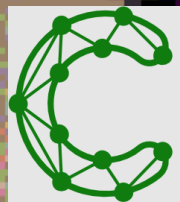


Project Yellow – Bringing Data Types and Functional Programming to Excel

Virtual Master Class – Andy Gordon
Senior Principal Research Manager
Microsoft Research

London Tech Centre – JPMorgan Chase
April 28, 2020



Future of Work

Calc Intelligence







*Transforming the world
through deep research*



Project Yellow

Excel as a Programming Language

A long-term partnership between Excel and MSR Cambridge

Presented by Andy Gordon, MSR Cambridge – adg@microsoft.com

Microsoft Research



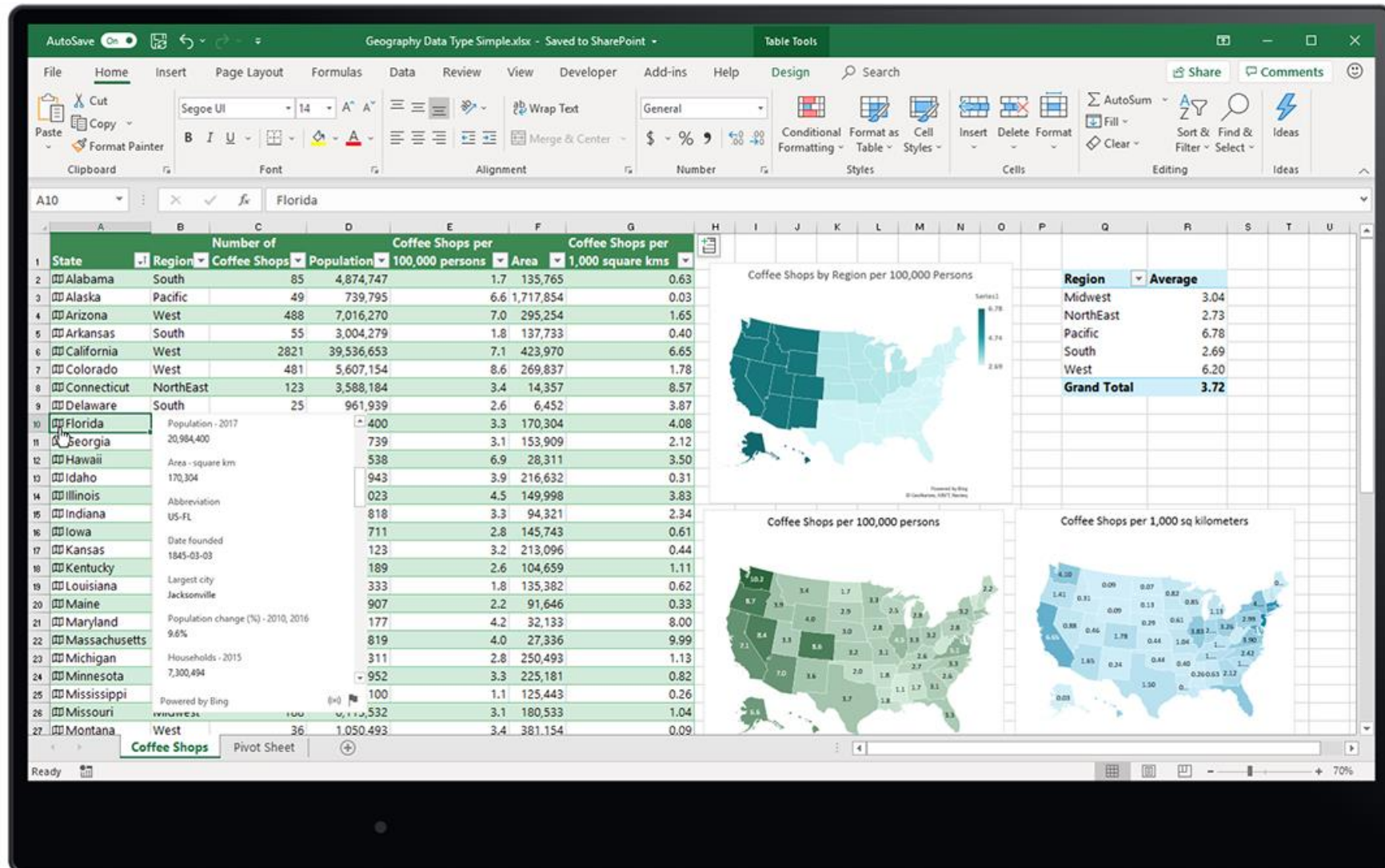
Aim

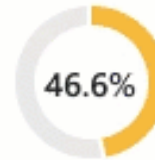
Remove the “glass ceiling” that limits the scope and reach of what a domain expert can do with Excel:

- **Make Excel functions reflect the abstractions of our end users**, by allowing end-users to define new functions using an ordinary worksheet.
- **Make Excel’s data values reflect the datatypes of our end users’ domains**, by adding arrays, vectors, records, and even domain-specific data types implemented by third parties.

So far, we've taken Excel beyond text and numbers

Ignite 2018



Nutrition - Saved						
Insert Page Layout Formulas Data Review View Help						
fx						
C	D	E	F	G	H	
 Gloria's Food	 Daily Goals					
#MondayMotivation Keeping up with my nutrition goals = #livingmybestlife						
	Calories	Carbohydrates	Fat			
Today	641.4 cal	61.1g	23.3g			
Goal	2000	250	50			
My food 						
food	calories	carbohydrates	fat			
 chicken breast	110.04	1.00	2.29			
 boiled egg (1 serving)	210.80	1.52	14.43			
 strawberry (4 items)	15.10	3.78	0.10			
 banana (1 item)	105.02	26.95	0.39			
 oatmeal cookie (2 items)	134.10	19.92	5.37			
 yogurt (3 ounces)	66.34	7.94	0.75			
						

Entities from Wolfram



Joe McDaid
@jjmcdaid

Starting today, the LET function is available to Excel users in the Insiders Ring to preview. The LET function allows you to define and use formula scoped names. Calculating a weighted average: =LET(values,A1:A4, weights,B1:B4, SUM(values*weights)/SUM(weights)) 💡

6:16 PM · Mar 17, 2020 · [Twitter Web App](#)

28 Retweets 93 Likes



David Benaim MVP @DaveBenaim · Mar 17
Replying to @jjmcdaid
Let it be!



3



Exceljet @exceljet · Mar 17
Replying to @jjmcdaid

Excellent. This will really streamline certain formulas that require the same operation more than 1x.



2



Ryan Bond @RyNBond · Mar 17
Replying to @jjmcdaid

This is similar to 'With' in Power Apps



1



Ed Hansberry @ehansalytics · Mar 18
Replying to @jjmcdaid

Now we just need to be able to format formulas easier in Excel like we can in #PowerBI and #PowerApps



1



Abiola David | Excel MVP 🇳🇮 🌐 🏆 🏆 @AbiolaDavid01 · Mar 17
Replying to @jjmcdaid
Really cool function



1



1



Reagan Onyango @rigs12 · 18h

Now even before I breathe xlookup, the real bomb is here!



Oz du Soleil @OzExcel · Mar 18
Replying to @jjmcdaid
So cool!



Breaking News!!!

Calculation View

What if we offered a code-centric view of the grid?

	A	B	C	D	E	F	G	H	I	J	
1	Depreciation	99%		HoldingCost	0.10%						
2	Assets	Present value	2019	2020	2021	2022	2023	2024	2025	2026	
3	Terminal with Electronic Components	£ 2,728.17	£ 2,698.16	£ 2,668.48	£ 2,639.13	£ 2,610.10	£ 2,581.39	£ 2,552.99	£ 2,524.91	£ 2,497	
4	Accessories Others	£ 196.77	£ 194.61	£ 192.46	£ 190.35	£ 188.25	£ 186.18	£ 184.14	£ 182.11	£ 180.11	
5	Accessories SAK	£ 10.32	£ 10.21	£ 10.09	£ 9.98	£ 9.87	£ 9.76	£ 9.66	£ 9.55	£ 9.45	
6	Accessories SAK	£ 38.28	£ 37.86	£ 37.44	£ 37.03	£ 36.62	£ 36.22	£ 35.82	£ 35.43	£ 35.04	
7	Other Terminals	£ 388.88	£ 384.60	£ 380.37	£ 376.19	£ 372.05	£ 367.85	£ 363.69	£ 359.91	£ 355.95	
8	SAK-Series	£ 430.48	£ 425.7	£ 421.06	£ 416.44	£ 411.83	£ 407.22	£ 402.61	£ 398.41	£ 394.02	
9	SAK-Series	£ 731.01	£ 722.97	£ 715.02	£ 707.15	£ 699.37	£ 691.68	£ 684.07	£ 676.55	£ 669.10	
10	SAK-Series	£ 423.61	£ 418.95	£ 414.34	£ 409.78	£ 405.28	£ 400.82	£ 396.41	£ 392.05	£ 387.74	
11	SAK-Series	£ 397.49	£ 393.12	£ 388.79	£ 384.52	£ 380.29	£ 376.10	£ 371.9	£ 367.87	£ 363.83	
12	SAK-Series	£ 321.88	£ 318.34	£ 314.84	£ 311.37	£ 307.95	£ 304.56	£ 301.2	£ 297.87	£ 294.62	
13	SAK-Series	£ 660.61	£ 653.3	£ 646.1	£ 639.5	£ 633.02	£ 626.57	£ 618.19	£ 611.39	£ 604.67	
14	SAK-Series	£ 748.58	£ 740.35	£ 732.2	£ 724.15	£ 716.18	£ 708.30	£ 700.51	£ 692.81	£ 685.19	
15	Coupler	£ 53.97	£ 53.38	£ 52.79	£ 52.21	£ 51.63	£ 51.07	£ 50.5	£ 49.95	£ 49.40	
16	SAK-Series	£ 356.36	£ 352.44	£ 348.56	£ 344.73	£ 340.94	£ 337.19	£ 333.48	£ 329.81	£ 326.18	
17	SAK-Series	£ 362.18	£ 358.20	£ 354.26	£ 350.36	£ 346.51	£ 342.69	£ 338.92	£ 335.20	£ 331.51	
18	Coupler	£ 49.81	£ 49.26	£ 48.72	£ 48.18	£ 47.65	£ 47.13	£ 46.61	£ 46.10	£ 45.59	
19	SAK-Series	£ 229.38	£ 226.86	£ 224.36	£ 221.89	£ 219.45	£ 217.04	£ 214.65	£ 212.29	£ 209.95	
20	SAK-Series	£ 155.25	£ 153.54	£ 151.85	£ 150.18	£ 148.53	£ 146.90	£ 145.28	£ 143.68	£ 142.10	
21	SAK-Series	£ 130.88	£ 129.44	£ 128.02	£ 126.61	£ 125.22	£ 123.84	£ 122.48	£ 121.13	£ 119.80	
22	SAK-Series	£ 130.88	£ 129.44	£ 128.02	£ 126.61	£ 125.22	£ 123.84	£ 122.48	£ 121.13	£ 119.80	
23	SAK-Series	£ 139.52	£ 137.99	£ 136.47	£ 134.97	£ 133.48	£ 132.01	£ 130.56	£ 129.13	£ 127.70	
24	SAK-Series	£ 144.00	£ 142.42	£ 140.85	£ 139.30	£ 137.77	£ 136.25	£ 134.75	£ 133.27	£ 131.81	
25	Accessories SAK	£ 37.59	£ 37.18	£ 36.77	£ 36.36	£ 35.96	£ 35.57	£ 35.18	£ 34.79	£ 34.41	
26	Accessories Others	£ 3.16	£ 3.13	£ 3.09	£ 3.06	£ 3.02	£ 2.99	£ 2.96	£ 2.92	£ 2.89	
27	Accessories Others	£ 1.91	£ 1.89	£ 1.87	£ 1.85	£ 1.83	£ 1.81	£ 1.79	£ 1.77	£ 1.75	
28	Accessories SAK	£ 38.21	£ 37.79	£ 37.37	£ 36.96	£ 36.56	£ 36.15	£ 35.76	£ 35.36	£ 34.97	
29	Accessories SAK	£ 34.69	£ 34.31	£ 33.93	£ 33.56	£ 33.19	£ 32.82	£ 32.46	£ 32.11	£ 31.75	
30	Accessories SAK	£ 34.69	£ 34.31	£ 33.93	£ 33.56	£ 33.19	£ 32.82	£ 32.46	£ 32.11	£ 31.75	
31	Accessories SAK	£ 34.69	£ 34.31	£ 33.93	£ 33.56	£ 33.19	£ 32.82	£ 32.46	£ 32.11	£ 31.75	

See and edit your formulae as a list.

Calculation View

☒ Show Formulas Only

Depreciation B1=99%

HoldingCost E1=0.1%

C3:N1002=B3*Depreciation-(B3*HoldingCost)

TotalPresentValue Q3=SUM(C3:C1002)

TotalEndValue Q4=SUM(N3:N1002)

TotalLoss Q5=TotalPresentValue-TotalEndValue

Small.xlsxExcel

Neil Toronto

FileHomeInsertDrawPage LayoutFormulasDataReviewViewDeveloperAdd-insLOAD TESTTeamTell me what you want to do

fx

Insert Function

Σ

AutoSum

★

Recently Used

📊

Financial

?

Logical

A

Text

📅

Date & Time

🔍

Lookup & Reference

θ

Math & Trig

⋮

More Functions

Name Manager

Define Name

Use in Formula

Create from Selection

Trace Precedents

Trace Dependents

Remove Arrows

Show Formulas

Error Checking

Evaluate Formula

Watch Window

Calculate Now

Calculate Sheet Options

Function Library

Defined Names

Formula Auditing

Calculation

C3

✖

✔

fx

=B3*Depreciation-(B3*HoldingCost)

	A	B	C	D	E	F	G	H	I	J	
1	Depreciation	99%		HoldingCost	0.10%						
2	Assets	Present value	2019	2020	2021	2022	2023	2024	2025	2026	
3	Terminal with Electronic Components	£ 2,728.17	£ 2,698.16	£ 2,668.48	£ 2,639.13	£ 2,610.10	£ 2,581.39	£ 2,552.99	£ 2,524.91	£ 2,497.13	£ 2,469.74
4	Accessories Others	£ 196.77	£ 194.61	£ 192.46	£ 190.35	£ 188.25	£ 186.18	£ 184.11	£ 182.07	£ 180.04	£ 178.02
5	Accessories SAK	£ 10.32	£ 10.21	£ 10.09	£ 9.98	£ 9.87	£ 9.76	£ 9.65	£ 9.54	£ 9.43	£ 9.32
6	Accessories SAK	£ 38.28	£ 37.86	£ 37.44	£ 37.03	£ 36.62	£ 36.21	£ 35.80	£ 35.39	£ 34.98	£ 34.57
7	Other Terminals	£ 388.88	£ 384.60	£ 380.37	£ 376.19	£ 372.05	£ 367.91	£ 363.77	£ 359.63	£ 355.49	£ 351.35
8	SAK-Series	£ 430.48	£ 425.74	£ 421.06	£ 416.43	£ 411.85	£ 407.26	£ 402.67	£ 398.08	£ 393.49	£ 388.90
9	SAK-Series	£ 731.01	£ 722.97	£ 715.02	£ 707.15	£ 699.37	£ 691.68	£ 684.07	£ 676.45	£ 668.83	£ 661.21
10	SAK-Series	£ 423.61	£ 418.95	£ 414.34	£ 409.78	£ 405.28	£ 400.82	£ 396.41	£ 392.05	£ 387.74	£ 383.42
11	SAK-Series	£ 397.49	£ 393.12	£ 388.79	£ 384.52	£ 380.29	£ 376.10	£ 371.97	£ 367.87	£ 363.81	£ 359.76
12	SAK-Series	£ 321.88	£ 318.34	£ 314.84	£ 311.37	£ 307.95	£ 304.56	£ 301.21	£ 297.90	£ 294.62	£ 291.35
13	SAK-Series	£ 640.00	£ 635.38	£ 630.76	£ 626.16	£ 621.55	£ 616.95	£ 612.34	£ 607.73	£ 603.12	£ 598.51
14	SAK-Series	£ 748.58	£ 743.85	£ 739.12	£ 734.39	£ 729.66	£ 724.93	£ 720.20	£ 715.47	£ 710.74	£ 706.01
15	Coupler	£ 53.97	£ 53.38	£ 52.79	£ 52.20	£ 51.63	£ 51.07	£ 50.50	£ 49.93	£ 49.35	£ 48.78
16	SAK-Series	£ 366.66	£ 362.44	£ 358.22	£ 354.00	£ 349.78	£ 345.56	£ 341.34	£ 337.12	£ 332.90	£ 328.68
17	SAK-Series	£ 362.18	£ 357.95	£ 353.72	£ 349.49	£ 345.26	£ 341.03	£ 336.80	£ 332.57	£ 328.34	£ 324.11
18	Coupler	£ 49.81	£ 49.26	£ 48.71	£ 48.16	£ 47.61	£ 47.13	£ 46.61	£ 46.10	£ 45.59	£ 45.07
19	SAK-Series	£ 229.28	£ 226.86	£ 224.36	£ 221.86	£ 219.36	£ 216.86	£ 214.36	£ 211.86	£ 209.36	£ 206.86
20	SAK-Series	£ 152.22	£ 151.85	£ 151.48	£ 151.11	£ 150.74	£ 150.37	£ 149.99	£ 149.62	£ 149.25	£ 148.88
21	SAK-Series	£ 130.88	£ 129.44	£ 128.00	£ 126.56	£ 125.12	£ 123.68	£ 122.24	£ 121.13	£ 119.80	£ 118.47
22	SAK-Series	£ 130.88	£ 129.44	£ 128.00	£ 126.56	£ 125.12	£ 123.68	£ 122.24	£ 121.13	£ 119.80	£ 118.47
23	SAK-Series	£ 139.82	£ 138.39	£ 136.97	£ 135.54	£ 134.11	£ 132.68	£ 131.25	£ 129.82	£ 128.39	£ 126.96
24	SAK-Series	£ 144.00	£ 142.25	£ 140.50	£ 138.75	£ 137.00	£ 135.25	£ 133.50	£ 131.75	£ 130.00	£ 128.25
25	Accessories SAK	£ 37.59	£ 37.18	£ 36.77	£ 36.36	£ 35.96	£ 35.57	£ 35.18	£ 34.79	£ 34.41	£ 34.02
26	Accessories Others	£ 3.16	£ 3.13	£ 3.09	£ 3.06	£ 3.03	£ 2.99	£ 2.96	£ 2.92	£ 2.89	£ 2.86
27	Accessories Others	£ 1.91	£ 1.89	£ 1.87	£ 1.85	£ 1.83	£ 1.81	£ 1.79	£ 1.77	£ 1.75	£ 1.73
28	Accessories SAK	£ 38.21	£ 37.79	£ 37.37	£ 36.96	£ 36.56	£ 36.15	£ 35.76	£ 35.36	£ 34.97	£ 34.57
29	Accessories SAK	£ 34.69	£ 34.31	£ 33.93	£ 33.56	£ 33.19	£ 32.82	£ 32.46	£ 32.11	£ 31.75	£ 31.40
30	Accessories SAK	£ 34.69	£ 34.31	£ 33.93	£ 33.56	£ 33.19	£ 32.82	£ 32.46	£ 32.11	£ 31.75	£ 31.40
31	Accessories SAK	£ 36.78	£ 36.33	£ 35.88	£ 35.43	£ 34.98	£ 34.53	£ 34.08	£ 33.63	£ 33.18	£ 32.73

Calculation View

✔ Show Formulas Only

C3:N1002 = B3*Depreciation-(B3*HoldingCost)

TotalLoss Q5 = TotalPresentValue-TotalEndValue

Shared formulae (e.g.,
are grouped and can be
viewed and edited as one.

	F	G	H	I	J	K	L	M	N	O	P	Q
1												
2	2022	2023	2024	2025	2026	2027	2028	2029	2030			
3	£ 2,610.10	£ 2,581.39	£ 2,552.99	£ 2,524.91	£ 2,497.13	£ 2,469.67	£ 2,442.50	£ 2,415.63	£ 2,389.06		Total present	
4	£ 188.25	£ 186.18	£ 184.14	£ 182.11	£ 180.11	£ 178.13	£ 176.17	£ 174.23	£ 172.31		Total value	
5	£ 9.87	£ 9.76	£ 9.66	£ 9.55	£ 9.45	£ 9.34	£ 9.24	£ 9.14	£ 9.04		Total loss	
6	£ 36.62	£ 36.22	£ 35.82	£ 35.43	£ 35.04	£ 34.65	£ 34.27	£ 33.89	£ 33.52			
7	£ 372.05	£ 367.96	£ 363.91	£ 359.91	£ 355.95	£ 352.03	£ 348.16	£ 344.33	£ 340.54			
8	£ 411.85	£ 407.32	£ 402.84	£ 398.41	£ 394.02	£ 389.69	£ 385.40	£ 381.16	£ 376.97			
9	£ 699.37	£ 691.68	£ 684.07	£ 676.55	£ 669.12	£ 661.77	£ 654.50	£ 647.31	£ 640.19			
10	£ 405.28	£ 400.82	£ 396.41	£ 392.05	£ 387.74	£ 383.47	£ 379.25	£ 375.08	£ 370.96			
11	£ 380.29	£ 376.10	£ 371.97	£ 367.87	£ 363.83	£ 359.83	£ 355.87	£ 351.95	£ 348.08			
12	£ 307.95	£ 304.56	£ 301.17	£ 297.80	£ 294.47	£ 291.17	£ 287.90	£ 284.67	£ 281.47			
13	£ 632.02	£ 625.07	£ 618.19	£ 611.39	£ 604.67	£ 598.01	£ 591.41	£ 584.83	£ 578.50			
14	£ 716.18	£ 708.30	£ 700.51	£ 692.81	£ 685.19	£ 677.65	£ 670.19	£ 662.82	£ 655.53			
15	£ 51.63	£ 51.07	£ 50.50	£ 49.95	£ 49.40	£ 48.86	£ 48.33	£ 47.79	£ 47.26			
16	£ 340.94	£ 337.19	£ 333.48	£ 329.81	£ 326.19	£ 322.61	£ 319.07	£ 315.57	£ 312.11			
17	£ 346.51	£ 342.69	£ 338.92	£ 335.20	£ 331.51	£ 327.86	£ 324.26	£ 320.69	£ 317.16			
18	£ 47.65	£ 47.13	£ 46.61	£ 46.10	£ 45.59	£ 45.09	£ 44.59	£ 44.10	£ 43.62			
19	£ 219.45	£ 217.04	£ 214.65	£ 212.28	£ 209.95	£ 207.65	£ 205.36	£ 203.10	£ 200.87			
20	£ 148.53	£ 146.90	£ 145.28	£ 143.68	£ 142.10	£ 140.54	£ 138.99	£ 137.46	£ 135.95			
21	£ 125.22	£ 123.84	£ 122.48	£ 121.13	£ 119.80	£ 118.48	£ 117.18	£ 115.89	£ 114.61			
22	£ 125.22	£ 123.84	£ 122.48	£ 121.13	£ 119.80	£ 118.48	£ 117.18	£ 115.89	£ 114.61			
23	£ 133.48	£ 132.01	£ 130.56	£ 129.13	£ 127.70	£ 126.30	£ 124.91	£ 123.54	£ 122.18			
24	£ 137.77	£ 136.25	£ 134.75	£ 133.27	£ 131.81	£ 130.36	£ 128.92	£ 127.50	£ 126.10			
25	£ 35.96	£ 35.57	£ 35.18	£ 34.79	£ 34.41	£ 34.03	£ 33.65	£ 33.28	£ 32.92			
26	£ 3.02	£ 2.99	£ 2.96	£ 2.92	£ 2.89	£ 2.86	£ 2.83	£ 2.80	£ 2.77			
27	£ 1.83	£ 1.81	£ 1.79	£ 1.77	£ 1.75	£ 1.73	£ 1.71	£ 1.69	£ 1.67			
28	£ 36.56	£ 36.15	£ 35.76	£ 35.36	£ 34.97	£ 34.59	£ 34.21	£ 33.83	£ 33.46			
29	£ 33.19	£ 32.82	£ 32.46	£ 32.11	£ 31.75	£ 31.40	£ 31.06	£ 30.72	£ 30.38			
30	£ 33.19	£ 32.82	£ 32.46	£ 32.11	£ 31.75	£ 31.40	£ 31.06	£ 30.72	£ 30.38			
31	£ 35.43	£ 34.74	£ 34.06	£ 33.38	£ 32.71	£ 32.04	£ 31.37	£ 30.71	£ 30.06			

It's easy to name cells and use names in formulae. This makes formulae more readable.

Formulas Only

Depreciation B1 = 99%

HoldingCost E1 = 0.1%

C3:N1002 = B3*Depreciation-(B3*HoldingCost)

TotalPresentValue Q3 = SUM(C3:C1002)

TotalEndValue Q4 = SUM(N3:N1002)

TotalLoss Q5 = TotalPresentValue-TotalEndValue

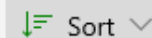
T260

	A	B	C	D	E	F	G	H	I	J	K	L	
1	Participa	First condition	Task 1 c	Task 1 t	Task 2	Task 2	Task 3	Task 3	Task 4	Task 4	Secon	Task 5 c	Tas
2	1	Normal	W1A	158	W2A	283	D1A	63	D2A	77	Calc View	W1B	104
3	2	Normal	W1B	170	W2B	182	D1B	246	D2B	122	Calc View	W1A	60
4	3	Calc View	W2A	258	W1A	80	D2A	213	D1A	78	Normal	W2B	235
5	4	Calc View	W2B	313	W1B	31	D2B	125	D1B	100	Normal	W2A	185
6	5	Normal	W1A	172	W2A	129	D1A	262	D2A	59	Calc View	W1B	61
7	6	Normal	W1B	512	W2B	215	D1B	223	D2B	23	Calc View	W1A	45
8	7	Calc View	W2A	400	W1A	68	D2A	160	D1A	124	Normal	W2B	307
9	8	Calc View	W2B	144	W1B	64	D2B	58	D1B	52	Normal	W2A	102
10	9	Normal	W1A	164	W2A	110	D1A	70	D2A	110	Calc View	W1B	59
11	10	Normal	W1B	193	W2B	287	D1B	75	D2B	59	Calc View	W1A	120
12	11	Calc View	W2A	240	W1A	120	D2A	83	D1A	23	Normal	W2B	266
13	12	Calc View	W2B	178	W1B	38	D2B	27	D1B	14	Normal	W2A	163
14	13	Normal	W1A	450	W2A	337	D1A	394	D2A	83	Calc View	W1B	103
15	14	Normal	W1B	73	W2B	134	D1B	120	D2B	55	Calc View	W1A	68
16	15	Calc View	W2A	110	W1A	50	D2A	50	D1A	44	Normal	W2B	175
17	16	Calc View	W2B	88	W1B	44	D2B	24	D1B	53	Normal	W2A	202
18	17	Normal	W1A	69	W2A	60	D1A	54	D2A	32	Calc View	W1B	27
19	18	Normal	W1B	341	W2B	388	D1B	72	D2B	22	Calc View	W1A	62
20	19	Calc View	W2A	80	W1A	72	D2A	27	D1A	26	Normal	W2B	428
21	20	Calc View	W2B	64	W1B	48	D2B	22	D1B	44	Normal	W2A	181
22	21	Normal	W1A	157	W2A	222	D1A	68	D2A	38	Calc View	W1B	52
23	22	Normal	W1B	375	W2B	408	D1B	63	D2B	33	Calc View	W1A	60
24	23	Calc View	W2A		W1A		D2A		D1A		Normal	W2B	
25	24	Calc View	W2B		W1B		D2B		D1B		Normal	W2A	

Sorting

	Minutes	Second	Particip	Task cc	Task ty	Normal	CV	Differ	Differen
33	3	180	1	D1	D		63	161	-98
34	4	240	1	D2	D		77	180	-103
37	7	420	2	D1	D		246	90	156
38	8	480	2	D2	D		122	67	55
41			3	D2	D		54	219	-165
42			3	D1	D		65	78	-13
45			4	D2	D		300	125	175
46			4	D1	D		143	100	43
49			5	D1	D		262	83	179
50			5	D2	D		182	59	123
53			6	D1	D		223	48	175
54			6	D2	D		40	20	20
57			7	D2	D		136	160	-24
58			7	D1	D		178	124	54
61			8	D2	D		24	58	-34

calculation-view



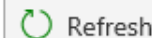
Sort



Filter



Search



Refresh

Sort Descending

Sort by:

Row wise

Column wise

Formula length

Alphabetical

T206:U206=MEDIAN(T184:T205)

AB206:AC206=MEDIAN(AB184:AB205)

K222=MEDIAN([Difference])

L222=MEDIAN([Difference %])

C229:D316=LOG10(F229)

T248:U248=MEDIAN(T226:T247)

AB248:AC248=MEDIAN(AB226:AB247)

T260

	A	B	C	D	E	F	G	H	I	J	K	L	
1	Participa	First condition	Task 1 c	Task 1 t	Task 2 c	Task 2 t	Task 3 c	Task 3 t	Task 4 c	Task 4 t	Secon	Task 5 c	Tas
2	1	Normal	W1A	158	W2A	283	D1A	262	D2A	77	Calc View	W1B	104
3	2	Normal	W1B	170	W2B	182	D1B	223	D2B	122	Calc View	W1A	60
4	3	Calc View	W2A	258	W1A	80	D2A	219	D1A	78	Normal	W2B	235
5	4	Calc View	W2B	313	W1B	31	D2B	125	D1B	100	Normal	W2A	185
6	5	Normal	W1A	172	W2A	125	D1A	262	D2A	182	Calc View	W1B	61
7	6	Normal	W1B	512	W2B	125	D1B	223	D2B	40	Calc View	W1A	45
8	7	Calc View	W2A	400	W1A	260	D2A	124	D1A	124	Normal	W2B	307
9	8	Calc View	W2B	144	W1B	14	D2B	27	D1B	14	Normal	W2A	102
10	9	Normal	W1A	164	W2A	110	D1A	394	D2A	83	Calc View	W1B	59
11	10	Normal	W1B	193	W2B	287	D1B	75	D2B	55	Calc View	W1A	120
12	11	Calc View	W2A	240	W1A	120	D2A	83	D1A	23	Normal	W2B	266
13	12	Calc View	W2B	178	W1B	38	D2B	27	D1B	14	Normal	W2A	163
14	13	Normal	W1A	450	W2A	337	D1A	394	D2A	83	Calc View	W1B	103
15	14	Normal	W1B	73	W2B	134	D1B	120	D2B	55	Calc View	W1A	68
16	15	Calc View	W2A	110	W1A	50	D2A	50	D1A	44	Normal	W2B	175
17	16	Calc View	W2B	88	W1B	44	D2B	24	D1B	53	Normal	W2A	202
18	17	Normal	W1A	69	W2A	60	D1A	54	D2A	32	Calc View	W1B	27
19	18	Normal	W1B	341	W2B	388	D1B	72	D2B	22	Calc View	W1A	62
20	19	Calc View	W2A	80	W1A	72	D2A	27	D1A	26	Normal	W2B	428
21	20	Calc View	W2B	64	W1B	48	D2B	22	D1B	44	Normal	W2A	181
22	21	Normal	W1A	157	W2A	222	D1A	68	D2A	38	Calc View	W1B	52
23	22	Normal	W1B	375	W2B	408	D1B	63	D2B	33	Calc View	W1A	60
24	23	Calc View	W2A		W1A		D2A		D1A		Normal	W2B	
25	24	Calc View	W2B		W1B		D2B		D1B		Normal	W2A	

Sort by
formula length

	Minutes	Second	Particip	Task co	Task ty	Normal	CV	Differ	Differen
33	3	180	1	D1	D	63	161	-98	-155.56
34	4	240	1	D2	D	77	180	-103	-133.77
37	7	420	2	D1	D	246	90	156	63.41
38	8	480	2	D2	D	122	67	55	45.08
41			3	D2	D	54	219	-165	-305.56
42			3	D1	D	65	78	-13	-20.00
45			4	D2	D	300	125	175	58.33
46			4	D1	D	143	100	43	30.07
49			5	D1	D	262	83	179	68.32
50			5	D2	D	182	59	123	67.58
53			6	D1	D	223	48	175	78.48
54			6	D2	D	40	20	20	50.00
57			7	D2	D	136	160	-24	-17.65
58			7	D1	D	178	124	54	30.34
61			8	D2	D	24	58	-34	-141.67

calculation-view

Sort Filter Search Refresh

K2:K25=IF([@[First condition]]="Normal","Calc View","Normal")

L31:L118=([@Difference]/[@Normal])*100

L222=MEDIAN([Difference %])

L171=MEDIAN([Difference %])

L119=MEDIAN([Difference %])

K222=MEDIAN([Difference])

K171=MEDIAN([Difference])

K119=MEDIAN([Difference])

AB248:AC248=MEDIAN(AB226:AB247)

AB206:AC206=MEDIAN(AB184:AB205)

T248:U248=MEDIAN(T226:T247)

T206:U206=MEDIAN(T184:T205)

K31:K118=[@Normal]-[@CV]

C31:C40=[@Minutes]*60

C229:D316=LOG10(F229)

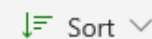
H31:H118=LEFT(G31,1)

T260

	A	B	C	D	E	F	G	H	I	J	K	L	
1	Participa	First condition	Task 1 c	Task 1 t	Task 2	Task 2	Task 3	Task 3	Task 4	Task 4	Secon	Task 5 c	Tas
2	1	Normal	W1A	158	W2A	283	D1A	63	D2A	77	Calc View	W1B	104
3	2	Normal	W1B	170	W2B	182	D1B	246	D2B	122	Calc View	W1A	60
4	3	Calc View	W2A	258	W1A	80	D2A	219	D1A	78	Normal	W2B	235
5	4	Calc View	W2B	313	W1B	31	D1B	125	D2B	100	Normal	W2A	185
6	5	Normal	W1A	172	W2A	129	D1A	258	D2A	59	Calc View	W1B	61
7	6	Normal	W1B	512	W2B	215	D1B	230	D2B	40	Calc View	W1A	45
8	7	Calc View	W2A	400	W1A	68	D2A	160	D1A	14	Normal	W2B	307
9	8	Calc View	W2B	144	W1B	64	D2B	58	D1B	52	Normal	W2A	102
10	9	Normal	W1A	164	W2A	110	D1A	70	D2A	110	Calc View	W1B	59
11	10	Normal	W1B	193	W2B	287	D1B	75	D2B	59	Calc View	W1A	120
12	11	Calc View	W2A	240	W1A	120	D2A	83	D1A	23	Normal	W2B	266
13	12	Calc View	W2B	178	W1B	38	D2B	27	D1B	14	Normal	W2A	163
14	13	Normal	W1A	450	W2A	337	D1A	394	D2A	83	Calc View	W1B	103
15	14	Normal	W1B	73	W2B	134	D1B	120	D2B	55	Calc View	W1A	68
16	15	Calc View	W2A	110	W1A	50	D2A	50	D1A	44	Normal	W2B	175
17	16	Calc View	W2B	88	W1B	44	D2B	24	D1B	53	Normal	W2A	202
18	17	Normal	W1A	69	W2A	60	D1A	54	D2A	32	Calc View	W1B	27
19	18	Normal	W1B	341	W2B	388	D1B	72	D2B	22	Calc View	W1A	62
20	19	Calc View	W2A	80	W1A	72	D2A	27	D1A	26	Normal	W2B	428
21	20	Calc View	W2B	64	W1B	48	D2B	22	D1B	44	Normal	W2A	181
22	21	Normal	W1A	157	W2A	222	D1A	68	D2A	38	Calc View	W1B	52
23	22	Normal	W1B	375	W2B	408	D1B	63	D2B	33	Calc View	W1A	60
24	23	Calc View	W2A		W1A		D2A		D1A		Normal	W2B	
25	24	Calc View	W2B		W1B		D2B		D1B		Normal	W2A	

	Minutes	Second	Particip	Task co	Task ty	Normal	CV	Differ	Differen
33	3	180	1	D1	D		63	161	-98
34	4	240	1	D2	D		77	180	-103
37	7	420	2	D1	D		246	90	156
38	8	480	2	D2	D		122	67	55
41			3	D2	D		54	219	-165
42			3	D1	D		65	78	-13
45			4	D2	D		300	125	175
46			4	D1	D		143	100	43
49			5	D1	D		262	83	179
50			5	D2	D		182	59	123
53			6	D1	D		223	48	175
54			6	D2	D		40	20	20
57			7	D2	D		136	160	-24
58			7	D1	D		178	124	54
61			8	D2	D		24	58	-34

calculation-view



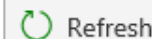
Sort



Filter



Search



Refresh

K2:K25=IF([@F
L31:L118=([@D
L222=MEDIAN(
L171=MEDIAN(
L119=MEDIAN(
K222=MEDIAN(
K171=MEDIAN(
K119=MEDIAN([
AB248:AC248=MEDIAN(AB226:AB247)
AB206:AC206=MEDIAN(AB184:AB205)
T248:U248=MEDIAN(T226:T247)
T206:U206=MEDIAN(T184:T205)
K31:K118=[@Normal]-[@CV]
C31:C40=[@Minutes]*60
C229:D316=LOG10(F229)
H31:H118=LEFT(G31,1)

H62

-7.66666666666667

	A	B	C	D	E	F	G	H	I	J
1	Normal									Calcu
2	Participant	Mental demand	Physical demand	Temporal Demand	Performance	Effort	Frustration	Average		Partici
3	1	18	2	11	13	16	16	14.17		
4	2	19	10	7	3	4	7	6.67		
5	3	3	16	7	16	16	7	12.83		
6	4	15	7	18	19	14	15.67			
7	5	12	10	2	2	14	7.00			
8	6	5	2	11	4	11	7.67			
9	7	11	2	6	2	11	2	6.33		
10	8	11	6	18	4	15	5	11.33		
11	9	15	11	15	4	4	3	5.50		
12	10	4	3	4	4	11	6	6.33		
13	11	12	1	1	4	10	2	5.67		
14	12	15	2	11	8	15	14	11.00		
15	13	15	3	3	3	8	2	4.00		
16	14	7	1	5	5	5	2	3.83		
17	15	4	2	3	6	11	9	8.83		
18	16	14	10	5	1	2	6	3.00		
19	17	3	1	4	13	16	12	10.33		
20	18	13	4	2	2	8	6	4.33		
21	19	2	2	11	6	16	6	9.50		
22	20	17	1	13	5	12	6	10.00		
23	21	13	11	1	17	11	11	9.17		
24	22	14	1							
25										
26										
27	Difference (CV - normal), lower is better									
28	Participant	Mental demand	Physical demand	Temporal Demand	Performance	Effort	Frustration	Average		
29	1	-14	0	-8	-3	-2	-2	-4.83		
30	2	-9	1	-3	-6	-7	-6	-5.00		
31	3	3	-1	-2	2	4	-3	0.50		
34	6	-3	0	0	-8	-5	-12	-4.67		
38	10	3	0	-11	5	-1	0	-0.67		
41	13	-8	-1	-2	0	-4	-6	-3.50		
46	18	-4	-2	-1	-2	-6	-6	-3.50		

Grid-aware search

calculation-view

Sort Filter H15 Refresh

Search Results for: H15

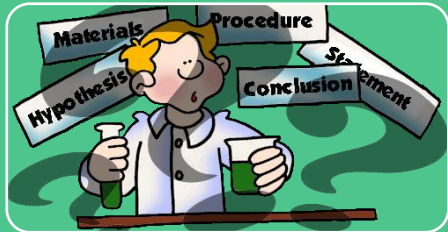
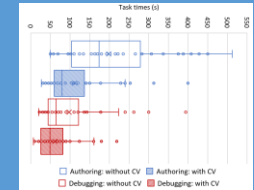
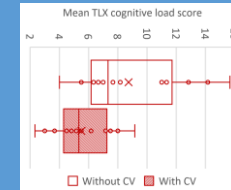
H3:H24=AVERAGE(Table4[@[Mental demand]:[Frustration]])

Studying calculation view



Authoring & debugging

- 20 participants, variety of backgrounds & expertise
- Improvement in task time and cognitive load



Comprehension

- 14 participants, spreadsheet comprehension test
- Improvement in comprehension and cognitive load in half the participants



Longitudinal deployment

- 7 MVPs, using CV for day to day work, ongoing reporting back
- Many uses, most positive feedback around auditing and comprehension

MVP feedback

- Solves the problem that formula view is aimed at
 - P6: *"[The current show formulas feature] is useless to me. [...] One of the most particular things that accountants do is get column size exactly right. And I need to see what the numbers are. I'm going to say words I've never said before. I like the fact that [Calc View] is in a task pane. That makes me feel dirty inside. But I love that I don't have to manipulate the sheet to flip it into formula view. Don't have to flip the grid. You guys are absolutely on the right track."*
- Very helpful for auditing and debugging
 - P17: *"Calc View has already been extremely useful to me in identifying spurious formulae, no longer needed, and the situation where not all formulae in a row had been amended to the newer [...] version. Calc View is already a winner!!"*
 - P9: *"Just plain text search is really good."*
 - P6: *"Cool to have name, location and formula in one place. Formula evaluation tool is kind of weak. Calc View is a logical place to enable stepping from one thing to another. Maybe don't want to make calc view as rich as formula bar. Maybe just need a quick way to get to the formula bar"*

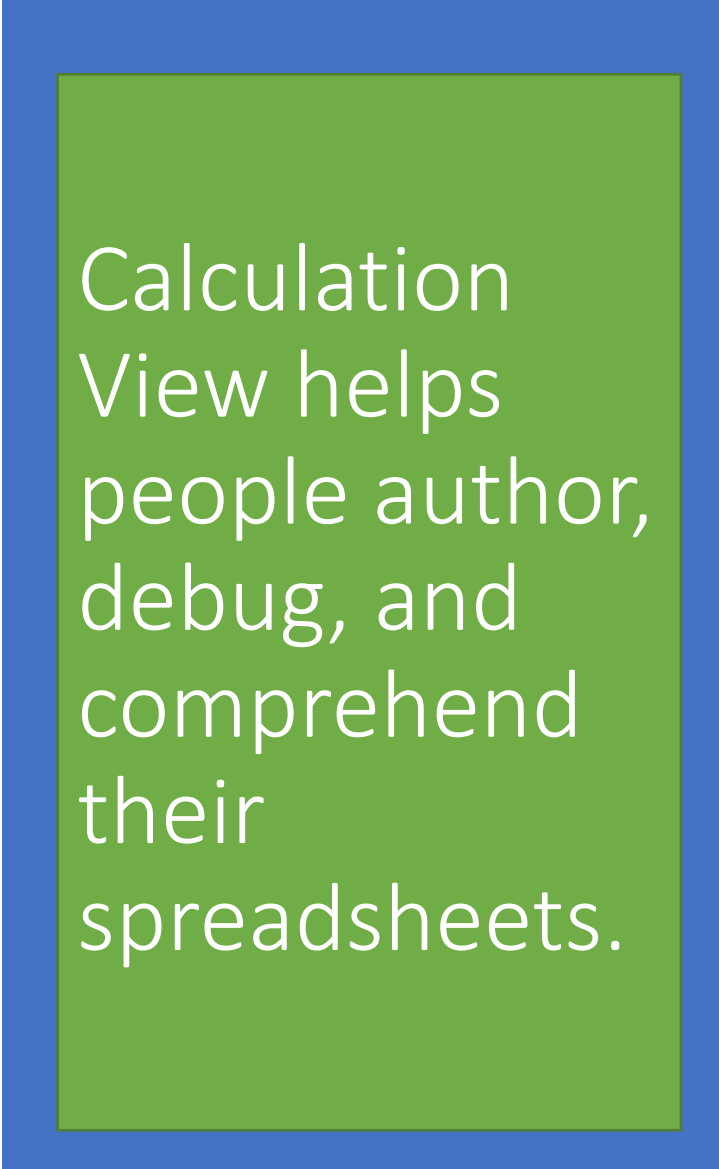
Calculation View: multiple-representation editing in spreadsheets

Advait Sarkar*, Andrew D. Gordon*[†], Simon Peyton Jones*, Neil Toronto*

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[†]University of Edinburgh School of Informatics, 10 Crichton Street, Edinburgh, United Kingdom
{advait,adg,simonpj,netoront}@microsoft.com

- Results from over a year of testing, across three studies, with ~40 total participants from a diverse range of backgrounds.
- A powerful successor to ‘show formulas’.



Calculation
View helps
people author,
debug, and
comprehend
their
spreadsheets.

Elastic Sheet-Defined Functions

Generalising Spreadsheet Functions to Variable-Size Input Arrays

Sheet defined functions

Peyton Jones, S.L., Blackwell, A.F., Burnett, M.M.:
A user-centred approach to functions in Excel. ICFP 165–176 (2003)

1: define function

	A	B	C	D	E	F
1	Average function					
2						
3	Input:	4		Count:	5	=COUNT(B3:B7)
4		5		Sum:	42	=SUM(B3:B7)
5		23		Average:	8.4	=E4/E3
6		4				
7		6				

2: use like any other

8.4

Elastic SDFs

	A	B	C	D	E	F
1	Average function					
2						
3	Input:	4		Count:	5	=COUNT(B3:B7)
4		5		Sum:	42	=SUM(B3:B7)
5		23		Average:	8.4	=E4/E3
6		4				
7		6				

In CalcView:

function AVERAGE(B3:B7) **returns** E5 {
 E3 = COUNT(B3:B7)
 E4 = SUM(B3:B7)
 E5 = E4/E3
}

Elastic SDFs

	A	B	C	D	E	F
1	Average function					
2						
3	Input:	4		Count:	5	=COUNT(B3:B7)
4		5		Sum:	42	=SUM(B3:B7)
5		23		Average:	8.4	=E4/E3
6		4				
7		6				

In CalcView:

```
function AVERAGE( B3:B7 ) returns E5 {  
  E3 = COUNT( B3:B7 )  
  E4 = SUM( B3:B7 )  
  E5 = E4/E3  
}
```

Problem:

- =AVERAGE(X5:X7) too small!
- =AVERAGE(G2:G200) too big!

Elastic SDFs

Solution:

- Somehow generalize what the user wrote

	A	B	C	D	E	F
1	Average function					
2						
3	Input:	4		Count:	5	=COUNT(B3:B7)
4		5		Sum:	42	=SUM(B3:B7)
5		23		Average:	8.4	=E4/E3
6		4				
7		6				

function AVERAGE(B3:B7) **returns**

```
E5 {  
    E3 = COUNT( B3:B7 )  
    E4 = SUM( B3:B7 )  
    E5 = E4/E3
```

```
}
```

function AVERAGE< α >(B3:B{3+ α }) **returns**

```
E5 {  
    E3 = COUNT( B3:B{3+ $\alpha$ } )  
    E4 = SUM( B3:B{3+ $\alpha$ } )  
    E5 = E4/E3
```

```
}
```


Elastic SDFs

	A	B	C	D	E	F
1	Average function					
2						
3	Input:	4		Count:	5	=COUNT(B3:B7)
4		5		Sum:	42	=SUM(B3:B7)
5		23		Average:	8.4	=E4/E3
6		4				
7		6				

```

function AVERAGE< $\alpha$ >( B3:B{3+ $\alpha$ } ) returns
E5 {
    E3 = COUNT( B3:B{3+ $\alpha$ } )
    E4 = SUM( B3:B{3+ $\alpha$ } )
    E5 = E4/E3
}

```

Elastic SDF can be called with any $\alpha \geq 0$
 =AVERAGE(G2:G200)

- Figure out $\alpha = 198$ from the arguments
- Instantiate the SDF sheet with $\alpha = 198$
- Calc it
- Return the result
- Discard the instantiated sheet

TIMESHEET													
First na	Last na	Categori	Rate	Date	01/04/2017	02/04/2017	03/04/2017	04/04/2017	05/04/2017	*****	*****	Total hours	Payment
John	Wire	Full-Time	20		0	0	4	8	0	4	0	16	320
Sophie	Gallaghe	Contract	25		0	0	0	0	8	8	4	20	500
												Total to be pai	820

First na	Last na	Categori	Rate	Date	01/08/2017	02/08/2017	03/08/2017	04/08/2017	05/08/2017	*****	*****	08/08/2017	*****	*****	11/08/2017	*****	*****	14/08/2017	Total hours	Payment
David	Green	Full-Time	20		0	0	3	0	0	5	0	9	4	0	0	5	0	0		
Sarah	Jones	Full-Time	20		5	7	8	9	0	5	5	10	0	0	4	4	4	4		
Edward	Muller	Contract	25		0	0	0	0	0	8	10	0	5	0	0	8	0	0		
Hannah	Kirk	Part-Tim	15		8	0	0	4	0	8	4	0	3	5	3	0	8	8		
Jo	Carter	Contract	25		8	8	8	8	8	0	0	8	8	8	9	0	8	0		
Max	Wells	Full-Time	20		8	0	0	0	8	8	8	8	0	0	0	8	8	8		
																			Total to be p	=E3:S18))

=E(PAYMENT(D13:D18,F13:S18))

User's eye view

- Write a function with fixed-size inputs, using familiar copy/paste
- Magic happens
- The function works on input of arbitrary size

Main point: we think that automatically inferred elasticity will dramatically broaden the audience that can use SDFs effectively.

The magic

- It really is quite amazing to
 - Take a single, concrete function working on fixed size inputs
 - And generalise it to arbitrary size inputs
 - In a predictable way
- But we can do it.
- We can even prove that the generalisation we find is the “**best generalisation**” in a very precise sense. Not just a set of heuristics.

Findings from user study (N=20, 7 female)

People perceived **significantly lower cognitive workload** for elastic SDFs than with SDFs based on map/reduce.

*I think elastic functions are easier to work with, also with the "mental model" that you have of Excel, because you can more just follow your normal Excel **workflow**. – P9*

*It'd be nice to have this kind of **middle ground**, of not having to write the same things over and over again, but not having to persuade someone to make a macro either. – P7*

Elastic Sheet-Defined Functions

Automatic generalization of map/reduce programs from example

Theorem: Elasticization yields most general generalization

User study: Easier for end-users than map/reduce programs

Elastic Sheet-Defined Functions: Generalising Spreadsheet Functions to Variable-Size Input Arrays*

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Cambridge, UK
advait@microsoft.com

aka.ms/CalcIntel

Aim

Remove the “glass ceiling” that limits the scope and reach of what a domain expert can do with Excel:

- **Make Excel functions reflect the abstractions of our end users**, by allowing end-users to define new functions using an ordinary worksheet.
- **Make Excel’s data values reflect the datatypes of our end users’ domains**, by adding arrays, vectors, records, and even domain-specific data types implemented by third parties.

Yellow Related Links

aka.ms/CalcIntel

[Dynamic Arrays and New Functions in Excel! - Office Insider Blog](#)

[Video tour of Microsoft Research Cambridge](#)

([gif2xlsx: Convert GIFs to XLSX format](#))

Microsoft Research

