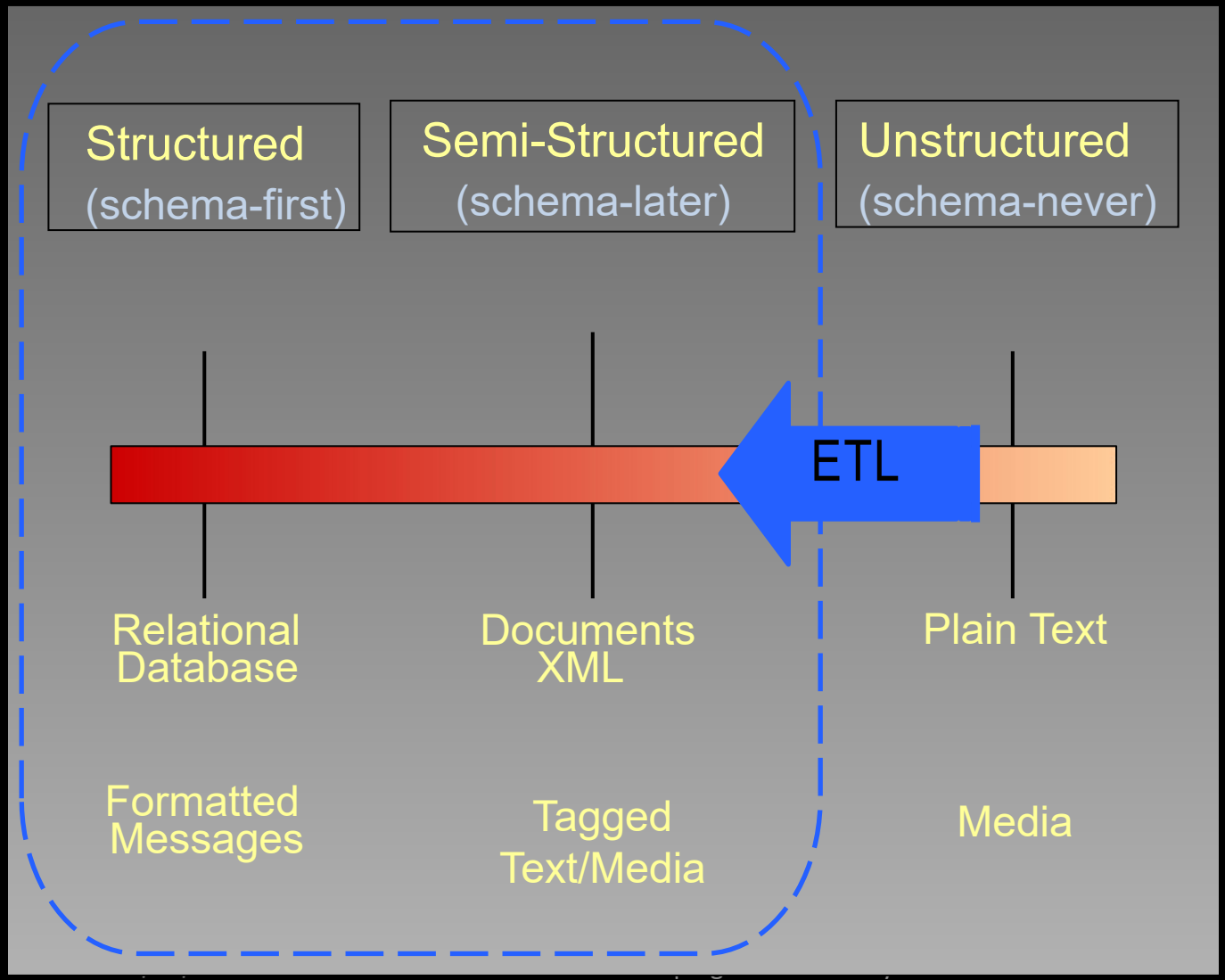






- More than 70%–80% of all data in organisations (Shilakes 1998)

Traverse the Data Structure Spectrum



- Impose structure on unstructured data
  - Extract
  - Transform
  - Load

Traditional Analysis Tools

- Unix shell commands (awk, grep, …)

```
root@nginx:~# awk ' {print $0}' file.txt
Item    Model   Country         Cost

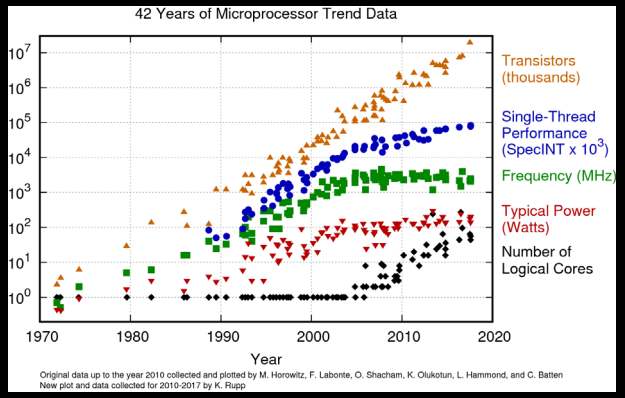
1       BMW     Germany         $25000
2       Volvo   Sweden          $15000
3       Subaru  Japan           $2500
4       Ferrari Italy           $2000000
5       SAAB    USA             $3000
```

```
vulphere@arifuretaarch:~|⇒  grep root /etc/passwd
root:x:0:0:root:/root:/bin/zsh
vulphere@arifuretaarch:~|⇒  grep -n root /etc/passwd
1:root:x:0:0:root:/root:/bin/zsh
vulphere@arifuretaarch:~|⇒  grep -c false /etc/passwd
3
vulphere@arifuretaarch:~|⇒  _
```

All run on a single machine!

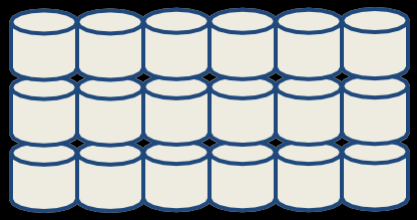
The Big Data Problem

- Data growing faster than computation speeds
- Growing data sources
  - Web, mobile, scientific, …
- Storage getting cheaper
  - Size doubling every 18 months
- But, stalling CPU speeds and storage bottlenecks

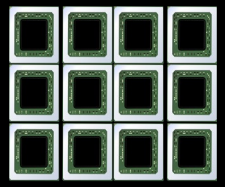


Solution for the Big Data Problem

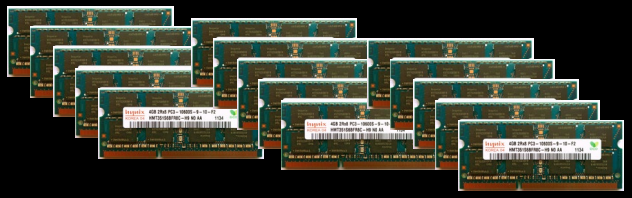
- One machine can not process or *even store* all the data!
- Solution: distribute data over a cluster of machines



Lots of hard drives



… and CPUs



… and memory!

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Apache Spark

- Fast and general cluster computing system
- Interoperable with 

- Improves efficiency through:
  - In-memory computing primitives
  - General computation graphs

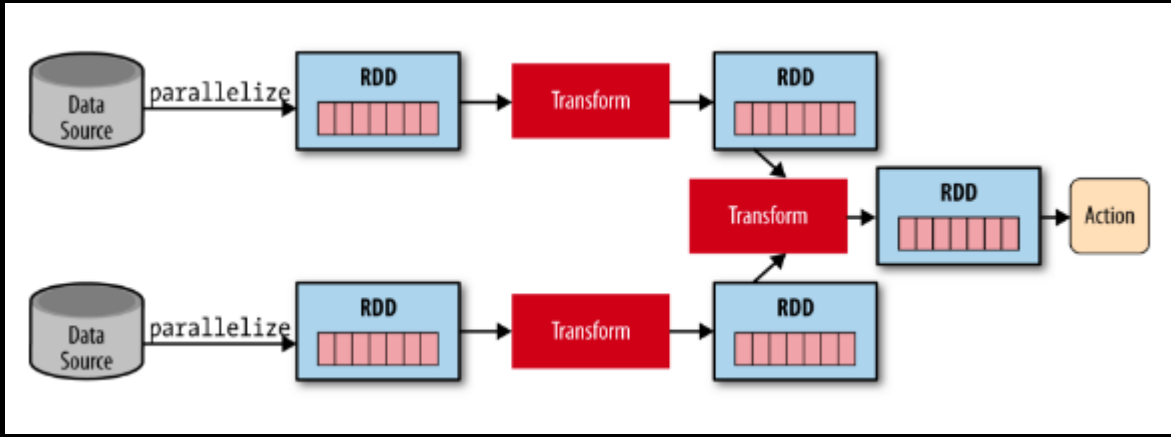
→ Up to 100× faster (2-10× on disk)

- Improves usability through:
  - Rich APIs in Scala, Java, Python
  - Interactive shell

→ 2-5× less code

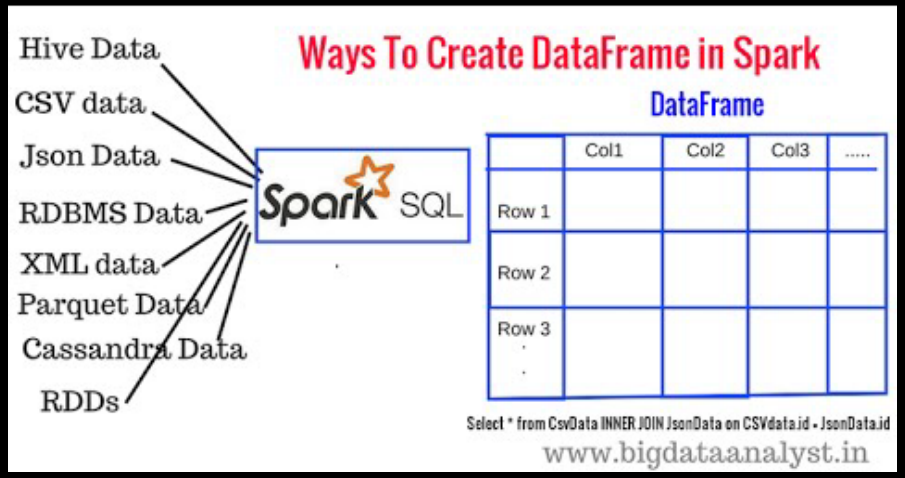
Spark Model

- Write programs in terms of transformations on distributed datasets
- Resilient Distributed Datasets (RDDs)
  - Collections of objects that can be stored in memory or disk across a cluster
  - Parallel functional transformations (map, filter, …)
  - Automatically rebuilt on failure



Spark for Data Science

- DataFrames
  - Structured data (SQL)
  - Familiar API based on R/Python Pandas
  - Distributed, optimised implementation
- Machine learning pipelines
  - Simple construction and tuning of ML workflows



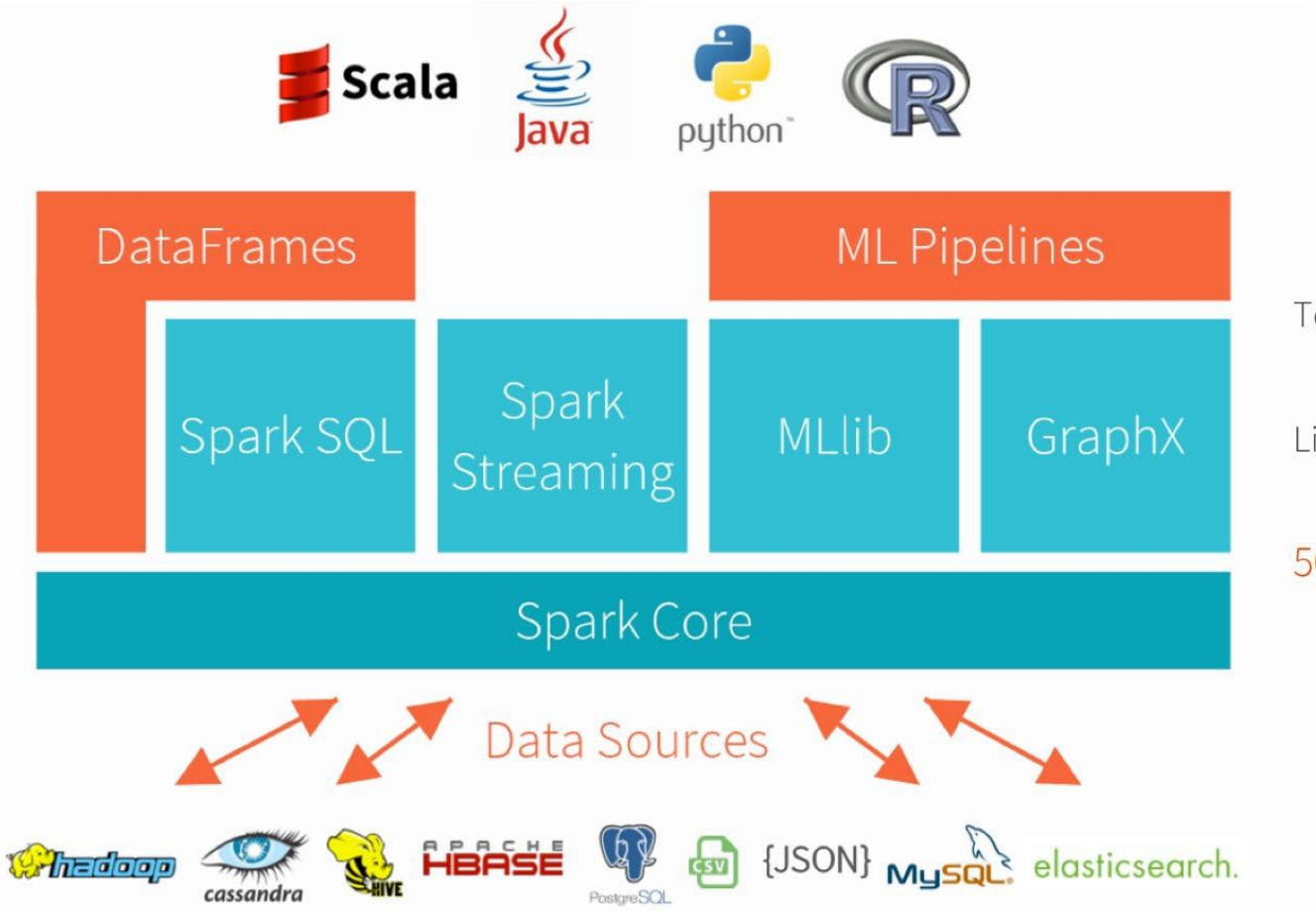
Spark Computing Framework

- Programming abstraction and parallel runtime to hide complexities of fault-tolerance and slow machines

"Here's an operation, run it on all of the data"

- I don't care where it runs (you schedule that)
- In fact, feel free to run it twice on different nodes (e.g. when it fails)

Apache Spark Ecosystem



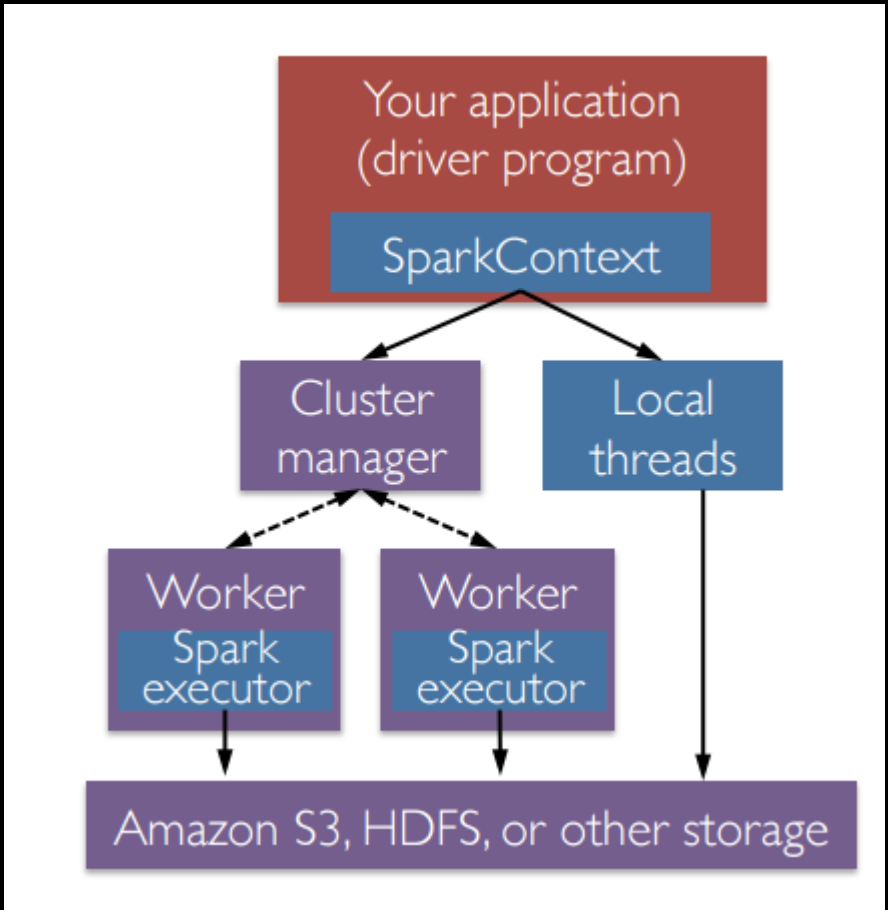
Total contributors: 150 → 500

Lines of code: 190K → 370K

500+ active production deployments

https://i.pinimg.com/originals/e7/f3/2d/e7f32d041846a5938a09e192bdf3885d.jpg

Spark Components



- A Spark program first creates a SparkSession object as the driver (including SparkContext)
  - Tells Spark how/where to access a cluster
  - Connect to cluster managers
- Cluster managers
  - Allocate resources across applications
- Spark executor (worker):
  - Run computations
  - Access data storage

SparkSession and SparkContext

- SparkSession
  - Entry point for DataFrame API, create DataFrames
  - PySpark shell automatically create SparkSession as spark
  - Programs: must create a new SparkSession first (see lab)
- SparkContext
  - Entry point for Spark functionality, create RDDs
  - Connect to a Spark cluster
  - Associated with a SparkSession
  - PySpark shell automatically create SparkContext as sc
  - Programs: sc = spark.sparkContext

The *'Master'* Parameter for a SparkSession

- Determines cluster type and size

Master Parameter	Description
`local`	run Spark locally with one worker thread (no parallelism)
`local[K]`	run Spark locally with K worker threads (ideally set to number of cores)
`spark://HOST:PORT`	connect to a Spark standalone cluster; PORT depends on config (7077 by default)
`mesos://HOST:PORT`	connect to a Mesos cluster; PORT depends on config (5050 by default)

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Spark Example: Log Mining (w/t RDD)

Load error messages from a log into memory, then interactively search for various patterns

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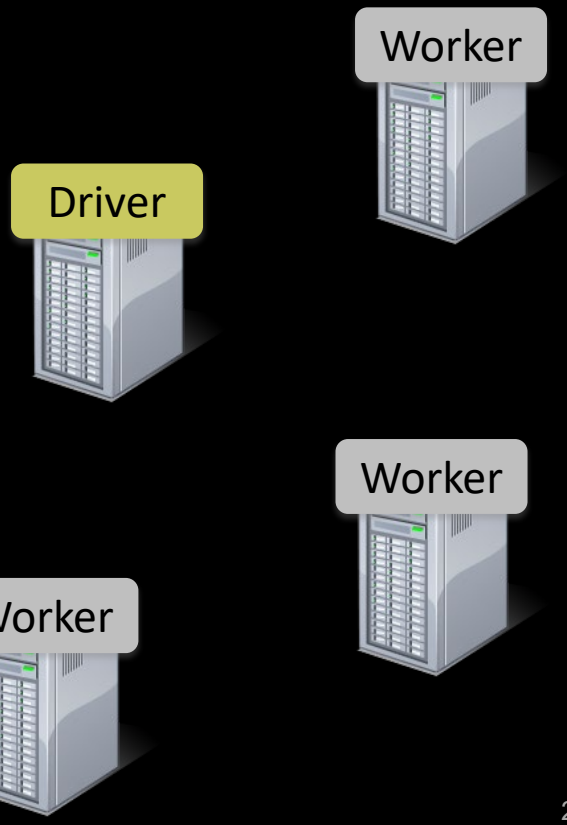

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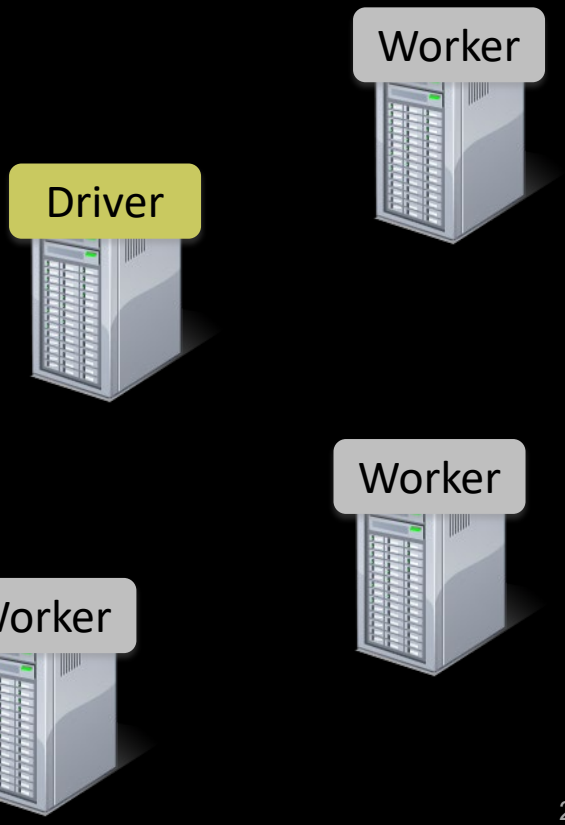

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Base RDD

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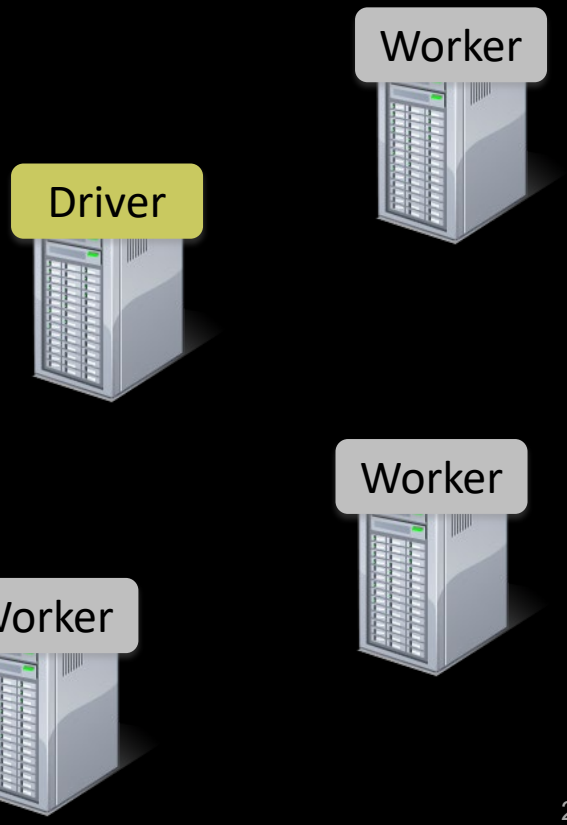

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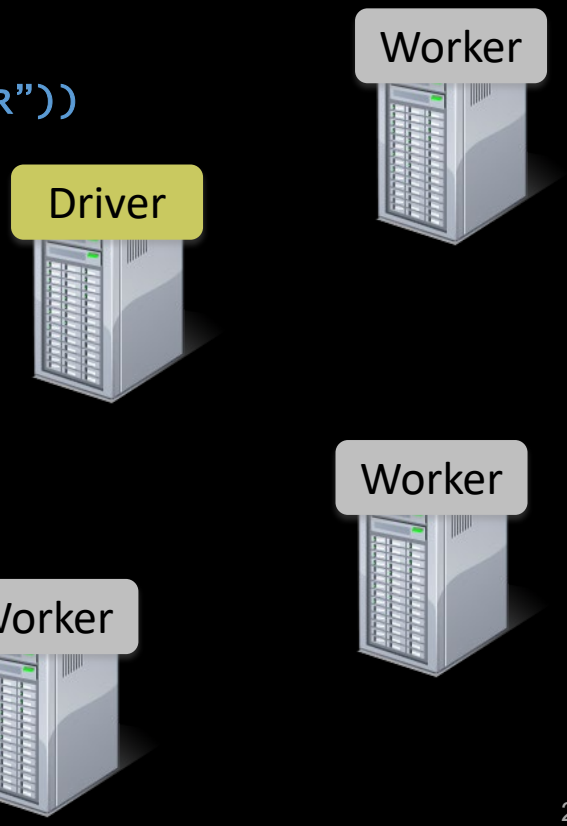

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Transformed RDD

```
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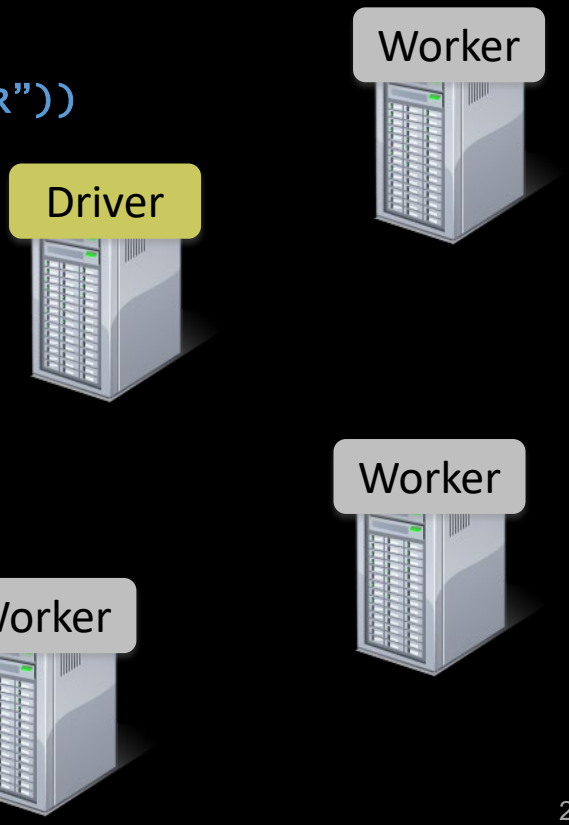
```



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messages.filter(lambda s: “mysql” in s).count()
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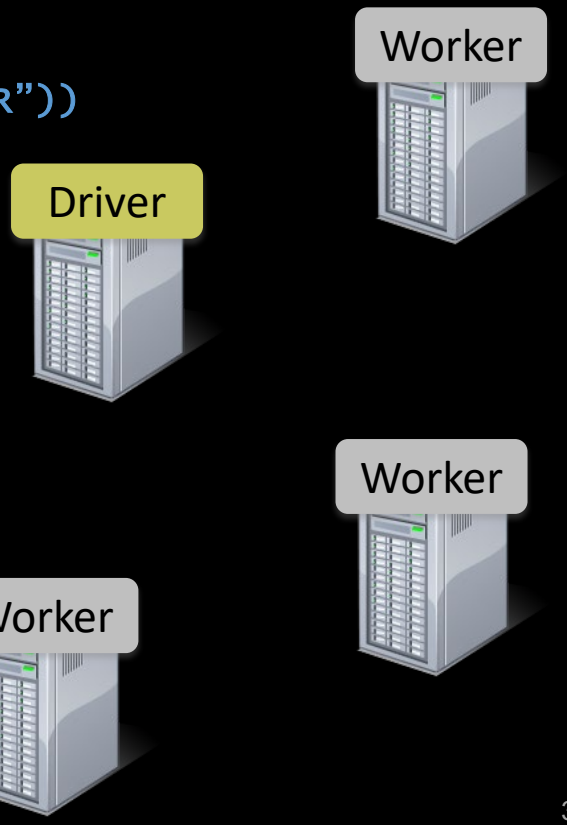

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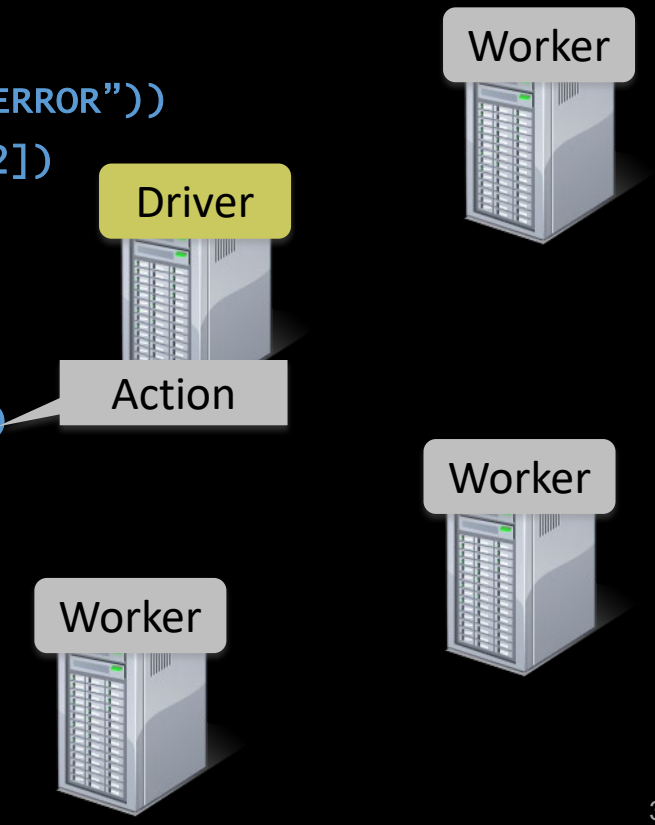

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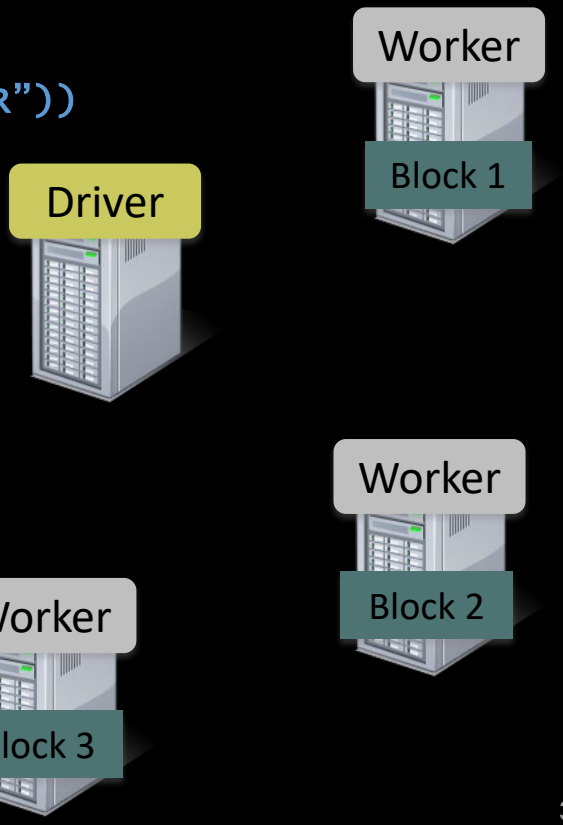

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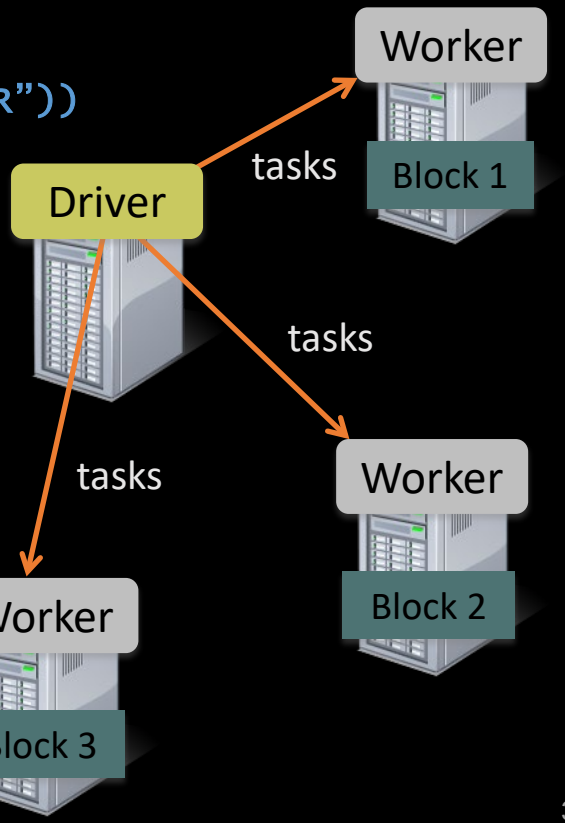

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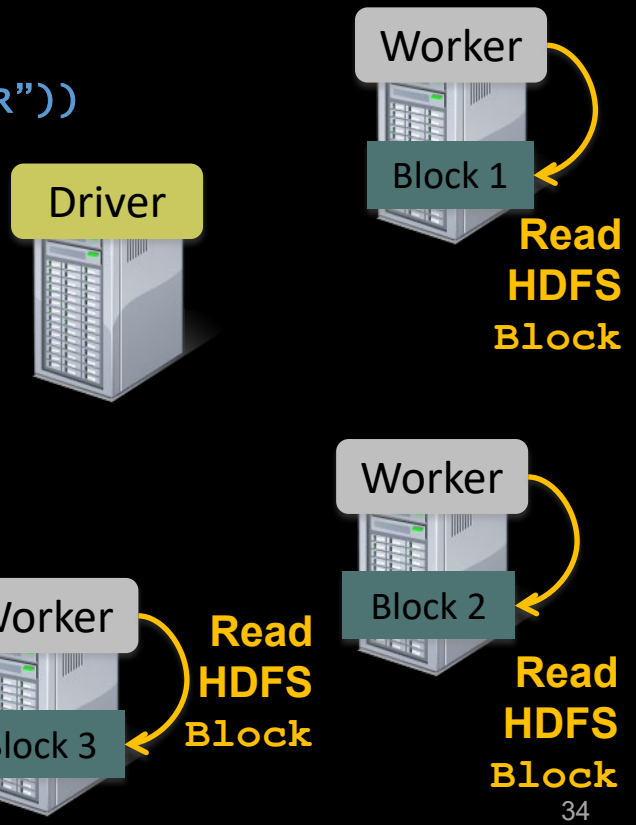

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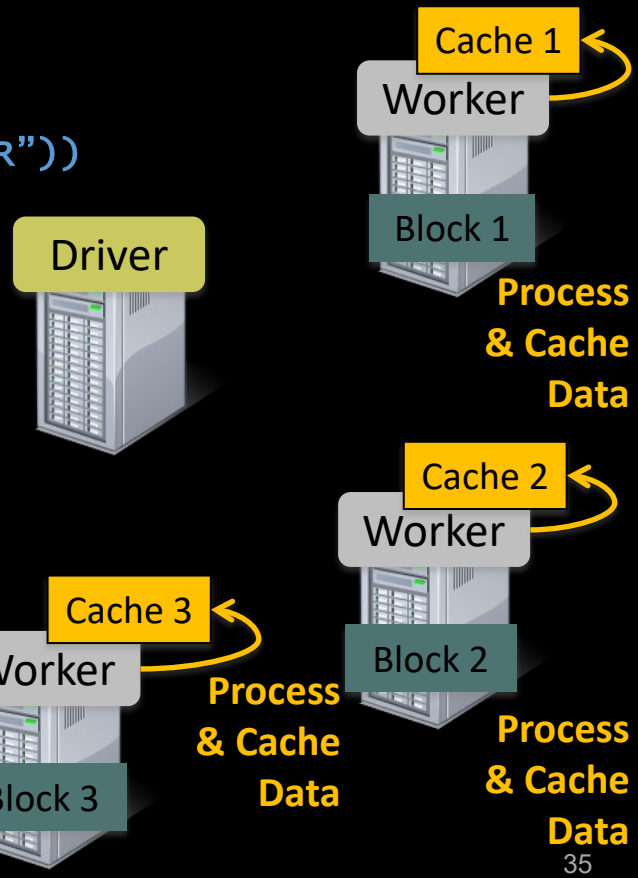

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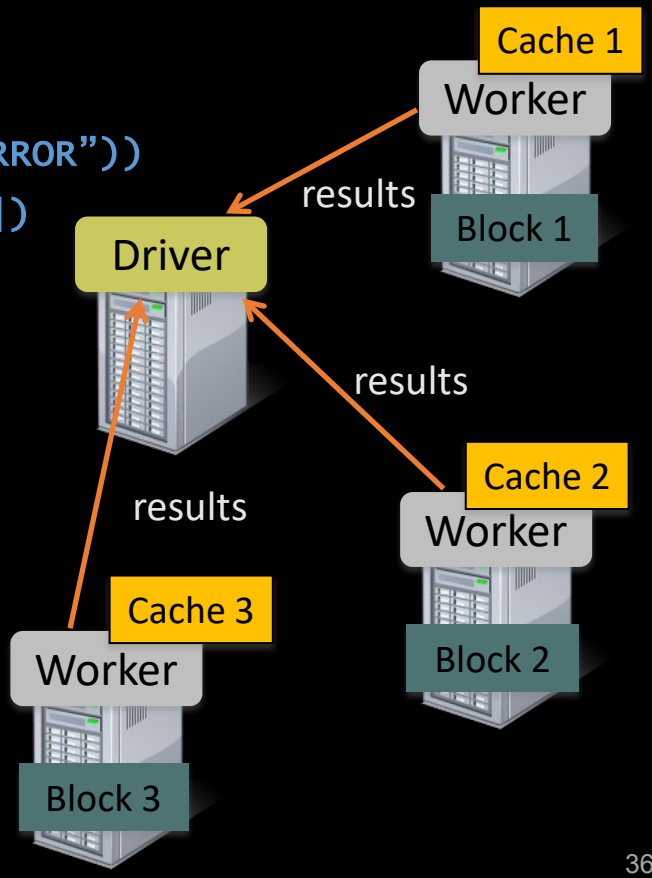

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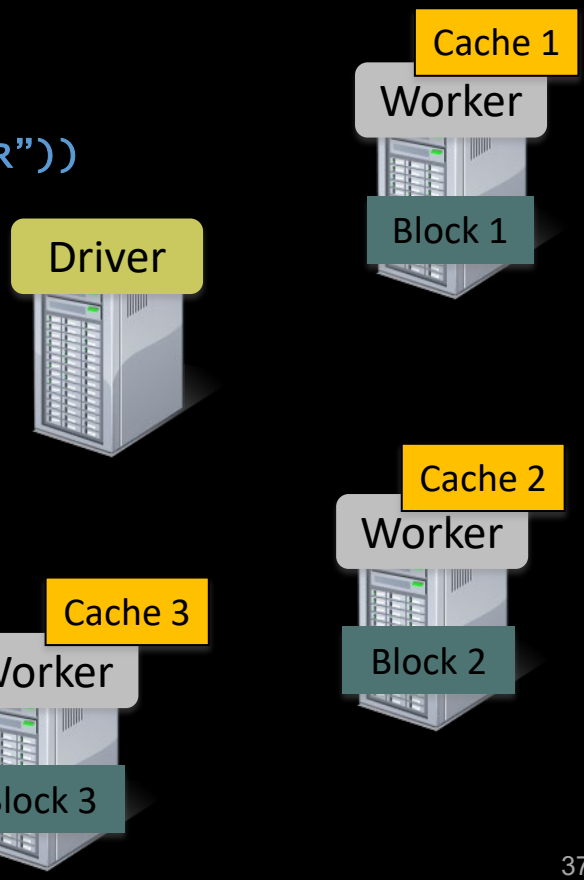

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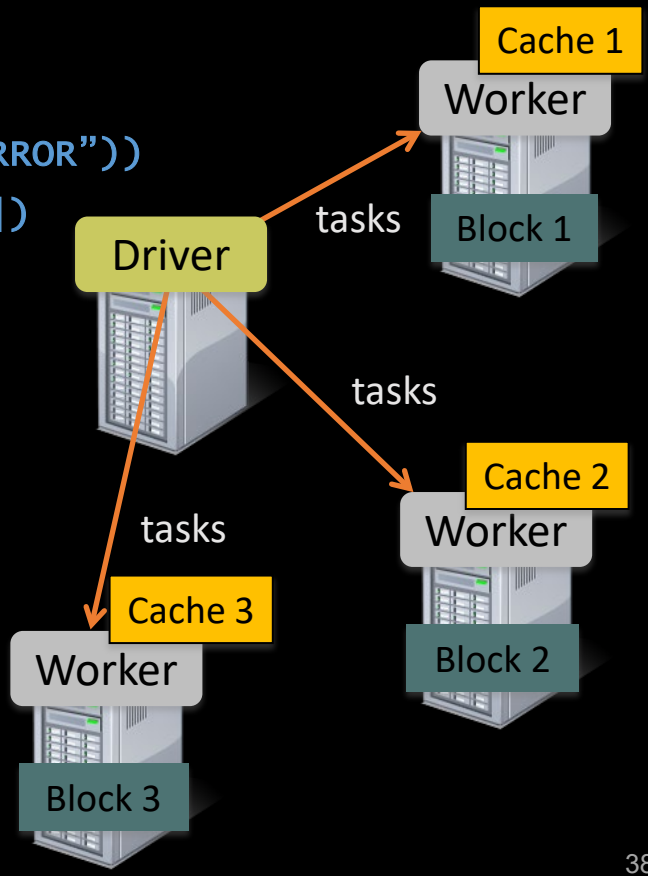

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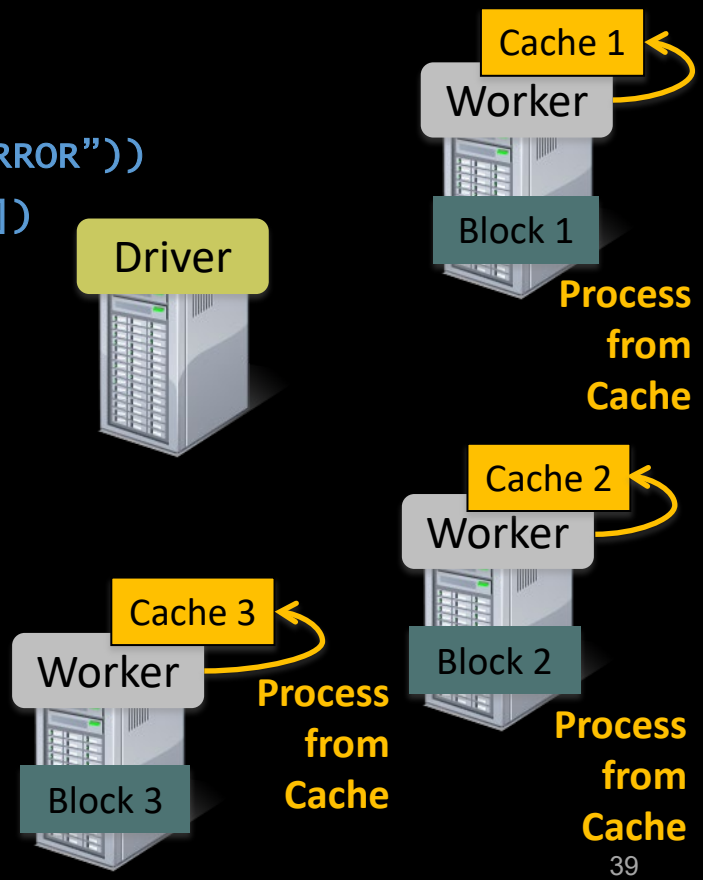

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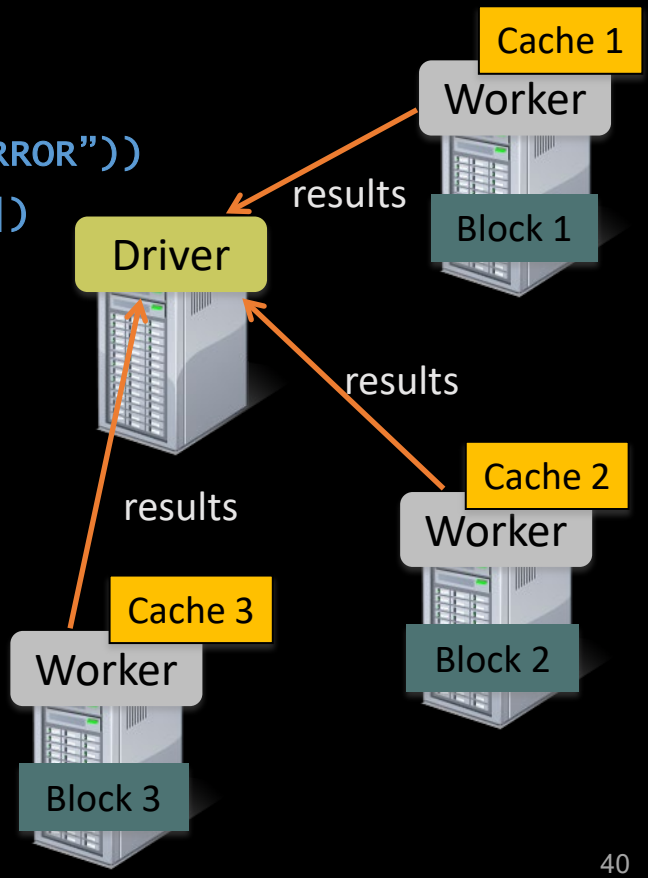

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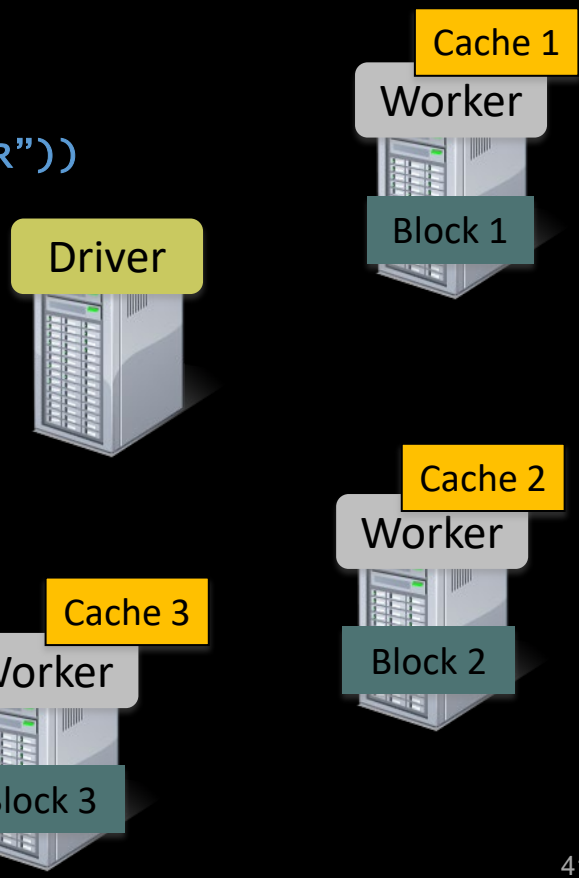
```

Cache your data ➔ Faster results

Full-text search of Wikipedia

- 60GB on 20 EC2 machines
- 0.5 sec from mem vs. 20s for on-disk



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Spark Program Lifecycle

- Create DataFrames from external data or createDataFrame from a collection in a driver program
- Lazily transform them into new DataFrames
- cache( ) some DataFrames for reuse
- Perform actions to execute parallel computation and produce results

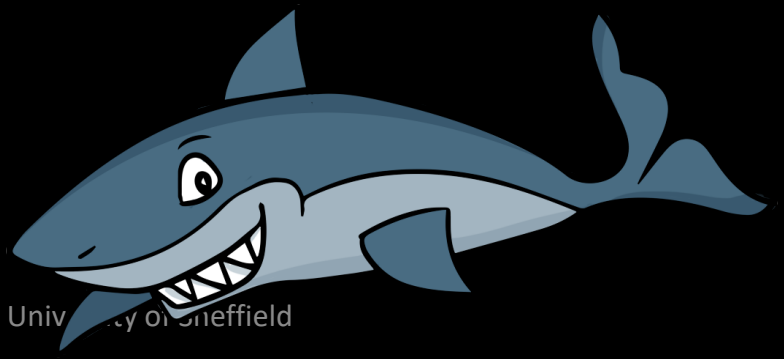
Use Spark Transformations and Actions wherever possible: Search DataFrame reference API

PySpark 3.2.1

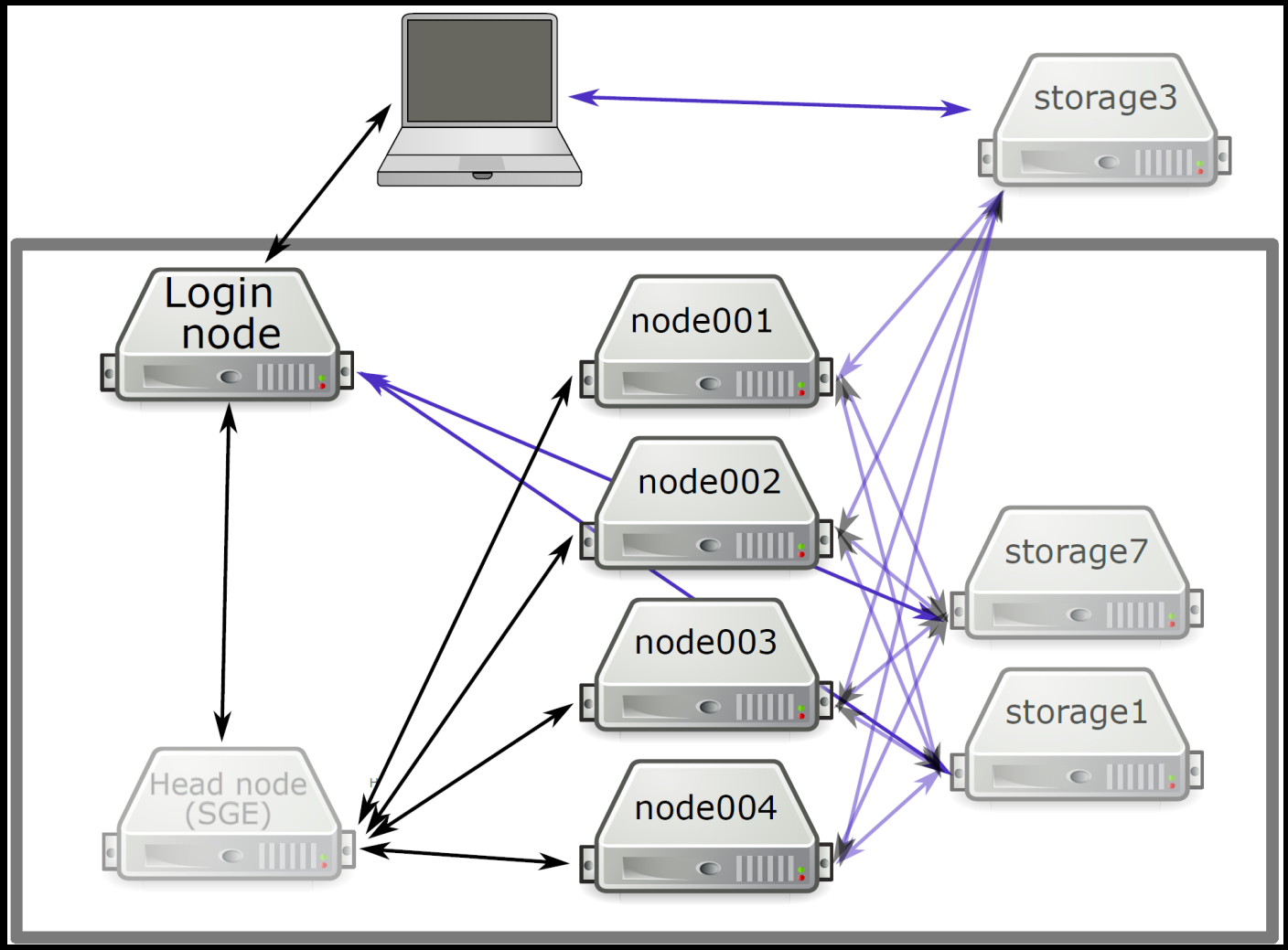
- Need: Java, Python, Spark
- See lab 1 on how to install on HPC
- To install on Windows (optional)
  - Lab 1 instructions: Install Java JRE, Python, Spark
  - Or pip install pyspark==3.2.1
- To install on Linux/Mac (optional): see lab references

ShARC HPC @ Sheffield

- ShARC: Sheffield Advanced Research Computer
- VPN: a **MUST** unless you are on a campus network
- Training: HPC Driving License test
- SSH access via sharc.sheffield.ac.uk
  - Windows: MobaXTerm
  - Linux/MAC OS: terminal (command line)
- Help: it-servicedesk@sheffield.ac.uk



HPC Cluster Structure



Storage

Location	Shared	Quota	Back ups	Speed	Suitable for?
/home/$USER	Y	10GB	Y	>	Personal data
/data/$USER	Y	100GB	Y	>	Personal data
/fastdata/$USER	Y	-	N	>>>	Temporary big files
/scratch	N	-	N	>>>	Temporary small files

Interactive Session

```
pyspark
```

```
.......
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 3.0.1
      /_/
Using Python version 3.6.2 (default, Jul 20 2017 13:51:32)
SparkSession available as 'spark'.
>>>
```

Batch Session – Shell Script xx.sh

Create a file `Lab1_SubmitBatch.sh`

```
#!/bin/bash
#$ -l h_rt=6:00:00  #time needed
#$ -pe smp 2 #number of cores
#$ -l rmem=8G #number of memery
#$ -o ../Output/COM6012_Lab1.txt  #This is where your output and errors are logged.
#$ -j y # normal and error outputs into a single file (the file above)
#$ -M youremail@shef.ac.uk #Notify you by email, remove this line if you don't like
#$ -m ea #Email you when it finished or aborted
#$ -cwd # Run job from current directory

module load apps/java/jdk1.8.0_102/binary

module load apps/python/conda

source activate myspark

spark-submit ../Code/LogMiningBig.py  # .. is a relative path, meaning one level up
```

Batch Session: Submit & Relax

- qsub your job (can run at the login node): see Lab 1
- Then?
  - Close the terminal and leave
  - Wait for pre-set email notification
  - Check status: qstat
  - Cancel/amend job: qdel
- How much resources to request
  1. Run short test jobs
  2. View resource utilisation
  3. Extrapolate
  4. Submit larger jobs

Spark Resources

- Apache Spark Documentation
- PySpark tutorial
- Spark videos on YouTube
- Open source code
- Suggested reading in labs

Suggested reading:

- Spark Overview
- Spark Quick Start (Choose **Python** rather than the default *Scala*)
- Chapters 2 to 4 of PySpark tutorial (several sections in Chapter 3 can be safely skipped)
- Reference: PySpark documentation
- Reference: PySpark source code

Acknowledgements

- Some slides (sec. 1) are modified from the "Introduction to Apache Spark" course by Prof. A. D. Joseph, University of California, Berkeley.
- This module benefits from many open resources. See the acknowledgement on our GitHub page.
- There are many other resources that I have consulted but somehow lost track of the origins.