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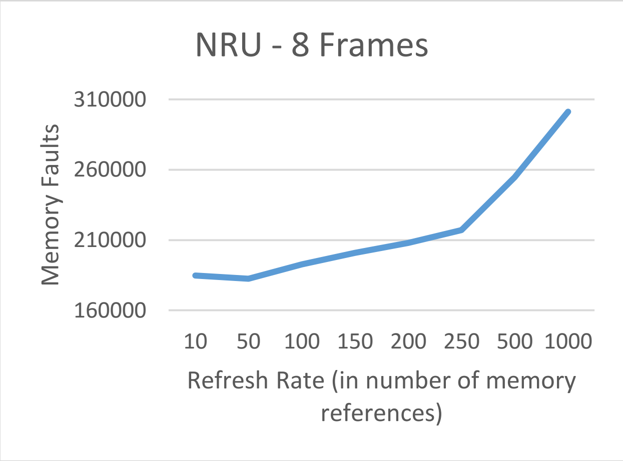
CS1550 – Tues/Thurs 2:30pm Recitation: Fri 12:00pm

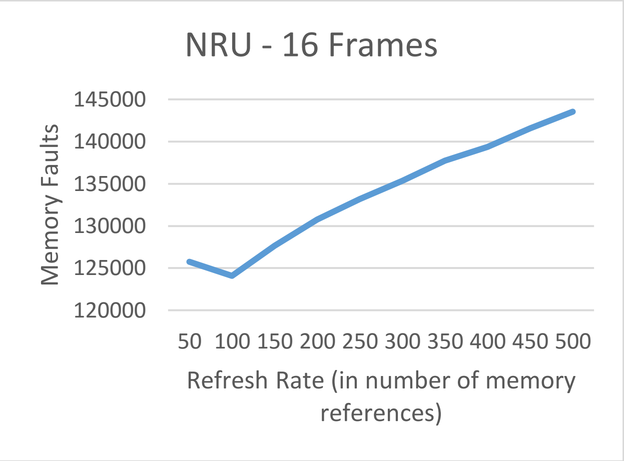
Project 3 Write Up

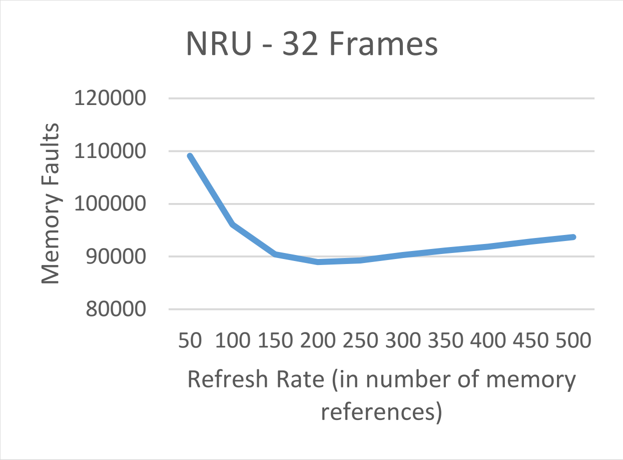
NRU Refresh Rate Analysis

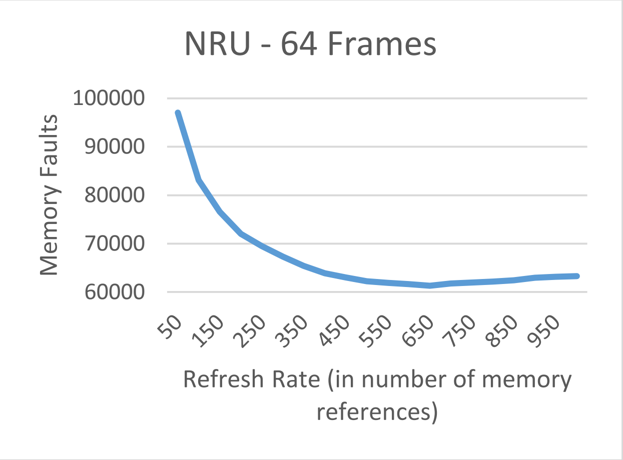
When going about finding the optimal refresh rate for the NRU algorithm, it quickly became apparent that optimal refresh rate for the given files was also dependent on the number of frames available. In other words, the best refresh rate with eight available frames was vastly different than the rate with 64 available frames. So, I tried to find a refresh rate that worked well with each of the four frame configuration. I used the gcc.trace when testing NRU's refresh rates. Of the two files we were given, it seemed to be by far the more varied in terms of memory pages used. I felt this would give more representative results.

I began with a coarse approach, increasing the refresh rate by 50 each time and recording the number of page faults. I kept doing so until it became apparent that the number of page faults had began to rise again. Note that due to the NRU algorithm choosing eviction victims at random when multiple candidates exist within the same eviction class, results may be slightly inaccurate. I was trusting that the C random number generator would provide the necessary variablity and forwent taking an average of a large sample size. See the graphs below for the coarse results.

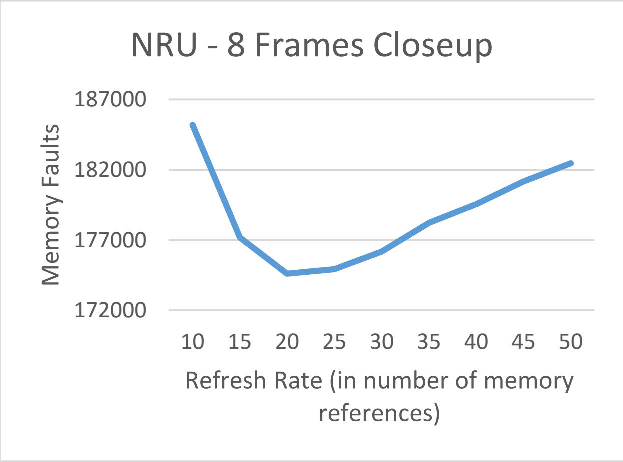


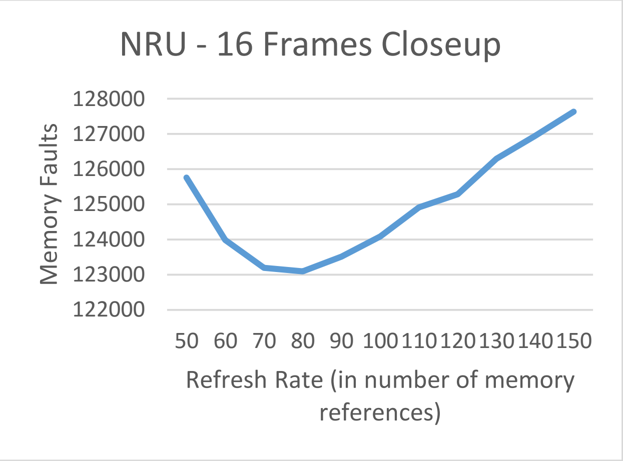


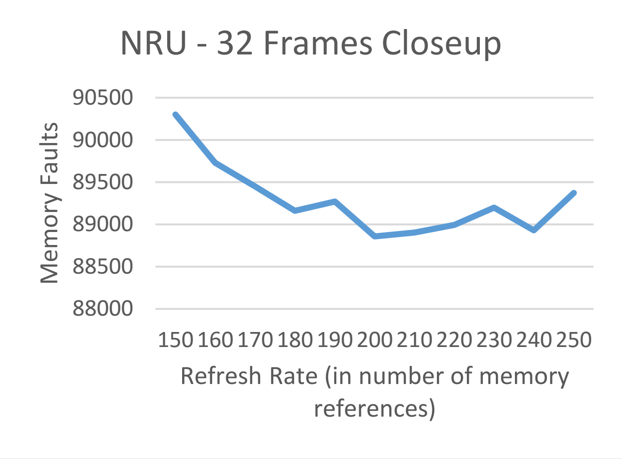


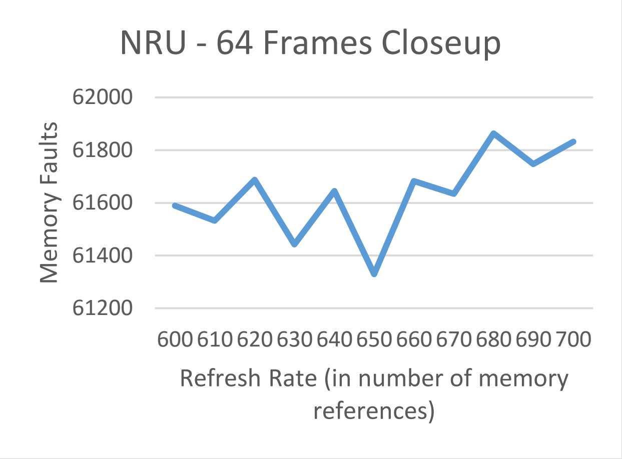


Once I found the refresh rate around which the number of page faults seemed to bottom out, I went through and to a more granular approach, getting page fault data with refresh rates increasing in steps of five for 8 frames and steps of ten for 16, 32, and 64 frames. See graphs below.









After comparing the statistics at each of the frame rate values, the refresh rates that I determined to use were the following:

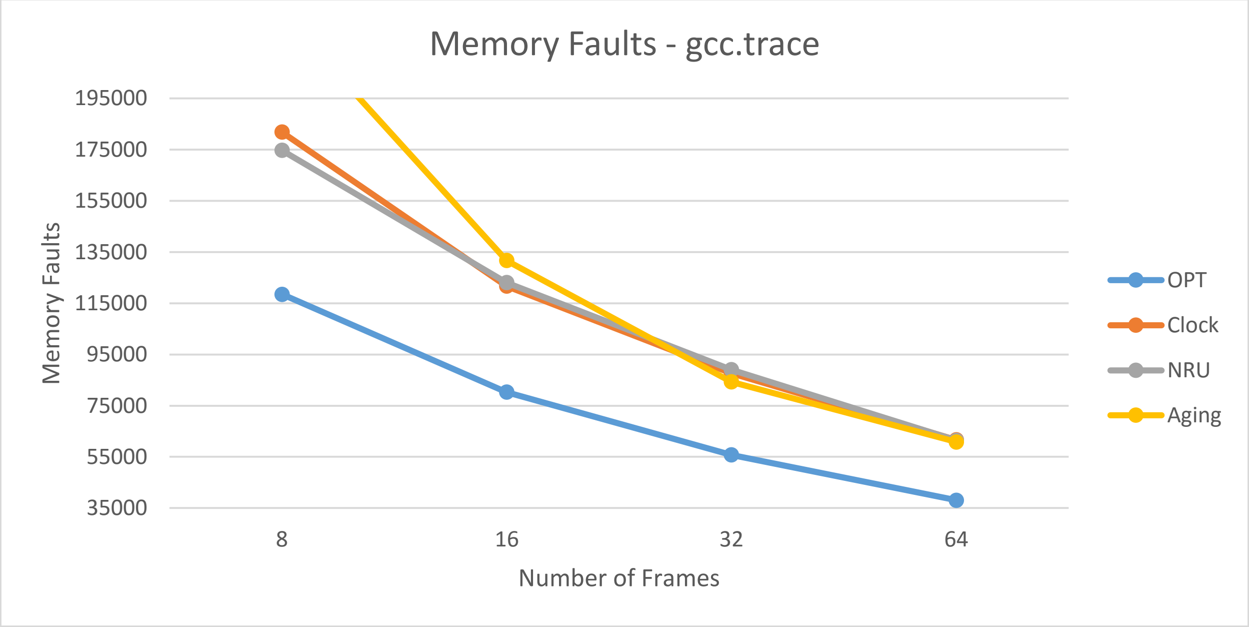
Frames	Optimal Refresh Rate
8	20
16	80
32	200
64	650

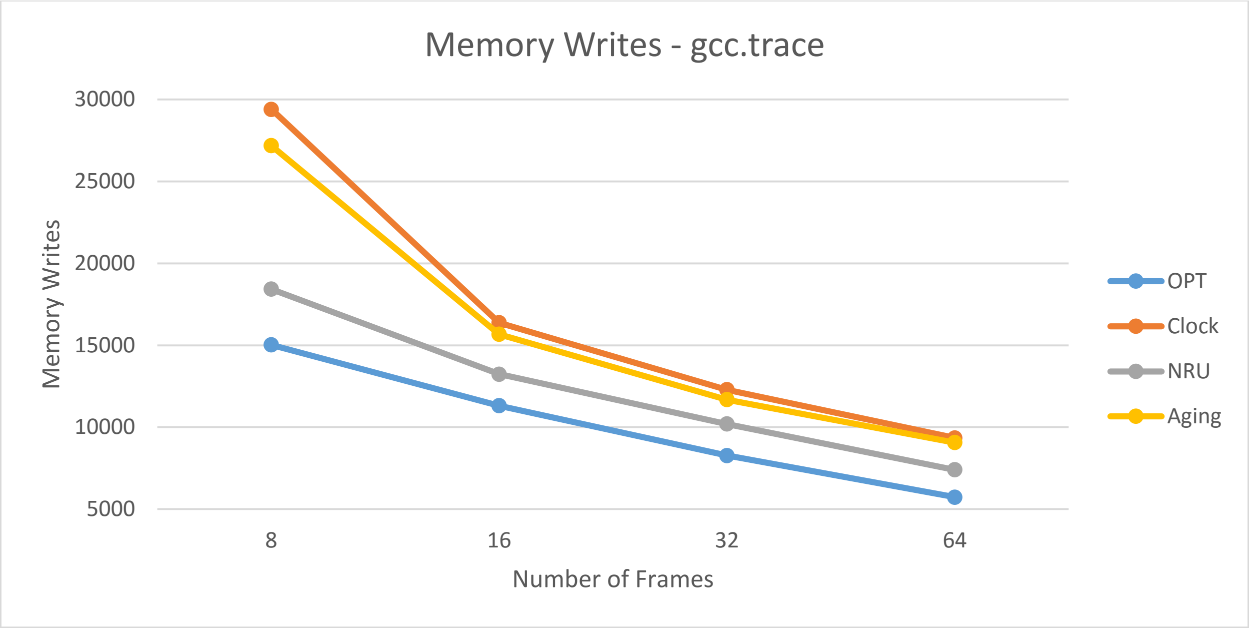
Page Replacement Algorithm Analysis

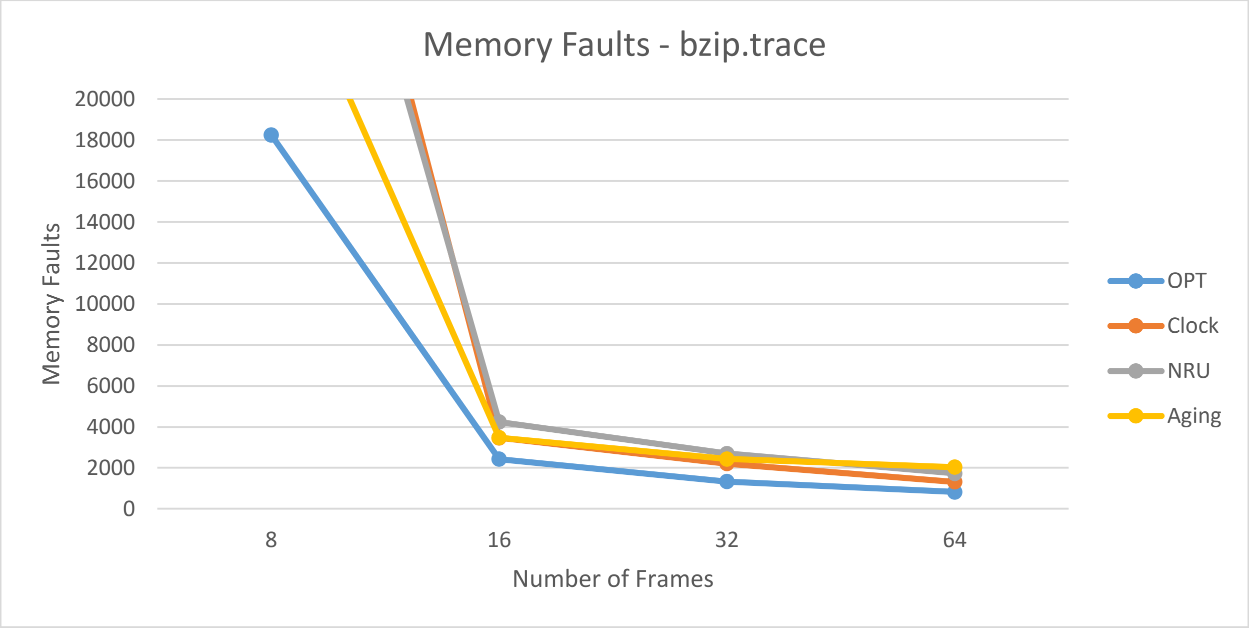
For analysis of the four page replacement algorithms there were two results to be considered: the number of memory faults and the number of writes to disk that needed to be performed due to evictions. So I ran each algorithm at 8, 16, 32, and 64 frames, using the refresh rates above for NRU. I started out using those refresh rates for the Aging algorithm as well, but before tracking the actual stats I had been using a placeholder refresh rate of 100 and that rate had given better results overall than NRU's refresh rates. I tested refresh rates for Aging a bit further (I did not do as complete of an analysis as with NRU) and landed on a refresh rate of 50 for the aging algorithm and I used that rate for each number of frames. Data is listed below, and graph representations follow.

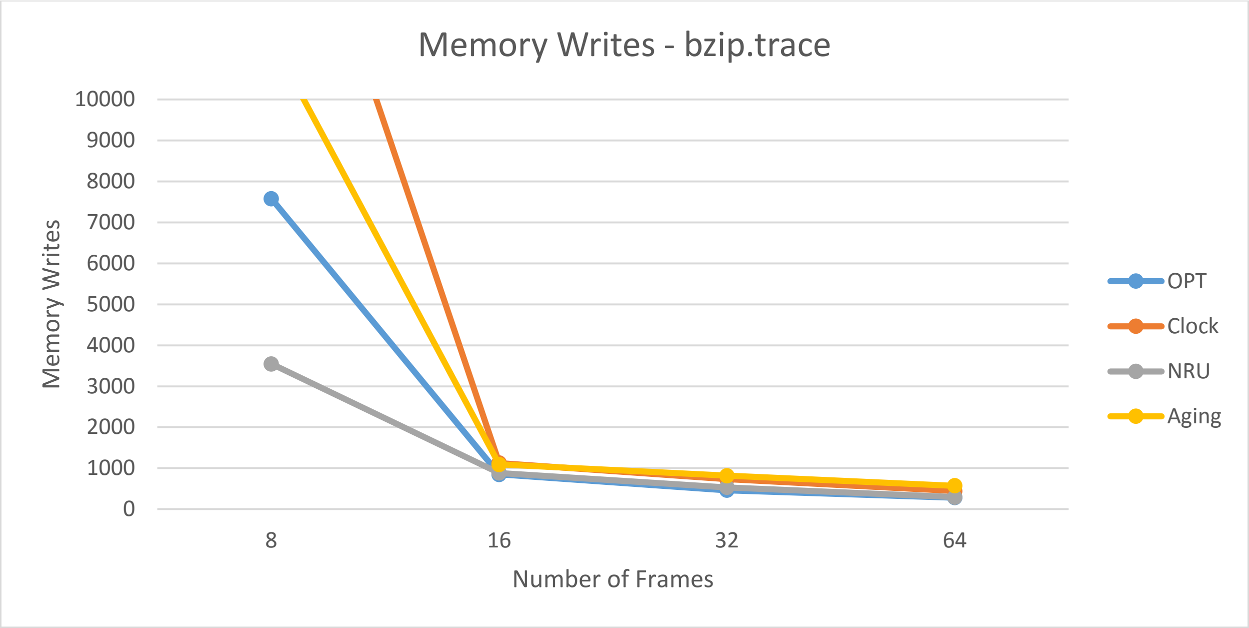
gcc.trace								
	OPT				Clock			
Frames	8	16	32	64	8	16	32	64
Faults	118480	80307	55802	38050	181856	121682	87686	61640
Writes	15031	11316	8274	5730	29401	16376	12293	9346
% Worse than OPT Faults	-	-	-	-	53.49	51.52	57.14	62.00
% Worse than OPT Writes	-	-	-	-	95.60	44.72	48.57	63.11
	NRU				Aging			
Frames	8	16	32	64	8	16	32	64
Faults	174734	123058	89037	61489	228396	131684	84304	60834
Writes	18428	13235	10198	7406	27184	15669	11680	9069
% Worse than OPT Faults	47.48	53.23	59.56	61.60	92.77	63.98	51.08	59.88
% Worse than OPT Writes	22.60	16.96	23.25	29.25	80.85	38.47	41.17	58.27
bzip.trace								
	OPT				Clock			
Frames	8	16	32	64	8	16	32	64
Faults	18251	2427	1330	821	46164	3468	2203	1318
Writes	7580	847	460	283	17568	1128	734	443
% Worse than OPT Faults	-	-	-	-	152.94	42.89	65.64	60.54
% Worse than OPT Writes	-	-	-	-	131.77	33.18	59.57	56.54

bzip.trace continued								
	NRU				Aging			
Frames	8	16	32	64	8	16	32	64
Faults	43191	4236	2701	1732	28695	3471	2436	2037
Writes	3547	884	532	292	11473	1091	818	573
% Worse than OPT Faults	136.65	74.54	103.08	110.96	57.22	43.02	83.16	148.11
% Worse than OPT Writes	-53.21	4.37	15.65	3.18	51.36	28.81	77.83	102.47




Memory Writes - gcc.trace
30000
25000
20000
15000
10000
5000
Memory Writes
8
16
32
64
Number of Frames
OPT
Clock
NRU
Aging


Memory Faults - bzip.trace
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Memory Faults
8
16
32
64
Number of Frames
OPT
Clock
NRU
Aging



Conclusion

After looking at all the numbers, it is somewhat disheartening just how much worse they all are than OPT. If only we could always have perfect future knowledge! That said, the number of memory faults that occur for each of the algorithms tend to follow the same general trajectory, decreasing when the number of available frames increases – this is as expected. And in terms of memory faults, none of the non-OPT algorithms really stand out as a clear winner.

This leads me to think that the determining metric in choosing an algorithm for use in a real operating system might instead come down to the number of writes to disk that need to be performed. After all, that is the most expensive part of swapping pages in and out. With these files, the clear winner was NRU. In the bzip.trace file, NRU beat OPT in terms of memory writes performed when there were eight available frames and continued to pretty closely mirror OPT's performance in this metric for the other runs. Based on these statistics, which are admittedly a small sample given we only had two files to work with, and assuming that the writing to disk is the primary source of work that needs to be done, I would choose the NRU algorithm over the other options.