Extreme Computing

Admin and Overview
Course Staff

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Website
http://www.inf.ed.ac.uk/teaching/courses/exc

Mailing List
exc-students at inf.ed.ac.uk is populated when you enroll.
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⇒ Check website for announcements, especially first two weeks.
Assessment

25% Assignment 1
25% Assignment 2
50% Exam in May 😊 (December 😊 for visitors)

Don’t start the assignments yet; they are being updated.
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Don’t start the assignments yet; they are being updated.

Solve the assignments on your own. Don’t share code. Exam is closed book.
Lectures  Online, subject to revision.

Labs   Practice on a cluster. Not marked.

Papers Linked from the website.

Books Don’t buy them. They’re in the library:
Data-Intensive Text Processing with MapReduce
Hadoop: The Definitive Guide.

The exam is based on the lectures. Reading may help digestion.
Labs
Get familiar with the tools and ask questions.

Three weeks starting 3 October.
Currently 4 groups, actual number depends on enrollment.
Unix Command Line

We assume you know the Unix command line (typically bash).

If you don’t know what this does

tar cz . | ssh server "cd $PWD && tar xz"

then work through the Unix material here:
http://www.ed.ac.uk/information-services/help-consultancy/is-skills/catalogue/program-op-sys-catalogue/unix1
Programming Languages

We do not require a particular programming language.\(^1\)

Examples are mostly Python and Java, with occasional C++.\(^1\)

\(^1\)Besides the aforementioned Unix command line.
1. Assignment extension requests go to the Informatics Teaching Organisation. I do not decide.

2. We don’t take attendance, including at labs.

3. Visiting from Caltech? I’ll fill out Lauren Stolper’s form.
Core Course Content

- Working with big data
- Cluster computing with 10,000 machines
- How to pass a Google interview\(^2\)
- How commercial services like Amazon Web Services and Microsoft Azure work

\(^2\)Job at Google not guaranteed.
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- Working with big data
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Not Part of the Course

- How to program (expected)
- Unix command line (learn it yourself)
- Mobile phones or Internet of things
- Exotic hardware

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## Petabytes

<table>
<thead>
<tr>
<th>Category</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 terabyte</td>
<td>a £50 drive holding 260,000 songs</td>
</tr>
<tr>
<td>25 terabytes</td>
<td>photos uploaded to Facebook each month</td>
</tr>
<tr>
<td>120 terabytes</td>
<td>all the data and images collected by the Hubble telescope</td>
</tr>
<tr>
<td>330 terabytes</td>
<td>data the Large Hadron Collider produces each week</td>
</tr>
<tr>
<td>460 terabytes</td>
<td>all the digital weather data compiled by the US climatic data centre</td>
</tr>
<tr>
<td>530 terabytes</td>
<td>all the videos on YouTube</td>
</tr>
<tr>
<td>600 terabytes</td>
<td>ancestry.com’s genealogy database (all US census records since 1790)</td>
</tr>
<tr>
<td>1 petabyte</td>
<td>data processed by Google’s servers every 72 minutes</td>
</tr>
</tbody>
</table>
Backblaze: 270TB, one machine, £9531
Applications

Government  Demographics, communication
Large Hadron Collider  15 PB/year
Fraud detection  Did your debit card work?
Social media  Who to follow?
Search  Can I borrow a copy of the web?
Online advertising  Placement, tracking, pricing
High performance and low latency

How quickly does data move around the network?

Examples

- High-frequency trading: put machines next to the exchange
- Simulating physical systems
- Amazon (2007): sales decrease 1% for every 100ms increase in load time
- Google (2006): increasing page load time by 0.5 second produces a 20% drop in traffic
- Google rankings include load time
Topics

Big Data
Cloud Computing Infrastructure
MapReduce and Hadoop
Beyond MapReduce
Fault Tolerance and Replication
Virtualisation
NoSQL
BASE vs ACID
BitTorrent
Data warehousing
Data streams
What is big data?

“You can turn small data into big data by wrapping it XML.”

“If things are breaking, you have big data.”
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Big data is relative: not the same for Google and Informatics.
What is big data?

“You can turn small data into big data by wrapping it XML.”

“If things are breaking, you have big data.”

Big data is relative: not the same for Google and Informatics. Sometimes Google’s big data is our small data! [Brants et al, 2007]
Scientific Challenges of Big Data

Hard to understand and visualize

Tools often fail: need new algorithms

Models may not scale
Models that do scale may not show gains anymore
Curating Scientific Data

- Effectiveness of medicine across multiple studies
- Evolution of language over years
- Communities on social media
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Is it reproducible?

- Preserving large data sets is hard. Who will pay?
- Who owns it?
- Privacy versus data retention
Repeated Observations

- Mobile phone location reports
- Twitter posts
- Every Google search
- Every web page

⇒ Challenges:

- Storage: disk performance/reliability
- Efficient access and analysis
Figure 3: Comparing Random and Sequential Access in Disk and Memory

- Random, disk: 316 values/sec
- Sequential, disk: 53.2M values/sec
- Random, SSD: 1924 values/sec
- Sequential, SSD: 42.2M values/sec
- Random, memory: 36.7M values/sec
- Sequential, memory: 358.2M values/sec

Note: Disk tests were carried out on a freshly booted machine (a Windows 2003 server with 64-GB RAM and eight 15,000-RPM SAS disks in RAID5 configuration) to eliminate the effect of operating-system disk caching. SSD test used a latest-generation Intel high-performance SATA SSD.
Sequential access impacts algorithm choice:

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O(n)$</td>
<td>Random</td>
</tr>
<tr>
<td>$O(n \log n)$</td>
<td>Sequential batches</td>
</tr>
</tbody>
</table>

Constant factors matter: merge sort is faster on disk.
Power Law

Big data often follows a power law.

Modelling the head (e.g. common words) is easier, but unrepresentative. Handling the tail is harder (e.g. selling all books, not just top 100).
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The machine responsible for “the” will take longer.
Distributed computing is a natural way to tackle big data. MapReduce tries to balance work over nodes in a cluster.

- Head of power law goes to one or two nodes $\implies$ slow
- Tail balanced over nodes $\implies$ fast

Power laws can turn parallel algorithms into sequential algorithms.
Economics of Servers: Own or Rent?

Many machines operate at 30% capacity.

**Own**
- Security
- Full control, customized hardware
- Tune for latency- or time-critical tasks
- Cheaper if machines will be used all the time

**Rent**
- Pay for servers, storage, and bandwidth by usage/hour
- Scale up to many servers when needed
- Compute is another commodity like electricity
Supercomputers

A pile of Linux boxes in the same room, with a fast network.

Top 2 (according to top500.org):

1. Tianhe-2 (China) $390 million, 33 TFLOP/s, 3,120,000 cores.
2. Titan (US) $97 million, 17 TFLOP/s, 560,640 cores.

Cost per hour, assuming 10 year life:

Tianhe-2 $4,110
Titan $1,107

And that’s not counting electricity, staff, maintenance, etc.
Provisioning

Web traffic changes: time of day, shopping seasons, news, link from major site

High traffic $\rightarrow$ more machines
Low traffic $\rightarrow$ save cost

**Target (US Retailer)**
Website target.com is hosted on Amazon Web Services
Busiest shopping day in 2009: 28 November
Day target.com went offline: 28 November
Data lock-in and third-party control

Some provider hosts our data:

- But we can only access it using proprietary (non-standard) APIs
- Lock-in makes customers vulnerable to price increases and dependent upon the provider

Providers may control our data in unexpected ways:

- July 2009: Amazon remotely remove books from Kindles
- Twitter prevents exporting tweets more than 3200 posts back
- Facebook locks user-data in
- August 2010: Google drops Google Wave
Privacy and Security

Laundry list of breaches:

- Ashley Madison hack
- US government HR database leaks, including security clearance
- Customer data: TJX, Carphone Warehouse, Target, Health insurers

- What if your cloud provider is hacked?
- Who has access? The government? Which governments?

Need for privacy guarantees and measures.
Summary: Big Data

- Scalable algorithms
- Tools for cluster computing
- Cloud providers and how they work