MY472 – Week 1: Overview and Fundamentals

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MY472: Data for Data Scientists

27 September 2021

Course website: lse-my472.github.io

What is this course about?

The 80/20 rule of data science:
80% data manipulation, 20% data analysis

It is about the 80%

In more detail

Course tries to provide “data science literacy”

- What is data?
  - Basic data types and structures
- How to collect data?
  - How to scrape data from the internet
  - How to work with APIs
- How to clean and process data?
  - How to format, organize, and reshape data
  - Cloud computing to process very large datasets
- How to store and query data?
  - How to create and use databases
  - How to create and manage (online) databases

Tools applicable in a wide range of fields

For example

- Private sector
- Public sector
- Healthcare
- Non-profit
- Data journalism
- Research

Plan for today

- Administration and logistics
- On the history of data and databases
- Data types and storage units
- Introduction to R
- Markdown in brief
- git and Github for version control

Course outline

1. Introduction to data
2. The shape of data
3. HTML and CSS
4. Using data from the internet
5. Working with APIs
6. (Reading week)
7. Textual data
8. Data visualisation
9. Creating and managing databases
10. Interacting with online databases
11. Cloud computing

Prerequisites and software

- Introductory course – no prerequisites (only completion of R preparatory course required!)
- Lab computers are available, but we strongly recommend bringing your own laptop
- Software:
  - R 4.1.1 – Install from https://www.r-project.org/
  - RStudio – Install from https://www.rstudio.com/products/rstudio/download/
  - GitHub Desktop – Install from https://desktop.github.com/

  → *Please install before lab session this week*
- Mirrors similar tool usage and learning in other Methodology courses

About me

- Assistant Professor of Computational Social Science at the London School of Economics
  - PhD in Economics, London School of Economics, 2020
- Research:
  - Topics at the boundary of machine learning and economics
  - Innovation, macroeconomic fluctuations, economic policy
  - Natural language processing, reinforcement learning, statistical machine learning
- Contact:
  - `f.c.geiecke@lse.ac.uk`
  - `https://sites.google.com/view/friedrichgeiecke/`

Your turn

1. Name?
2. MSc/PhD Programme?
3. Previous experience with R?
4. Why are you interested in this course and what would you most like to learn?

Course philosophy

How to learn the techniques in this course?

- Lecture approach: not ideal for learning how to code
- You can only learn by doing

→ We will cover each concept three times during each week

   1. Introduction to the topic in lecture
   2. Guided coding session in lecture and lab
   3. Course assignments

- We will move relatively fast

Readings

Course webpage: https://lse-my472.github.io/

- Mixed set of readings, very specific to each week
  - Often freely available online, otherwise, available for purchase (often in electronic versions)
  - Some books are (freely) available online and in print, and the online version may be more recent
- Please do the readings!

Course meetings

- Pre-recorded lectures
- One-hour lecture discussions (also called 'Q&A') via Zoom (you only have to attend one per week)
    - Group 1: Tuesdays 09:00–10:00 via Zoom
    - Group 2: Tuesdays 15:00–16:00 via Zoom
- Ten one-hour classes ("labs")
    - Group 1: Fridays 11:00–12:00 in KSW.1.01 and via Zoom
    - Group 2: Fridays 16:00–17:00 in NAB.2.04 and via Zoom
- No lecture/class in Week 6
- Office hours (book via StudentHub)
    - Friedrich: Tuesdays 16:00-18:00
    - Patrick: Tuesdays 14:00-15:00 and Fridays 15:00-16:00

Assessment

- 5 assignments will be assessed (50%).
  - Submitted via GitHub (more in lab)
  - Only “knitted” R-markdown assignments in HTML accepted
  - One will be collaborative; rest will be individual submissions
- Take-home assignment (50%)
  - Individual assignment that asks to answer a series of question with data
  - More open-ended format than assignments
  - Deadline: 14 January 2022, 14:00

A note on plagiarism and collaboration

- Four individual term time assignments, one group term time assignment, one individual final assignment
- **Strictly no discussion and collaboration with others allowed in any individual assignment**
- You can use online resources but always give credit and cite if you borrow code or solutions
- Any forbidden collaboration or not cited code/solutions/papers/resources are considered plagiarism

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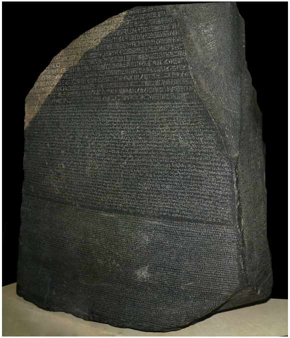
History of data



Rosetta Stone, British Museum

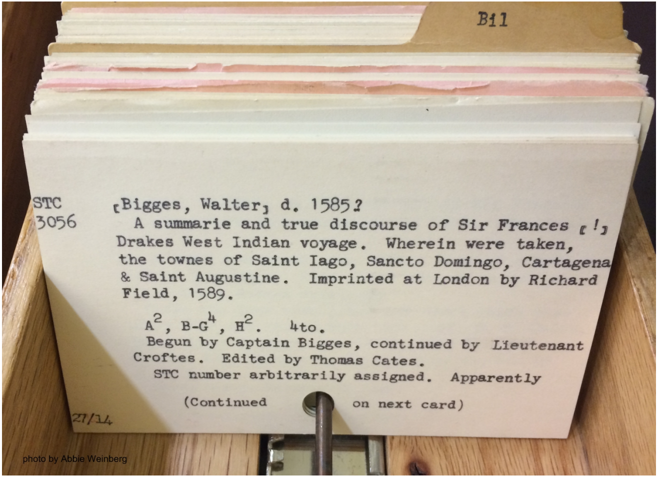
- Great book on the history of information and data: The Information by James Gleick (not on the formal reading list)
- Early example of database often government records: Who is paying taxes and how much, census of citizens, etc.

Early example of a database index

Index cards used in a library catalog of books

- Initially developed to catalog species by botanist Carl Linnaeus (19th century)
- Units (species, books) are a record; records are *indexed* using a specific reference / sorting system

Each record looked like this:



STC
3056

[Bigges, Walter] d. 1585?

A summarie and true discourse of Sir Frances [!] Drakes West Indian voyage. Wherein were taken, the townes of Saint Iago, Sancto Domingo, Cartagena & Saint Augustine. Imprinted at London by Richard Field, 1589.

A^2, $B\text{-}G^4$, H^2. 4to.

Begun by Captain Bigges, continued by Lieutenant Croftes. Edited by Thomas Cates.

STC number arbitrarily assigned. Apparently

(Continued on next card)

27/14

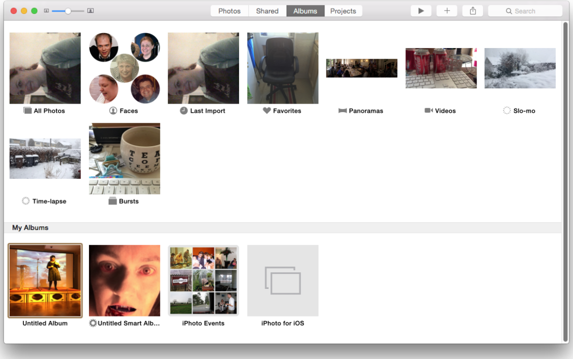
photo by Abbie Weinberg

Dewey decimal system

- A proprietary library classification system first published in the United States by Melvil Dewey in 1876
- Scheme is made up of ten classes, each divided into ten divisions, each having ten sections
- The system's notation uses Arabic numbers, with three whole numbers making up the main classes and sub-classes and decimals creating further divisions
- Example:

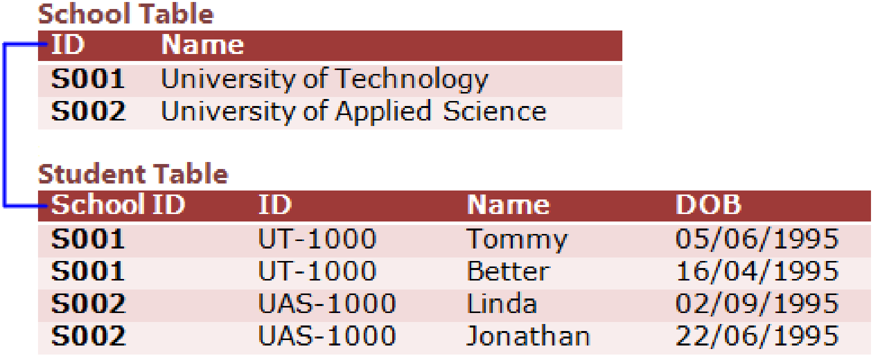
```
500 Natural sciences and mathematics
   510 Mathematics
      516 Geometry
         516.3 Analytic geometries
            516.37 Metric differential geometries
               516.375 Finsler Geometry
```

- Problem: Cards only sorted in one way. Re-referencing literally a manual operation
- Contrast with the idea of electronic indices, where assets are stored once and many indexing and referencing systems can be applied



Relational databases

- Codd, E.F. (1970) “A Relational Model of Data for Large Shared Data Banks.” *Communications of the ACM*.



School Table

ID	Name
S001	University of Technology
S002	University of Applied Science

Student Table

School ID	ID	Name	DOB
S001	UT-1000	Tommy	05/06/1995
S001	UT-1000	Better	16/04/1995
S002	UAS-1000	Linda	02/09/1995
S002	UAS-1000	Jonathan	22/06/1995

Recent developments in data storage/management

- **NoSQL**: beyond relational structure; flexible; more scalable & compatible with distributed cloud storage (Big Data)

redis
CouchDB
relax
RAVENDB
Neo4j
Cassandra
riak
mongoDB
APACHE
HBASE
membase
amazon
DynamoDB

Trying to define Big Data

1. Volume: Around 8 billion mobile phones, around 2.5 billion Facebook users, 500+ million tweets per day...
2. Velocity: How quickly is data flowing? Personal, spatial and temporal granularity
3. Variability: Images, networks, long and short text, geographic coordinates, streaming...

Dumbill (2012), Monroe (2013)

Big Data: Data that is so large, complex, and/or variable that some new tools to understand it must be created

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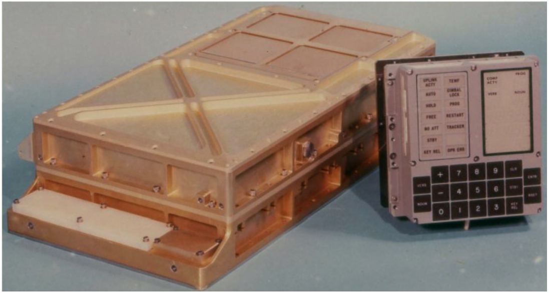
Changes in the world of data

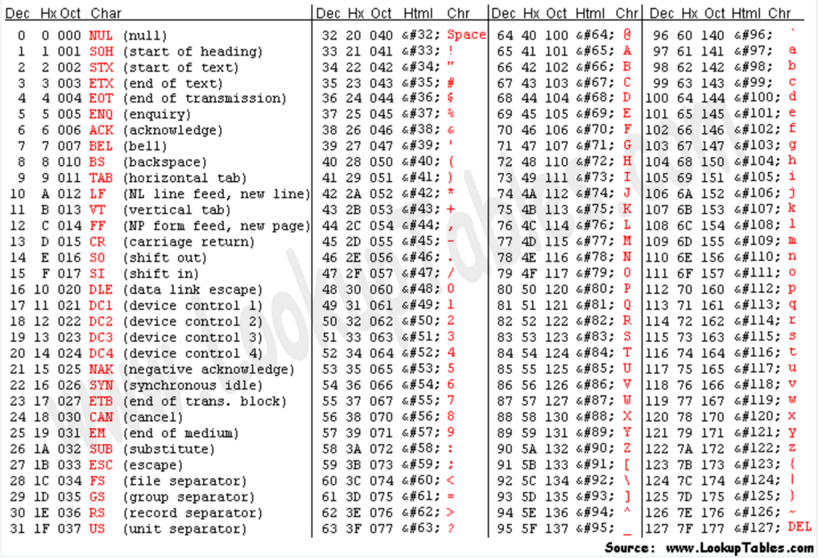
- Volume of data in the modern world: Very large fraction of the world's data has been generated in the last *two years*
- Facebook processes 500+ terabytes of data each day
- Square Kilometer Array (SKA) telescope
  - Southern hemisphere radio telescope with a total of 1km^2 of data sensors
  - Will generate 1 exabyte *daily* $= 10^{18}$ bytes

- Compare this with the Apollo Guidance Computer (1966), which guided the first humans to the moon:
  - Magnetic core memory: 16-bit word length, 2048 words RAM = 4KB
  - Core rope memory: 36,864 words. 73KB



Basic units of data

- Bits
  - Smallest unit of storage; a 0 or 1
  - With n bits, can store 2^n patterns
- Bytes
  - 8 bits = 1 byte (why 1 byte can store 256 patterns)
  - "eight bit encoding" - used to represent characters, such as `A` represented as 65 = 01000001

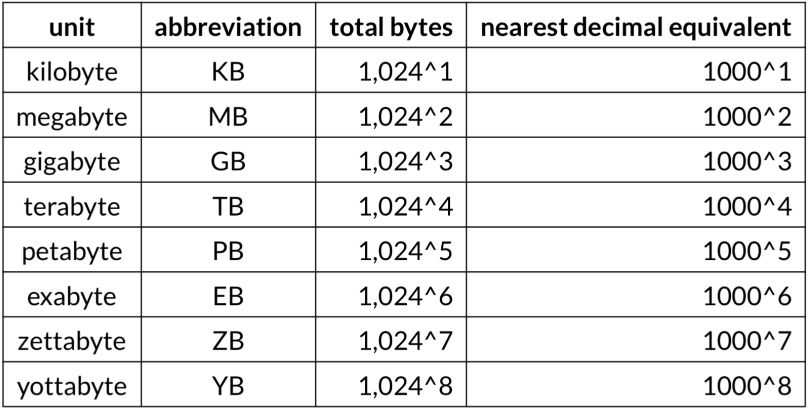


Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040	&#32;	Space	64	40	100	&#64;	@	96	60	140	&#96;	`
1	1	001	SOH (start of heading)	33	21	041	&#33;	!	65	41	101	&#65;	A	97	61	141	&#97;	a
2	2	002	STX (start of text)	34	22	042	&#34;	"	66	42	102	&#66;	B	98	62	142	&#98;	b
3	3	003	ETX (end of text)	35	23	043	&#35;	#	67	43	103	&#67;	C	99	63	143	&#99;	c
4	4	004	EOT (end of transmission)	36	24	044	&#36;	$	68	44	104	&#68;	D	100	64	144	&#100;	d
5	5	005	ENQ (enquiry)	37	25	045	&#37;	%	69	45	105	&#69;	E	101	65	145	&#101;	e
6	6	006	ACK (acknowledge)	38	26	046	&#38;	&	70	46	106	&#70;	F	102	66	146	&#102;	f
7	7	007	BEL (bell)	39	27	047	&#39;	'	71	47	107	&#71;	G	103	67	147	&#103;	g
8	8	010	BS (backspace)	40	28	050	&#40;	(	72	48	110	&#72;	H	104	68	150	&#104;	h
9	9	011	TAB (horizontal tab)	41	29	051	&#41;	)	73	49	111	&#73;	I	105	69	151	&#105;	i
10	A	012	LF (NL line feed, new line)	42	2A	052	&#42;	*	74	4A	112	&#74;	J	106	6A	152	&#106;	j
11	B	013	VT (vertical tab)	43	2B	053	&#43;	+	75	4B	113	&#75;	K	107	6B	153	&#107;	k
12	C	014	FF (NP form feed, new page)	44	2C	054	&#44;	,	76	4C	114	&#76;	L	108	6C	154	&#108;	l
13	D	015	CR (carriage return)	45	2D	055	&#45;	-	77	4D	115	&#77;	M	109	6D	155	&#109;	m
14	E	016	SO (shift out)	46	2E	056	&#46;	.	78	4E	116	&#78;	N	110	6E	156	&#110;	n
15	F	017	SI (shift in)	47	2F	057	&#47;	/	79	4F	117	&#79;	O	111	6F	157	&#111;	o
16	10	020	DLE (data link escape)	48	30	060	&#48;	0	80	50	120	&#80;	P	112	70	160	&#112;	p
17	11	021	DC1 (device control 1)	49	31	061	&#49;	1	81	51	121	&#81;	Q	113	71	161	&#113;	q
18	12	022	DC2 (device control 2)	50	32	062	&#50;	2	82	52	122	&#82;	R	114	72	162	&#114;	r
19	13	023	DC3 (device control 3)	51	33	063	&#51;	3	83	53	123	&#83;	S	115	73	163	&#115;	s
20	14	024	DC4 (device control 4)	52	34	064	&#52;	4	84	54	124	&#84;	T	116	74	164	&#116;	t
21	15	025	NAK (negative acknowledge)	53	35	065	&#53;	5	85	55	125	&#85;	U	117	75	165	&#117;	u
22	16	026	SYN (synchronous idle)	54	36	066	&#54;	6	86	56	126	&#86;	V	118	76	166	&#118;	v
23	17	027	ETB (end of trans. block)	55	37	067	&#55;	7	87	57	127	&#87;	W	119	77	167	&#119;	w
24	18	030	CAN (cancel)	56	38	070	&#56;	8	88	58	130	&#88;	X	120	78	170	&#120;	x
25	19	031	EM (end of medium)	57	39	071	&#57;	9	89	59	131	&#89;	Y	121	79	171	&#121;	y
26	1A	032	SUB (substitute)	58	3A	072	&#58;	:	90	5A	132	&#90;	Z	122	7A	172	&#122;	z
27	1B	033	ESC (escape)	59	3B	073	&#59;	;	91	5B	133	&#91;	[	123	7B	173	&#123;	{
28	1C	034	FS (file separator)	60	3C	074	&#60;	<	92	5C	134	&#92;	\	124	7C	174	&#124;	|
29	1D	035	GS (group separator)	61	3D	075	&#61;	=	93	5D	135	&#93;	]	125	7D	175	&#125;	}
30	1E	036	RS (record separator)	62	3E	076	&#62;	>	94	5E	136	&#94;	^	126	7E	176	&#126;	~
31	1F	037	US (unit separator)	63	3F	077	&#63;	?	95	5F	137	&#95;	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Basic units of data

Multi-byte units:



unit	abbreviation	total bytes	nearest decimal equivalent
kilobyte	KB	1,024^1	1000^1
megabyte	MB	1,024^2	1000^2
gigabyte	GB	1,024^3	1000^3
terabyte	TB	1,024^4	1000^4
petabyte	PB	1,024^5	1000^5
exabyte	EB	1,024^6	1000^6
zettabyte	ZB	1,024^7	1000^7
yottabyte	YB	1,024^8	1000^8

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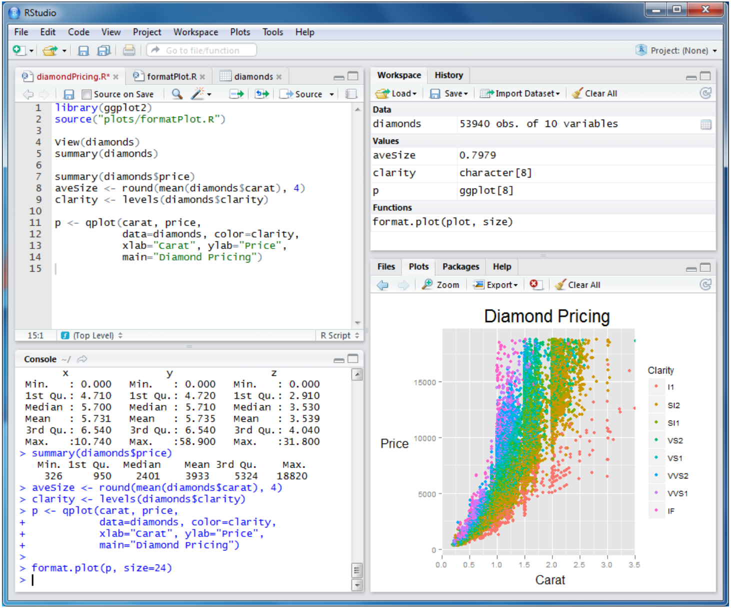
Why we're using R

- Becoming *lingua franca* of statistical analysis in academia
- Often demanded by employers in the private sector
- It's free and open-source
- Flexible and extensible through *packages* (over 10,000 and counting!)
- Powerful tool to conduct automated text analysis, social network analysis, and data visualization, with packages such as quanteda, igraph or ggplot2
- Command-line interface and scripts favor reproducibility
- Excellent documentation and online help resources

R is also a full programming language; once you understand how to use it, you can learn other languages too.

RStudio



```
library(ggplot2)
source("plots/formatPlot.R")

View(diamonds)
summary(diamonds)

summary(diamonds$price)
aveSize <- round(mean(diamonds$carat), 4)
clarity <- levels(diamonds$clarity)

p <- qplot(carat, price,
           data=diamonds, color=clarity,
           xlab="Carat", ylab="Price",
           main="Diamond Pricing")
```

Data

diamonds	53940 obs. of 10 variables

Values

aveSize	0.7979
clarity	character[8]
p	ggplot[8]

Functions

format.plot(plot, size)

```
          x                  y                  z
 Min.   : 0.000    Min.   : 0.000    Min.   : 0.000
 1st Qu.: 4.710    1st Qu.: 4.720    1st Qu.: 2.910
 Median : 5.700    Median : 5.710    Median : 3.530
 Mean   : 5.731    Mean   : 5.735    Mean   : 3.539
 3rd Qu.: 6.540    3rd Qu.: 6.540    3rd Qu.: 4.040
 Max.   :10.740    Max.   :58.900    Max.   :31.800
> summary(diamonds$price)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
    326     950    2401    3933    5324   18820
> aveSize <- round(mean(diamonds$carat), 4)
> clarity <- levels(diamonds$clarity)
> p <- qplot(carat, price,
+            data=diamonds, color=clarity,
+            xlab="Carat", ylab="Price",
+            main="Diamond Pricing")
>
> format.plot(p, size=24)
> |
```

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- git and Github for version control

Exemplary markdown files

```
01-RMarkdown.Rmd
02-intro-to-R.Rmd
```

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Introduction to git/GitHub

Git is a type of version control system or VCS

- A VCS keeps records of your changes: It helps track who made changes when
- Possibility of reverting any changes and go back to previous state
- Distributed (entire code and history on each machine) – allows for collaborative development
- Git: Created by Linus Torvalds in 2005 to facilitate Linux kernel development
- Other options: Mercurial, Subversion
- GitHub allows you to host repositories and adds extra functionalities (UI, documentation, issues, user profiles...)

Basic concepts of git

- Code lives in a repository: Collection of all files (and history)
- Every time you make changes, you need to make a commit:
  - Creates a snapshot of your code
  - Informs how files have changed
  - You need to add a message explaining changes
- After you commit, you need to push the changes to the repository on GitHub so that others can see them
- Note – you also need to pull first to receive changes from other people
- When you start from a repository someone created, you will have to first fork it (create a copy on GitHub) and then clone it (download) to your computer