Technological Progress Data Search - Update

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July 2019

1 Summary of Activities

Performance metrics for Quantum Computation, Blockchain, Industrial Robots researched. Key metric for QC identified as "Quantum Volume"[1]. Blockchain and Industrial Robots more involved, metrics better defined for Robots, but can be defined for Blockchain.

Initially took an "anything and everything" approach. Searched "Technological Forecasting and Social Change" for any useful datasets. Googled units such as "dollar per megabyte", yielded good results. Results below are the distilling of these wide searches, with priority on information technologies, particularly those in the PCDB already. All datasets that have been found are summarised in Table 1.

2 HDDs

Nine datasets across four sources found, presented in Fig. 1. More detailed information in Table 1. Data given in various combinations of price (in US $) and memory size. Changed all to units of US $/Megabyte. Deflators that were mentioned in the sources have been stated in Fig. 1, but these deflators haven't been reversed. PCDB data has also been printed to Fig. 1 for comparison.

3 RAM

Nine datasets across two sources found, presented in Fig. 2. Data again translated to one unit (US $/Megabit). Note, data in Megabits rather than Megabytes. PCDB data again printed for comparison. Data from [6] divided up according to RAM size, detailed further in Table 1.

4 Transistors

[3] contained one dataset on transistor price. PCDB dataset printed alongside. Digging deeper however, both seem to originate via Moore, and [3]'s in particular originates from Intel/Dataquest reports from 2002. Perhaps overlook Fig. 3 for now. Recent data points should be available, but would need a more targeted search.

Fig. 4 shows a dataset from [3]. Thought it interesting that the feature sizes have reducing slopes over time (perhaps?). Hard to judge by eye. Will discuss this below, but in the next few weeks, I would like to plot the slopes/rates of improvement for all data presented, if that would be of use.

5 Processors/Computing power

[3] provides data on the cost per transistor cycle (Fig. 5), which I assume is a relevant cost/performance metric. A quick search hasn't yielded the meaning to me yet though. Trend is nice and (moderately) straight on log-linear plot.

6 Desktop Printers

[5] provides data on different types of desktop printer, using cost/resolution as the key performance metric. Plotted in Fig. 7. I still need to look into whether the PCDB data from Chris Magee could be compared to this. The types of desktop printer for each dataset are provided in Table 1.

Dataset ID	Figure	Technology	N	Timeframe	Dataset description	Source description	Source
1	1	HDDs	213	1956-2019	Disk-Drives	Prof. John McCallum's work	[2]
2	1	HDDs	111	2003-2018	Flash-Drives	‘’	[2]
3	1	HDDs	363	1957-2019	Memory (RAM?)	‘’	[2]
4	1	HDDs	53	2013-2019	SSDs	‘’	[2]
5	1	HDDs	53	1952-2004	Magnetic storage	Book	[3]
6	1	HDDs	282	1980-2014	-	Personal blog	[4]
7	1	HDDs	20	1980-2001	Magnetic storage	Paper	[5]
8	1	HDDs	14	1988-2002	Magneto-Optical	Paper	[5]
9	1	HDDs	20	1980-2001	Optical	Paper	[5]
10	2	RAM	38	1949-2004	$/Mb	Book	[3]
11	2	RAM	12	1973-1985	4K $/Mb	Paper	[6]
12	2	RAM	10	1976-1985	16K $/Mb	Paper	[6]
13	2	RAM	15	1977-1991	64K $/Mb	Paper	[6]
14	2	RAM	14	1981-1996	256K $/Mb	Paper	[6]
15	2	RAM	14	1985-1997	1M $/Mb	Paper	[6]
16	2	RAM	11	1988-1998	4M $/Mb	Paper	[6]
17	2	RAM	7	1991-1995	16M $/Mb	Paper	[6]
18	2	RAM	5	1994-1998	64M $/Mb	Paper	[6]
19	3	Transistors	35	1968-2002	Transistor Price	Book	[3]
20	4	Transistors	74	1990-2010	Wafer cost	Book	[3]
21	5	Microprocessors	34	1976-2016	$/Transistor/Hz	Book	[3]
22	6	Computing Power	107	1880-2001	MSOPS	Paper	[7]
23	7	Printers	20	1978-2001	Dot matrix $/dpi	Paper	[5]
24	7	Printers	20	1984-2000	Inkjet $/dpi	Paper	[5]
25	7	Printers	18	1984-2001	Laser $/dpi	Paper	[5]
26	7	Printers	20	1978-2001	Thermal $/dpi	Paper	[5]
27	8	Games Consoles	30	1976-2006	CPU Score	Paper	[8]
28	-	Brain scanning	8	1972-2004	Resolution(mm)	Book	[3]
29	-	Brain image reconstruction time	7	1972-2014	-	Book	[3]
30	-	DNA Sequencing	7	1990-2004	$/base pair	Book	[3]
31	-	Oil productivity	152 x 3-6 sets	2007-2019	Barrels/rig/day	Paper	[9]
32	-	Tractor engine	48	1920-1968	fuel + mechanical efficiency	Paper	[10]
33	-	Smartphone cameras	25	2008-2018	Megapixels	Paper	[10]
34	-	Data transfer	20 x 3 sets	1962-2002	Household internet (Bits/Second)	Paper	[7]
35	-	Lighting	15 x 4 sets	1740-1992	Lumens/Watts	Paper	[7]
36	-	Undersea cable systems	30	1858-2002	Bits/Second	Paper	[7]
37	-	DRAM	20	1967-2016	Smallest feature size	Book	[3]
38	-	Microprocessor clock speed (Hz)	34	1976-2016	Hz	Book	[3]
39	-	Transistors per microprocessor	13	1971-2003	-	Book	[3]
40	-	Processor performance	15	1971-2003	MIPS	Book	[3]
41	-	Calcs/Sec/$1000	47	1900-1998	-	Book	[3]
42	-	Supercomputer FLOPS	15	1993-2007	-	Book	[3]
43	-	Wireless data	10	1990-2004	Bits/Second/$	Book	[3]
44	-	Internet backbone	28	1968-2005	Bits/Second	Book	[3]
45	-	Signal processing	10 x 3	1971-2015	Watts/MIPS	Book	[3]

Table 1: All datasets

7 Games consoles

[8] provides data on the improvement of games consoles, via a metric consisting of the product of the following three variables: core frequency; instruction size; and the number of cores. This metric is named the CPU Score. Data plotted in Fig. 8. The names of each console are available, and with a bit more work can be placed on the figure, but I ran out of time to do this. The costs of each console could then be easily researched, and a cost/performance metric could then be created, if desired.

8 Remaining datasets

I didn't have time to visualise the rest of the datasets in Table 1, but I thought I'd provide summary information, from which you may be able to select ones which could be of interest for further processing.

9 Future work

I have around 10-11 working days left, up to the 23rd August. I'd quite like to follow through on the research done within Quantum Computation, Blockchain and ML/AI improvement over time. I also feel like there is potentially some more low-hanging fruit in extending the remaining information technology PCDB datasets, particularly for recent years, even if this is done datapoint by datapoint. I'll also be working on the patent data a little bit.

If I had to roughly divide up my remaining time, I could dedicate four days to QC/ML/AI/Blockchain data, three days to extending PCDB datasets further, two days to the patent data, with any remaining days being initially reserved for processing and write-up. I'd also be interested in doing some further statistical analysis on all data gathered (drawing conclusions on improvement rates for instance). Writing a script to crawl websites like Amazon could also yield large (but noisy) datasets, and this would also really appeal to me.

I'm of course open to any and all ideas though, and I'm looking forward to discussing this further on Friday.

References

[1] L. S. Bishop, "Quantum volume." Mar. 2017.

[2] J. McCallum, "https://jcmit.net/diskprice.htm."

[3] R. Kurzweil, *The Singularity is Near.* Viking, 2005.

[4] M. Komorowski, "http://www.mkomo.com/cost-per-gigabyte."

[5] A. Shood, "Technological evolution and radical innovation," *Journal of Marketing*, 2005.

[6] N. M. Victor and J. H. Ausubel, "Drams as model organisms for study of technological evolution," *Technological Forecasting and Social Change*, 2002.

[7] Y. S. Chang, "Limit to improvement: Myth or reality? empirical analysis of historical improvement on three technologies influential in the evolution of civilization," *Technological Forecasting & Social Change*, 2010.

[8] T. Daim, "Identifying and forecasting the reverse salient in video game consoles: A performance gap ratio comparative analysis," *Technological Forecasting & Social Change*, 2014.

[9] H. Hassani, "The role of innovation and technology in sustaining the petroleum and petrochemical industry," *Technological Forecasting & Social Change*, 2017.

[10] M. Coccia, "The theory of technological parasitism for the measurement of the evolution of technology and technological forecasting," *Technological Forecasting & Social Change*, 2019.

List of Figures

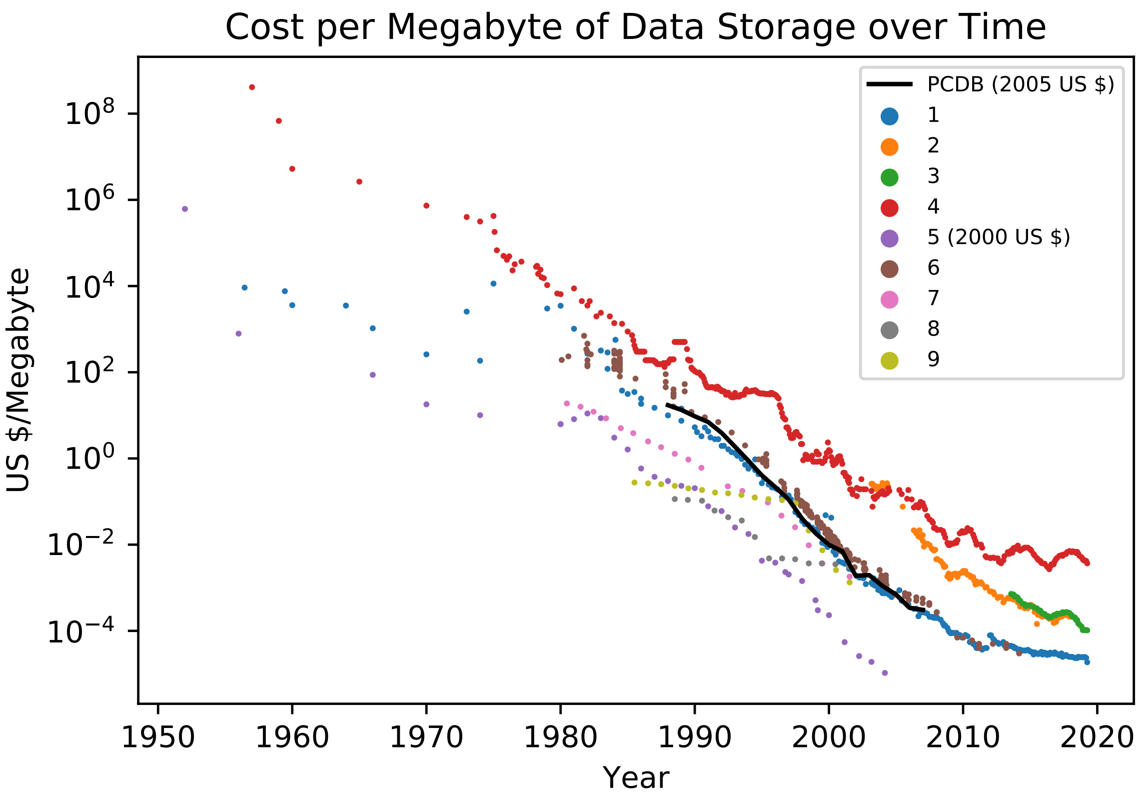

Figure 1: Data on the price of HDDs over time.

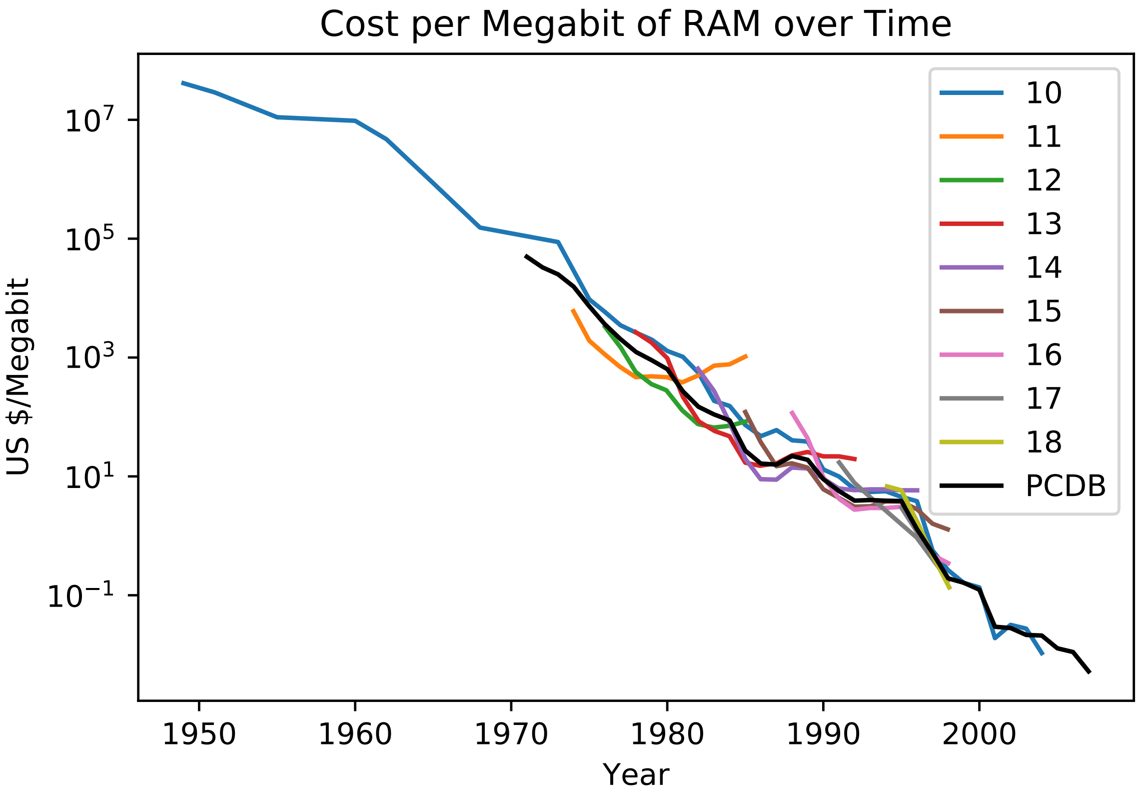

Figure 2: Data on the price of RAM over time.

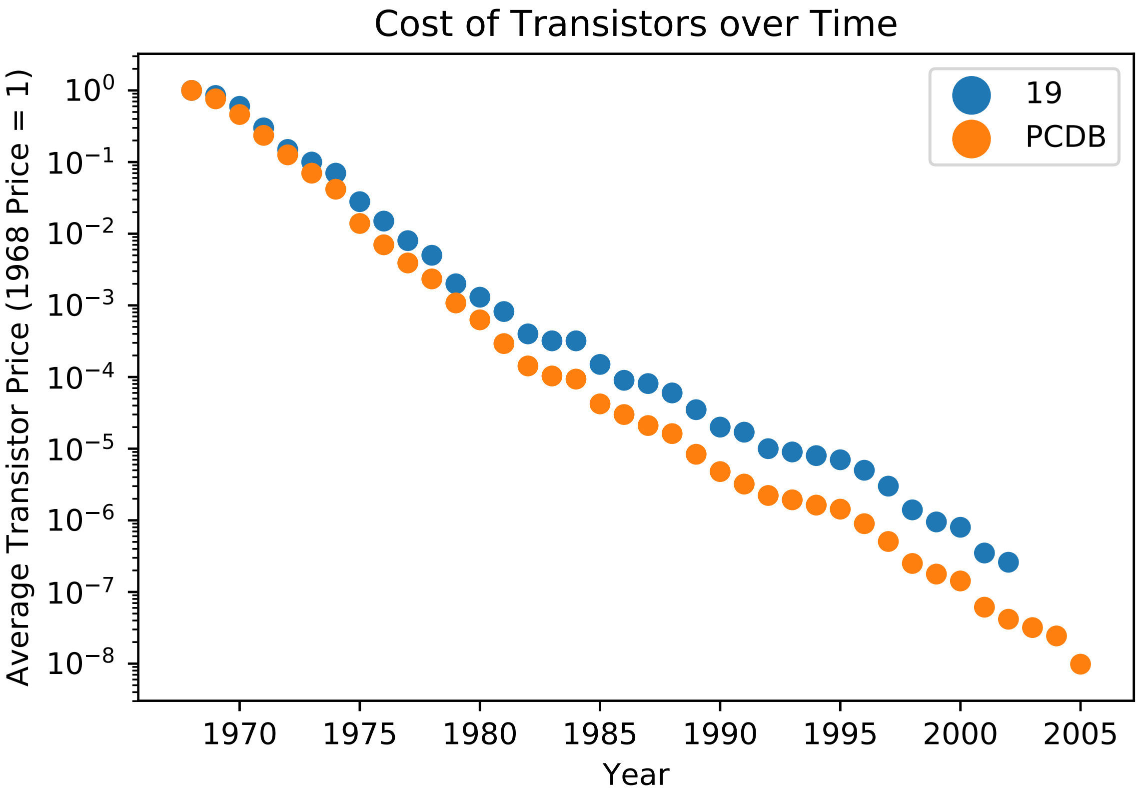

Figure 3: Data on the price of transistors over time.

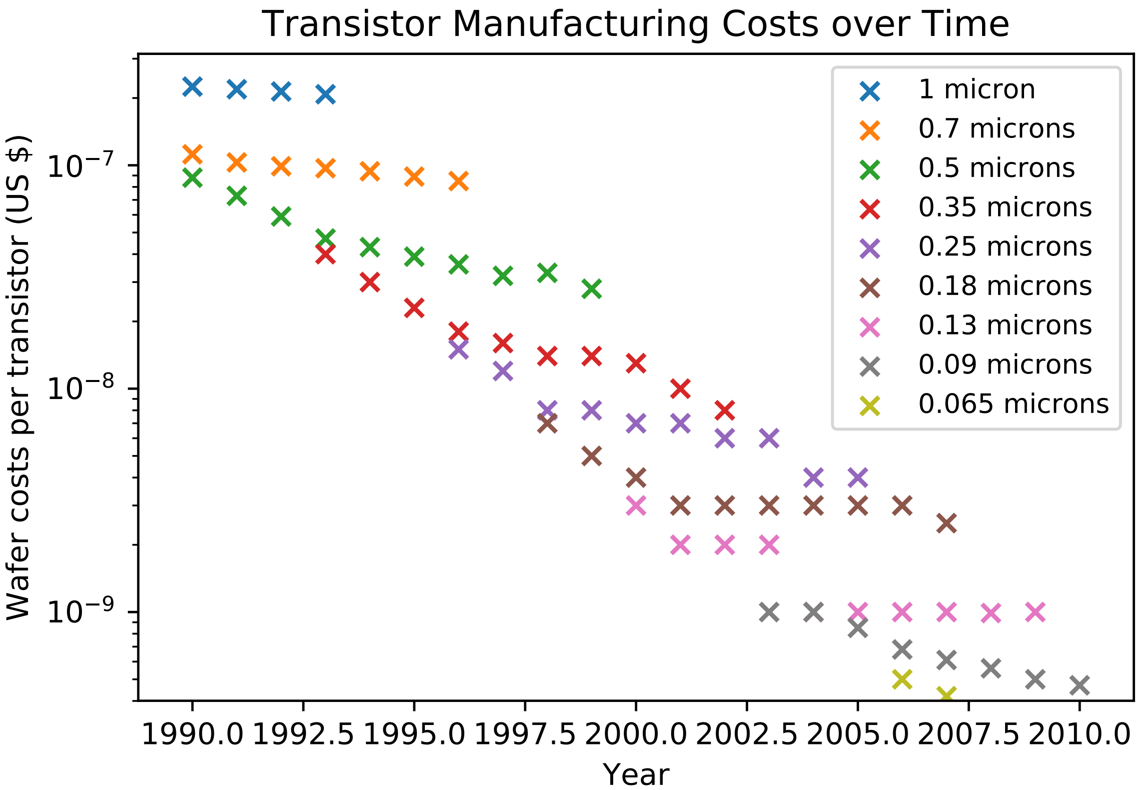

Figure 4: Data on the manufacturing costs of transistors over time.

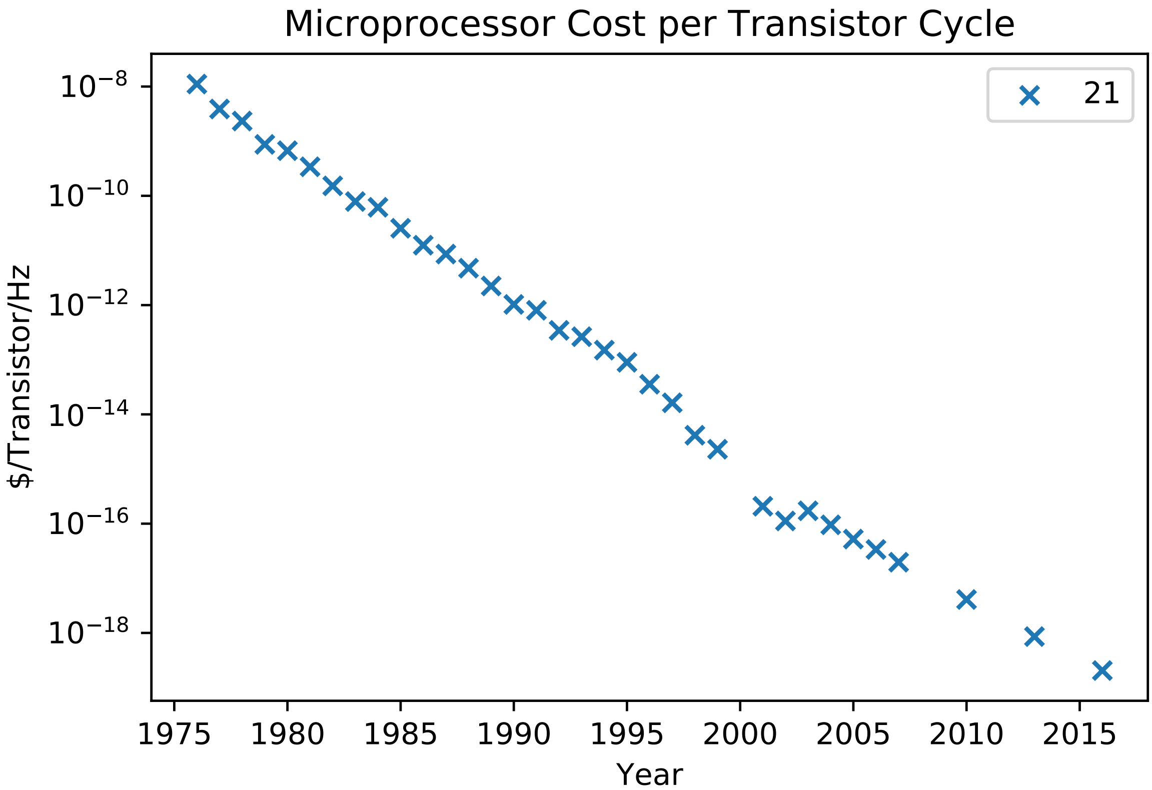

Figure 5: Data on microprocessor cost over time.

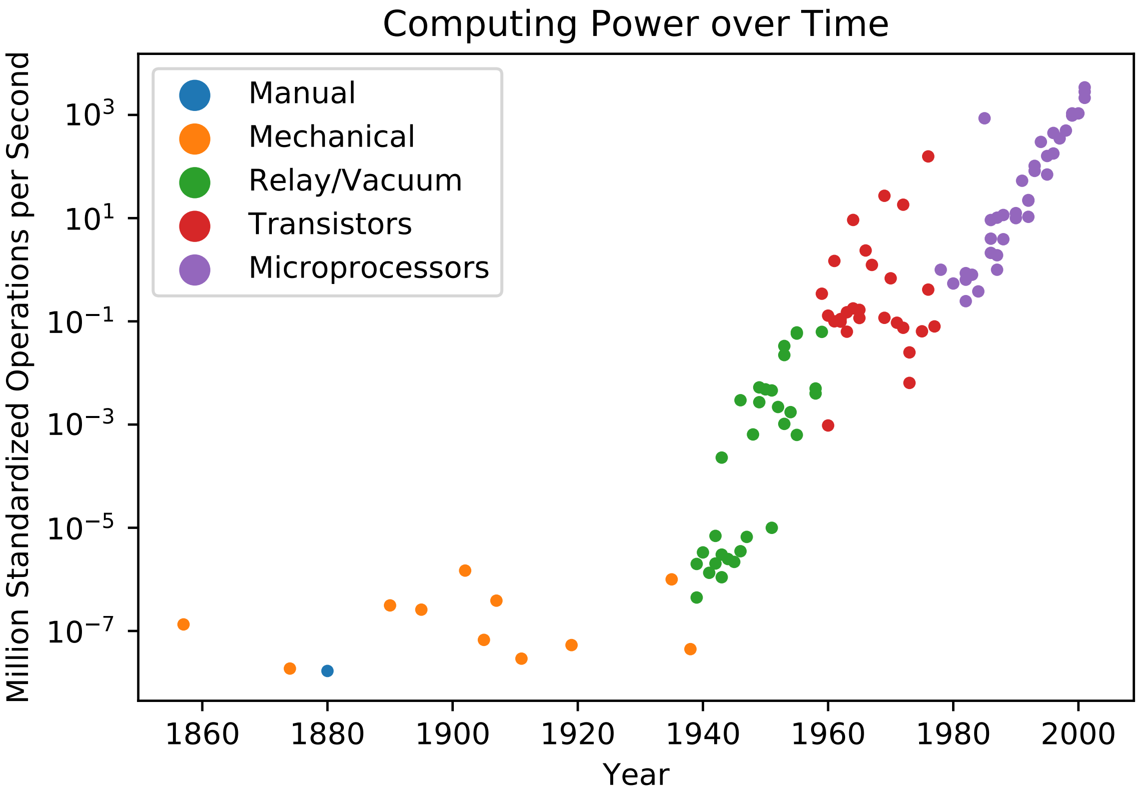

Figure 6: Data on computing power over time.

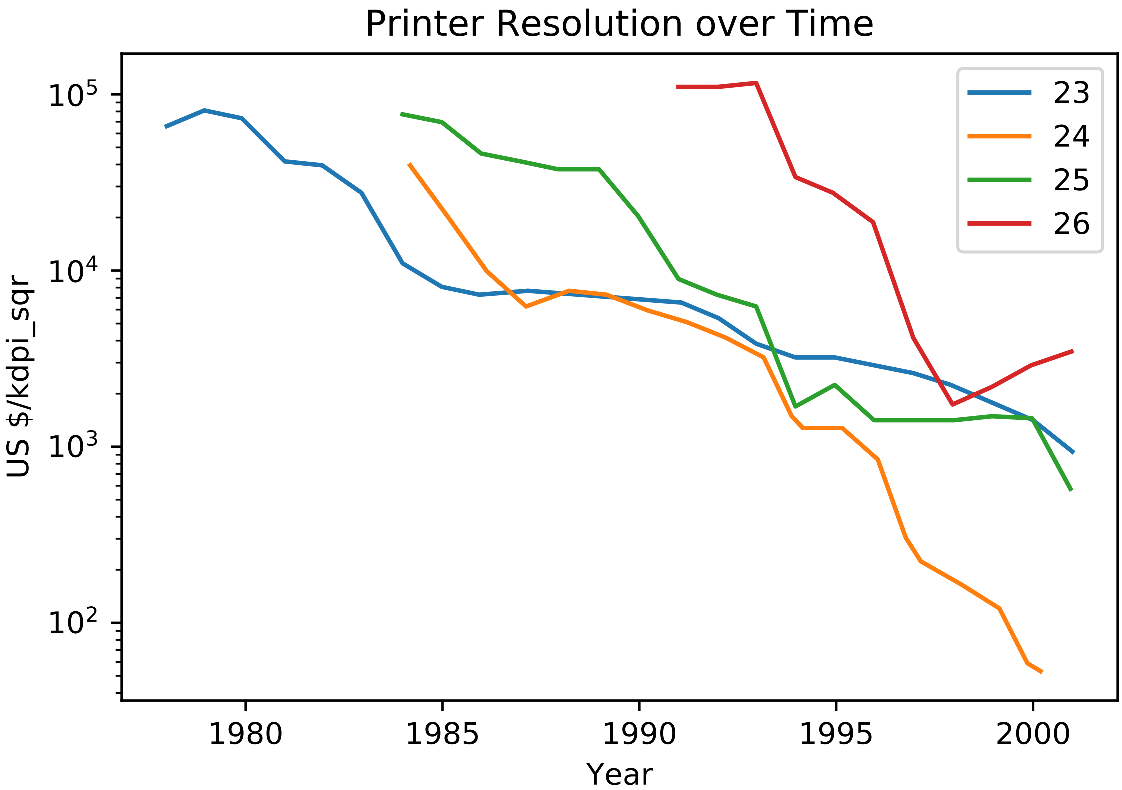

Figure 7: Data on printing resolution over time.

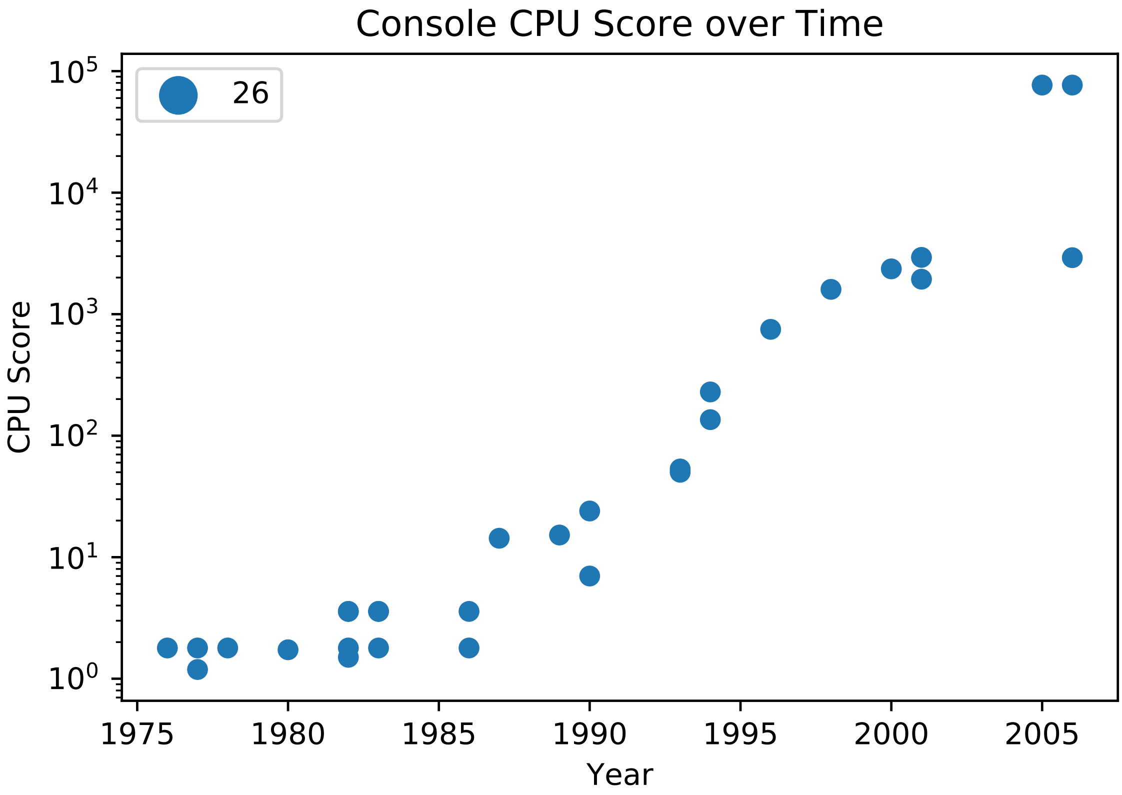

Figure 8: Data on games console improvement over time.