Some Reminders for a Seamless Online Class…

- Please turn on your video
- Mute yourself (press and hold spacebar when you'd like to talk)
- Don't do anything you wouldn't do in an in-person class
- I will occasionally check the chat for messages if you'd like to share there instead
- Please say your name before you speak

Logistics

- Midterm report due tonight midnight
  - One person per team should submit the report, mentioning names of others
- Programming homework due tonight midnight
  - If you discussed with/worked together with others, make sure you mention it in your submission
- Programming homework 2 will be out soon
- We are a bit behind (which is OK!), so we may push our last lecture back by a week, and/or have you record your presentations
- Other considerations
  - Grading will be lenient. It will not be on a curve. We're all going through a lot. I don't want to cause you any additional stress.
  - Class participation has gotten a lot harder to quantify, plus many of you are not in ideal setups for participation (poor internet, travel to home etc.) So I will award everyone complete class participation points, while providing a bonus (if it becomes helpful) for those who have participated a lot thus far.

Recap

- Data-savviness is the future!
- "Classical" relational databases
  - Notion of a DBMS
  - The relational data model and algebra: bags and sets
  - SQL Queries, Modifications, DDL
  - Database Design
  - Views, constraints, triggers, and indexes
  - Query processing & optimization
  - Transactions
- Non-classical data systems
  - Semi-structured data and document stores
  - Unstructured data and search engines
  - Next: Cell-structured data and spreadsheets

So far…

- After relational/structured data, we've studied
  - Unstructured data, which is essentially text-based, with no schema at all
  - Semi-structured data, where the schema is nested, flexible, and non-atomic…
- We're now going to look at yet another way to relax requirements from a database

Classical Database Assumption II

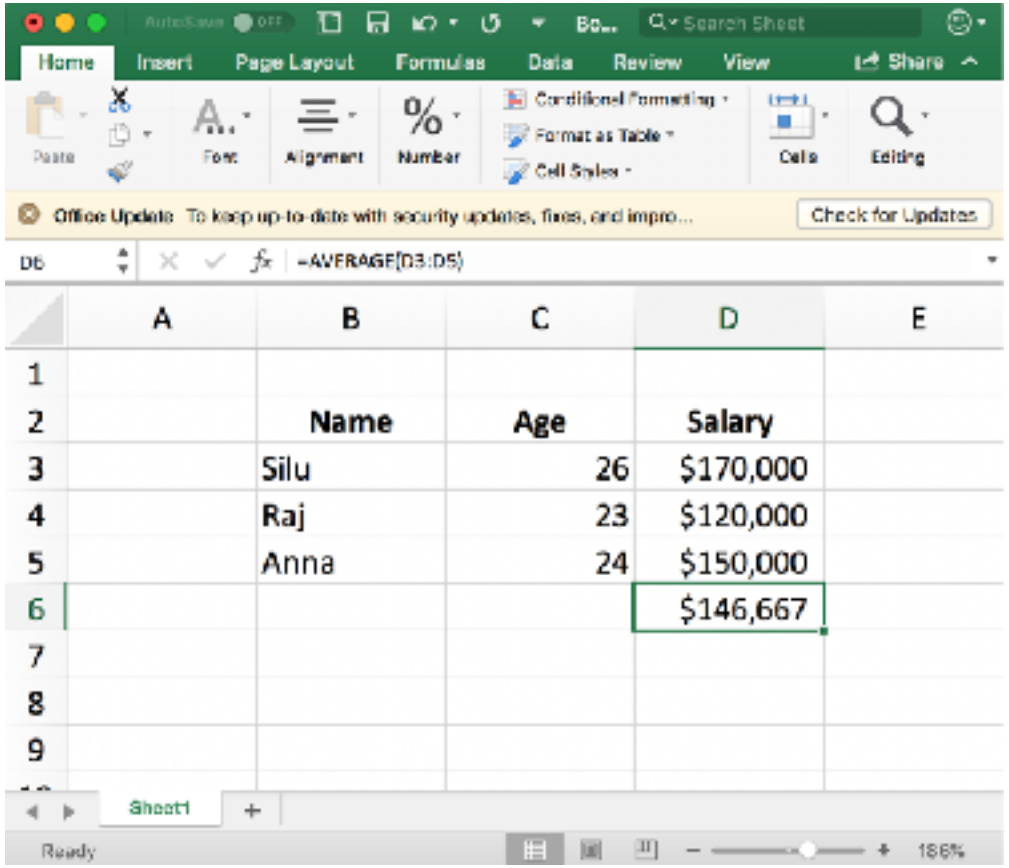
- *Data systems should manage data in relations that can only be accessed through queries, that are unordered, and have a well-defined schema, with queries that operate on relations as a whole and kept separate from the data.*

- We'll consider cell-structured data — the basis of spreadsheets, where these assumptions are relaxed.

- Let's introduced spreadsheets and cell-structured data management first before we revisit these assumptions.

Q: Who has used spreadsheets?

- And what for?

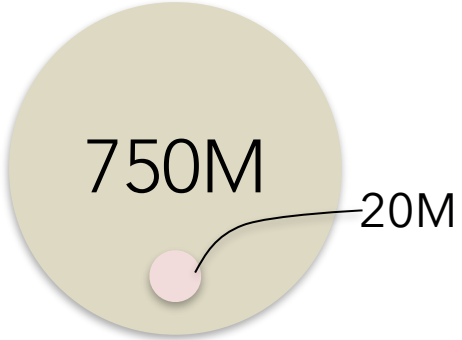


Basic Demo of Spreadsheets

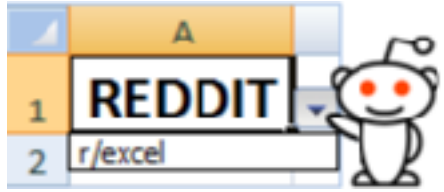
- Features:
  - Cells contain data or formulae
  - Rows and columns are equivalent
  - Cells are referenced by position
  - Formulae can reference data or other formulae
  - “Dragging down” to create a collection of related formulae
  - Direct manipulation

The most popular data management tool!

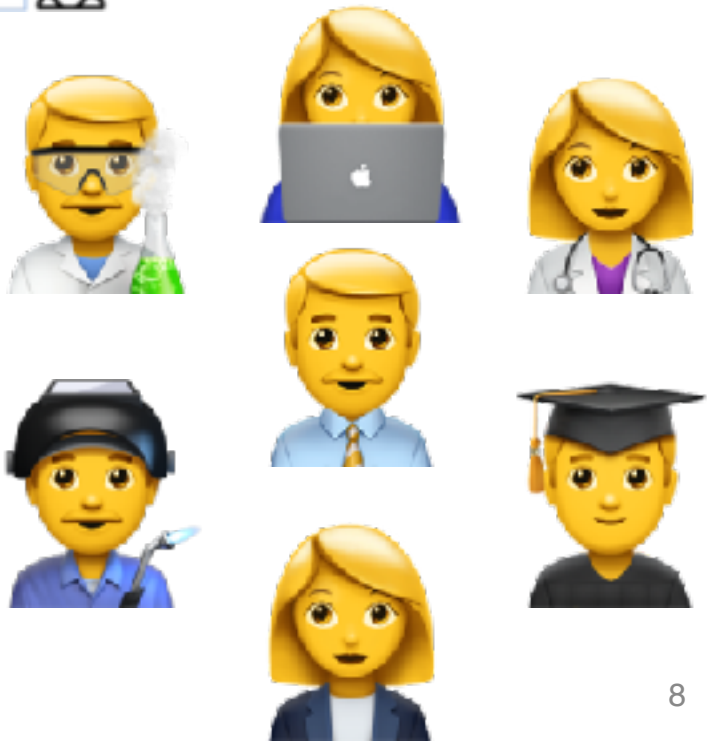
- 10% of the word uses spreadsheets (750 M)
  - Programmers a small fraction (20M)



- Use cases from /r/Excel [Mack, …, P., CHI'18]

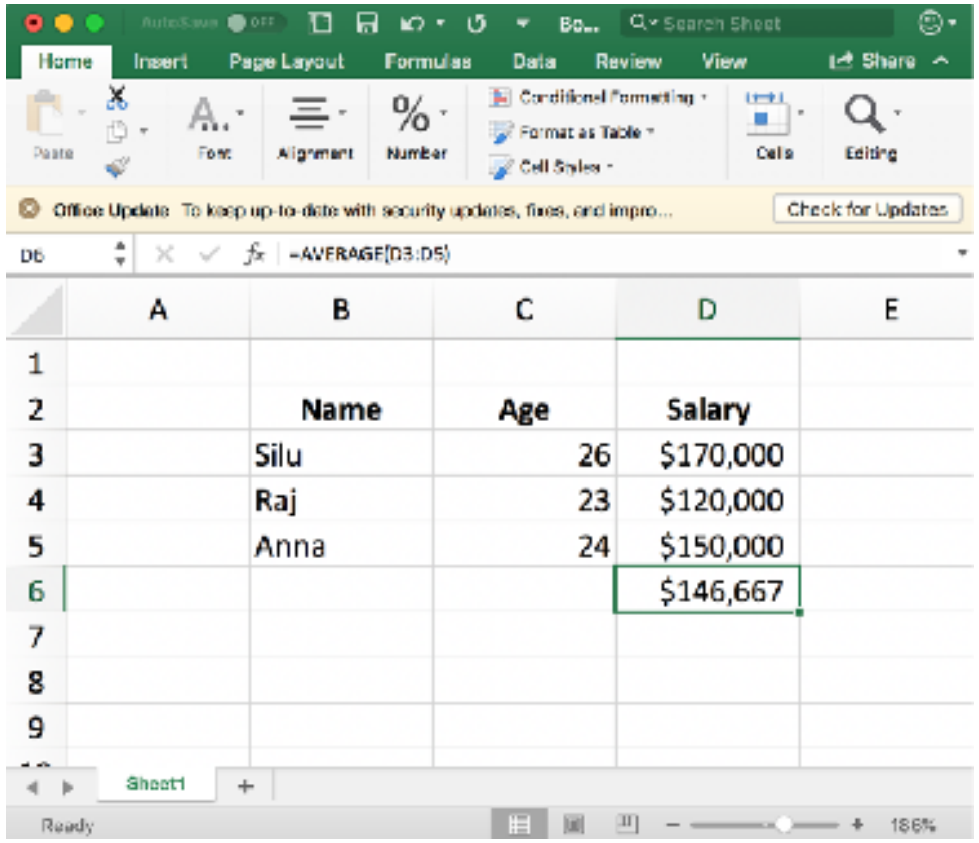


  - Professional:
    - stock tracking
    - finance data
    - inventory tracking
    - real-estate & manuf.
    - scientific exp. data
    - accounting info
    - patient info
  - Personal:
    - health & quantified self
    - sports
    - personal finance
    - …



Q: Why are spreadsheets so popular?

- Easy-to-use and flexible
- Can get started immediately
- Easy to see what is going on and get feedback
- Comes bundled together with most office software
- "Export to excel"



HCI Literature on Spreadsheet Popularity

- useful due to a "table-oriented layout" & "computation without programming" [Nardi & Miller HPL '90]
- "facilitates collaborative work", allowing sharing of knowledge [Nardi & Miller CSCW '90]
- "direct manipulation" capabilities for edits, with immediate feedback [Shneiderman '83]
  - In fact, spreadsheets are heralded as an example of a direct manipulation interface…
  - Q: what is direct manipulation?

Direct Manipulation [Shneiderman'97]

- Direct manipulation interfaces have three properties:
  - Continuous representations of the objects and actions of interest;
  - Physical actions instead of complex syntax;
  - Rapid, incremental, reversible operations whose effect on the object of interest is immediately visible
- Many examples of direct manipulation in daily life!
  - Driving a car via a steering wheel
  - Q: others?
    - Document/word editing
    - Smartphone screens

Benefits of Direct Manipulation

- Shneiderman claims the following benefits of direct manipulation:
  - *Novices can learn basic functionality quickly, especially after demonstration*
  - *Experts can work rapidly to carry out a wide range of activities, including defining new features and functions*
  - *Knowledgeable intermediate users can retain operational concepts*
  - *Users can see the effects of their actions, and can change them if needed*
  - *Users experience less anxiety because the system is comprehensible and actions can be reversed*
  - *Users gain confidence and mastery because they are initiators of actions, they feel in control, and system responses are predictable*

Direct Manipulation [Shneiderman'97]

- Direct manipulation interfaces have three properties:
  - Continuous representations of the objects and actions of interest;
  - Physical actions instead of complex syntax;
  - Rapid, incremental, reversible operations whose effect on the object of interest is immediately visible
- Many examples of direct manipulation in daily life!
- Q: Why are relational databases NOT direct manipulation interfaces?
- Q: What aspects of spreadsheets make them direct manipulation interfaces? What aspects don't?

Downsides of Direct Manipulation

- Not all is great with direct manipulation, however…
- The main downside comes from the size of data being manipulated
  - If you want to add a new column for 1000s of rows
  - Scrolling through 1000s of rows to find what you want
- One could argue that it may be easier to write code (or a SQL query) to do what you want

Spreadsheet Concepts

- A Spreadsheet Workbook comprises many sheets
- Each sheet has *cells* — thus, a spreadsheet is structured around cells
  - Cells contain
    - *values,* e.g., numbers, strings, date/time; or
    - *formulae*, indicated by a "=<Expression>"
      - formula expressions can involve arithmetic +/-
        - e.g., =A1+B1
      - or special *functions*
        - e.g., =AVERAGE(B1, D1)

Spreadsheets: Ad-hoc data layouts, from dense to sparse

	A	B	C	D	E	F
1	snp	chromosome	position	minor	major	
2	rs1208247	1	740857	T	C	
3	rs3094315	1	752566	G	A	
4	rs3131972	1	752721	A	G	
5	rs3115860	1	753406	C	A	
6	rs3131969	1	754182	A	G	
7	rs1048488	1	760912	G	A	
8	rs3115850	1	761147	A	G	
9	rs2286139	1	761732	C	T	
10	rs1256203	1	768448	A	G	
11	rs1212481	1	776546	G	A	
12	rs1080310	1	777122	A	T	
13	rs4040617	1	779322	G	A	
14	rs1080300	1	785089	A	G	
15	rs1124077	1	798959	A	G	
16	rs4970383	1	838555	A	C	
17	rs4475691	1	846808	A	G	
18	rs2860985	1	851190	A	G	
19	rs1806509	1	853954	C	A	
20	rs7537756	1	854250	G	A	
21	rs1330298	1	861808	A	G	
22	rs4040604	1	863124	C	A	
23	rs2340587	1	864938	G	A	
24	rs2857669	1	870645	G	A	
25	rs1110052	1	873558	C	A	
26	rs7523549	1	879317	A	G	
27	rs3748592	1	880238	A	G	
28	rs3748593	1	880890	A	C	
29	rs2272756	1	882033	A	G	
30	rs2340582	1	882803	A	G	
31	rs4246503	1	884815	A	G	
32	rs3748594	1	886384	A	G	
33	rs3748595	1	887560	A	C	
34	rs3748597	1	888659	T	C	
35	rs1330810	1	891945	A	G	
36	rs1330801	1	894573	G	A	

	A	B	C	D	E	F	G	H
1	bob							
2								
3		sally						steven
4				james				
5							jennifer	
6			charles					
7					dan			
8								
9						alice		
10								
11								
12					rick			
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Formula Functions

- The arguments to formulae are other cells, which can contain formulae or values.
  - Can be tedious when referring to lots of cells, e.g., cell A1 to A1000
- Shortcuts:
  - rectangular ranges of cells
    - e.g., B1:C3 = B1, B2, B3, C1, C2, C3
  - entire column
    - e.g., F:F = F1, F2, ….
- Standard statistical functions
  - AVERAGE (B1:C3), SUM (F:F), MIN (A1:A100)
  - Relational mapping: Like the aggregation functions in a group by query

Conditional statistical functions

- COUNTIF, AVERAGEIF, SUMIF

- Two arguments: list of cells, followed by a condition
  - e.g., = COUNTIF (F:F, "*HURRICANE*")
    - counts number of values in text field that contain HURRICANE

- Demo: three variants of COUNTIF

- Q: What does this map to from a relational database perspective?
  - Relational Mapping: Essentially extending grouping with a WHERE

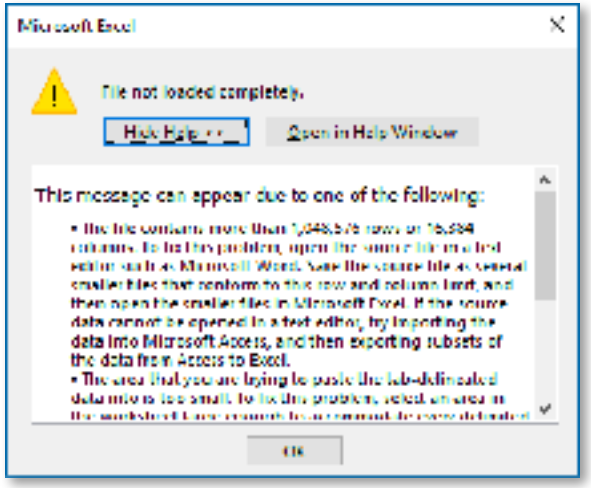
Lookups

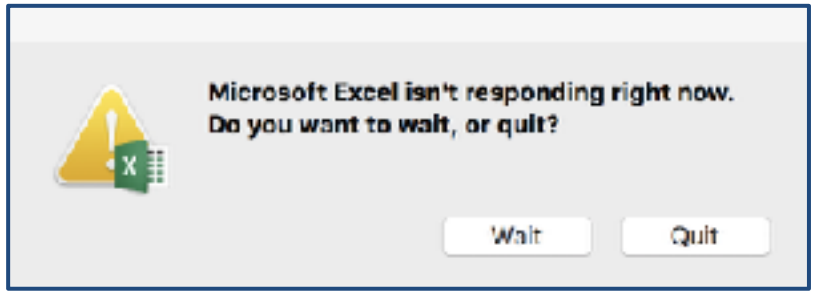
- VLOOKUP or Value Lookup
  - VLOOKUP (value v, tabular range R, col index i, approximate = FALSE)
  - Look for value v in first column of R, if matched, fetch the value in the ith column of R on the same row, and return it

- Demo: VLOOKUP of states

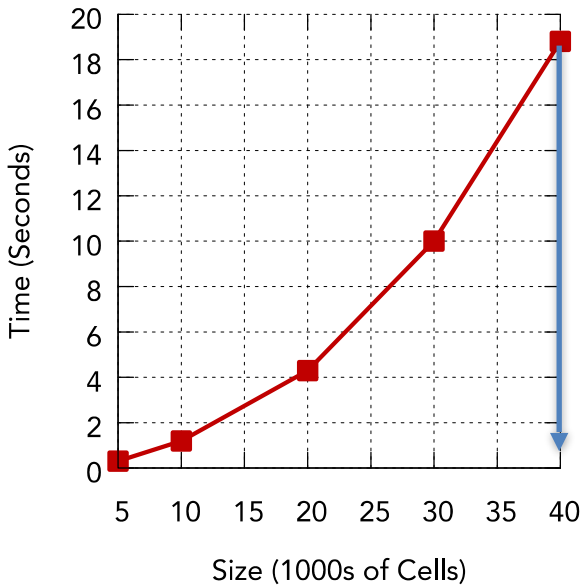
- Q: What does this remind you of from a relational perspective?
  - Relational Mapping: Like a foreign key lookup as part of join
    - Can't do full joins!

Aside: Spreadsheets are slow!





- Scalability: Can't handle large datasets > 1M rows
- Interactivity: Changes cause delays, crashes
  - More at [Rahman, …, P., SIGMOD'20]



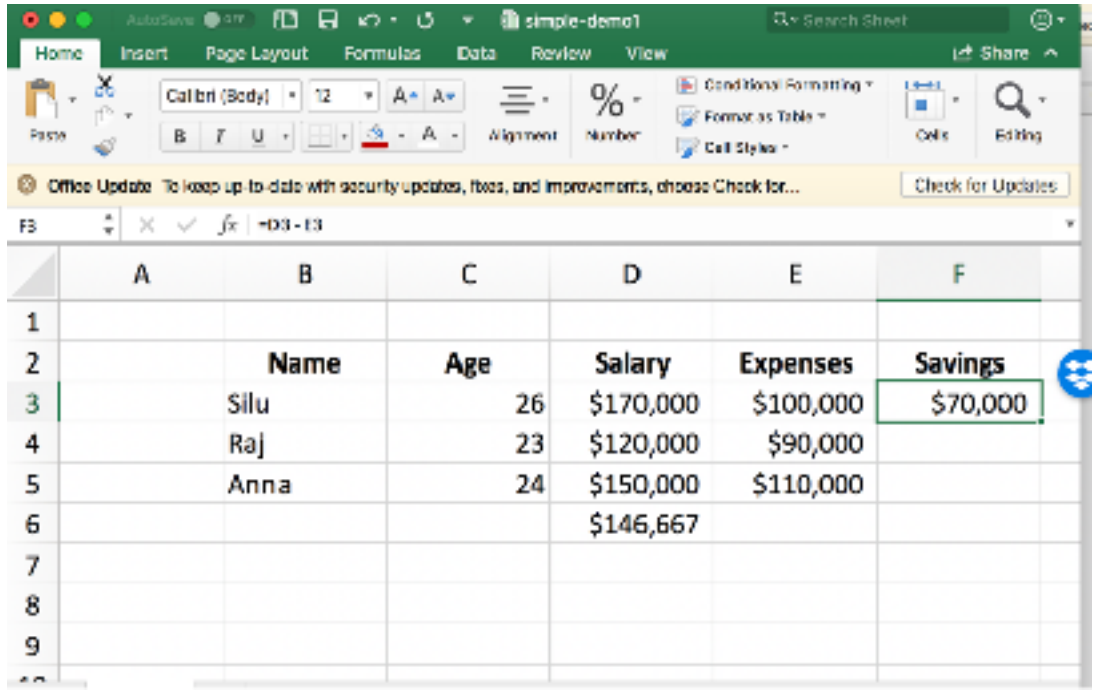
VLOOKUP Times:
Takes minutes on 100k!

Aside: Why are Spreadsheets Slow? [Rahman, …, P., SIGMOD'20]

- They perform limited query optimization, preferring to execute each formula as written
- Their optimization doesn't share computation:
  - Each VLOOKUP is executed separately, rather than treating it together as a "join"
- They don't use any indexes, even for find-and-replace
- They recompute all formulae from scratch even if there are small changes

Aside 2: Relative and Absolute Referencing

- By default, spreadsheets do relative referencing
  - So if F3 has a formula "= D3 - E3", then this means:
    - subtract the cell one step to left from the cell two steps to the left, and place the value in the current cell
  - So, when we "drag" F3 down to F4, … , we are implicitly copying the same formula
- Sometimes, we may want to keep referencing the same absolute cell
- Suppose we want to create a new column G, with savings after 1 year, where the savings after 1 year is simply the current savings (in F) multiplied by a growth rate in cell H1, then we say:
  - G3 = F3 * H1



	A	B	C	D	E	F
1						
2		Name	Age	Salary	Expenses	Savings
3		Silu	26	$170,000	$100,000	$70,000
4		Raj	23	$120,000	$90,000	
5		Anna	24	$150,000	$110,000	
6				$146,667		
7						
8						
9						

So far, we've looked at cell at a time functions…

- That is, these functions take in a collection of cells and other arguments, and return **a single value**
  - Which is why you can't do joins easily in a spreadsheet — since most joins are "multiplicative", you can't anticipate how large a join result will be.

- We'll now see some other functionality that isn't cell-at-a-time

Sorting and Filtering

- Relational mapping:
  - Sorting = ORDER BY in a relational context;
  - Filtering = WHERE in a relational context

- Sorting orders the spreadsheet based on some criteria
- Filtering retains rows that match certain criteria

- Demo of filtering

Pivot Tables

- Pivot tables are one of the most interesting & unique capabilities that spreadsheets support

- It's essentially a more group-by style aggregation, but with the ability to move data to the schema (hence the term pivot)

- Demo: Let's consider some examples…
  - Sum of disasters of various types across states
    - Like a group-by aggregation
  - Sum of disasters by year and state
    - Year is moved to the schema

Conditional Formatting

- Conditional formatting allows you to specify the formatting for cells depending on conditions
  - e.g., color the cells red if they are greater than a certain value, or among the top 10% of the values in that column

- Demo: Color the "Sum of disasters" column based on whether it is equal to 2

Summary of Spreadsheet Functionality

- Cells & Formulae, with shortcuts to reference rectangular areas
- Statistical and conditional statistical functions
- Lookup functions
- Sorting and filtering
- Pivot tables
- Conditional formatting
- Other functionality:
  - subtotals, charting capabilities, macros (a full-fledged programming language)

Downsides of Spreadsheets

- We've already covered one in Aside 1: Spreadsheets are very slow
- Q: Any other downsides?
- The second major downside essentially from the positional aspects of spreadsheets, which encourages **mistakes**, for several reasons
    - Remember Aside 2? Formulae can be confusing
    - Copy pasting of formulae often leads to spreadsheet mistakes percolating
    - Partly because of the reliance on position (which is brittle) rather than underlying intent
    - Formulae are hidden away
    - Users of spreadsheets end up being sloppy because it is so easy to edit
    - Apparently, more than half of spreadsheets contain at least one error!
- Spreadsheets have limited functionality: can't support joins, cell-at-a-time
- Spreadsheets make it hard to manipulate large volumes of data directly

Returning to the Spreadsheet-Database Comparison

- Q: How do spreadsheets and databases differ?
  - Talk about data model, modifications/updates, queries

	Aspect	Databases	Spreadsheets
I. Organization	structure	rigid	flexible
	presentation	unordered, uniform	ordered, ad-hoc
II. Manipulation	modality	relation at a time	cells, using position
	granularity	predicate-based	direct edits + add/delete row/ columns
III. Computation	modality	external	in-situ, with data
	granularity	queries on relations	formulae on cells

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When should you use Spreadsheets?

- A spreadsheet is not just a data management system
  - Unlike databases, spreadsheets are embedded with hundreds or thousands of materialized views in the form of formulae, plus charts as well
- Thus, it contains the data plus the analysis/presentation of the data
  - Emphasized by formatting (e.g., conditional)

- If your dataset is small and ad-hoc ~1000-10000, and the kinds of analysis you want to do to your data is modest and quick-and-dirty (e.g., simple statistics, pivot tables), spreadsheets are a perfectly fine tool
  - Also easy to share your analysis with others and present it all in one tool
  - No need to install and set up your database, set a schema, …
- Another setting would be if you are actively collecting small volumes of data by editing
  - Much easier to edit than a traditional database

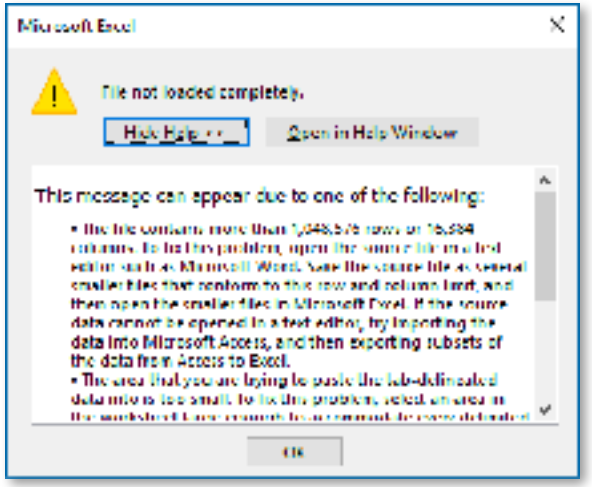
Classical Database Assumption II

- *Data systems should manage data in relations that can only be accessed through queries, that are unordered, and have a well-defined schema, with queries that operate on relations as a whole and kept separate from the data.*

- Spreadsheets violate many of these assumptions
  - Data is ad-hoc and cell-structured, not relational
  - Data can be directly manipulated
  - Data is ordered, and position is central
  - Data doesn't need to have a schema
  - Queries = formulae, operate on collections of cells at a time
  - Queries are embedded as materialized views along with data

Research Plug

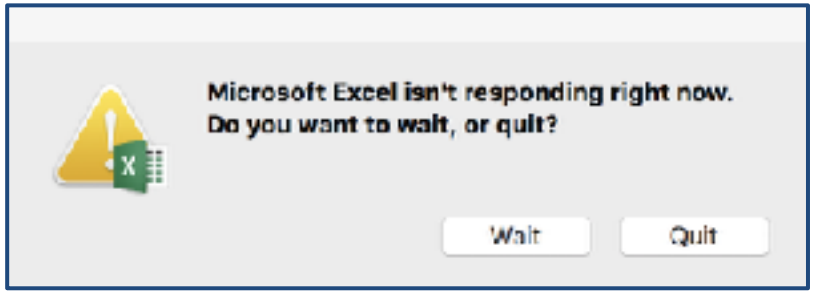
- We're working on a spreadsheet-database hybrid called DataSpread
- More at dataspread.github.io

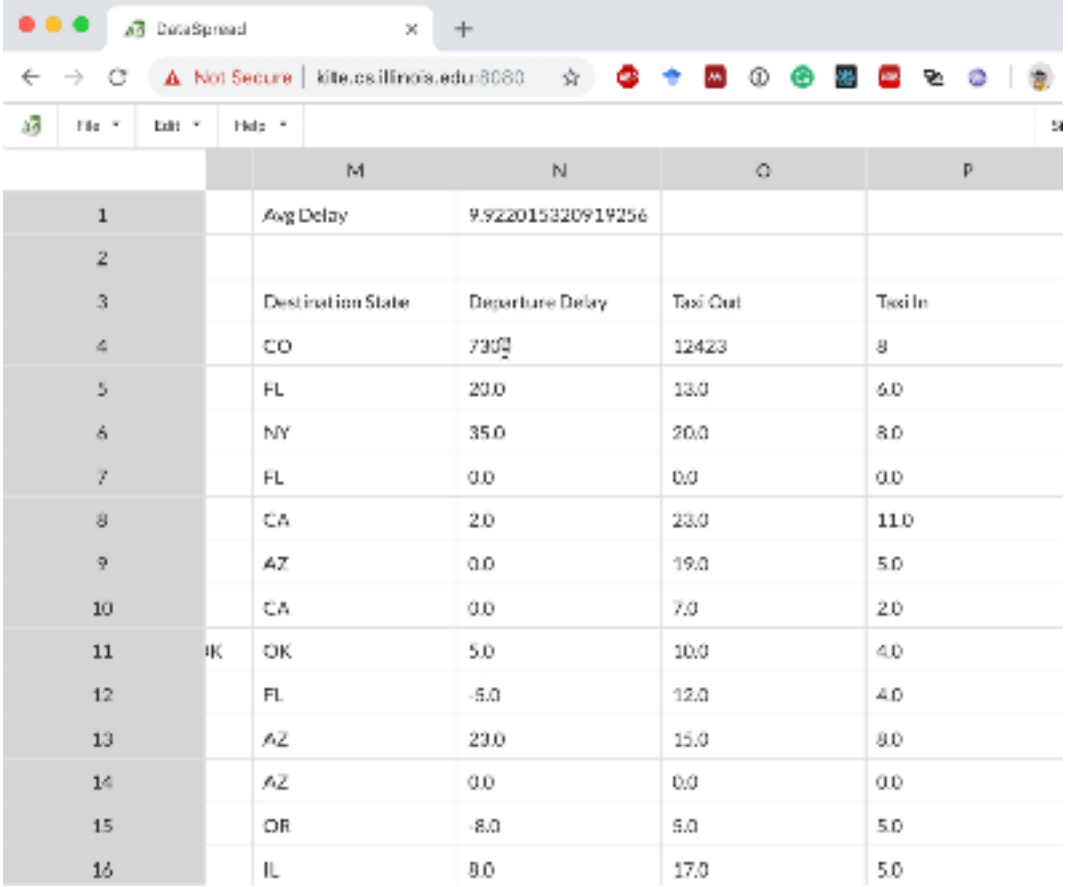


	J	K	L	M	N
1	Origin State	Destination Airport	Destination City	Destination State	Departure Delay
2	MO	LIT	Little Rock- AR	AR	30.0
3	NH	EWR	Newark- NJ	NJ	-4.0
4	NV	DEN	Denver- CO	CO	73.0
5	FL	TPA	Tampa- FLrt	FL	20.0
6	NC	LGA	New York- NY	NY	35.0
7	CA	MIA	Miami- FL	FL	0.0
8	TX	LAX	Los Angeles- CA	CA	2.0
9	UT	PHX	Phoenix- AZ	AZ	0.0
10	CA	SMF	Sacramento- CA	CA	0.0
11	NM	OKC	Oklahoma City- OK	OK	5.0
12	TX	MIA	Miami- FL	FL	-5.0
13	TX	PHX	Phoenix- AZ	AZ	23.0
14	AZ	FLG	Flagstaff- AZ	AZ	0.0
15	OR	PDX	Portland- OR	OR	-8.0
16	NC	ORD	Chicago- IL	IL	8.0
17	TX	DFW	Dallas/Fort- TX	TX	29.0
18	MN	GTF	Great Falls- MT	MT	-3.0
19	MI	ALB	Albany- NY	NY	3.0
20	GA	EWR	Newark- NJ	NJ	3.0
21	FL	ATL	Atlanta- GA	GA	0.0

Research Plug (contd.)

- Asynchronous formula computation





	M	N	O	P
1	Avg Delay	9.922015320919256		
2				
3	Destination State	Departure Delay	Taxi Out	Taxi In
4	CO	730	12423	8
5	FL	20.0	13.0	6.0
6	NY	35.0	20.0	8.0
7	FL	0.0	0.0	0.0
8	CA	2.0	23.0	11.0
9	AZ	0.0	19.0	5.0
10	CA	0.0	7.0	2.0
11	OK	5.0	10.0	4.0
12	FL	-5.0	12.0	4.0
13	AZ	23.0	15.0	8.0
14	AZ	0.0	0.0	0.0
15	OR	-8.0	5.0	5.0
16	IL	8.0	17.0	5.0

Research Plug (Contd.)

Navigation via zooming in and out

- "Scrolling and windowing introduce a discontinuity between information displayed at different times & places" [Cockburn et al. '08]

- Spreadsheet users use crutches, such as pen and paper and landmarks to help navigate. [Watts et al. '99]

- Users have difficulty comparing data across screens, requiring copying data over [Nardi & Miller '90]

https://youtu.be/MAK36CB14YI?t=73