**Part I: Determining Optimal Refresh Period for Aging Algorithm**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 8 Frames | Swim.trace | | Gzip.trace | | Gcc.trace | |
| **Refresh Period** | **Page Faults** | **Disk Writes** | **Page Faults** | **Disk Writes** | **Page Faults** | **Disk Writes** |
| 1 | 45085 | 15935 | 40037 | 39909 | 64699 | 24215 |
| 2 | 32961 | 14130 | 39974 | 39889 | 41246 | 11745 |
| 3 | 29814 | 11622 | 39947 | 39878 | 30739 | 8608 |
| 4 | 26279 | 3832 | 39935 | 39869 | 27728 | 7791 |
| 5 | 23078 | 3664 | 39927 | 39867 | 25584 | 6979 |
| 6 | 21293 | 4264 | 39918 | 39865 | 24277 | 6588 |
| 7 | 18106 | 3107 | 39907 | 39861 | 24045 | 6615 |
| 8 | 7919 | 3412 | 39913 | 39865 | 22769 | 6213 |
| 9 | 8735 | 3581 | 39909 | 39863 | 22420 | 6223 |
| 10 | 8600 | 4280 | 39906 | 39863 | 22769 | 6463 |
| 11 | 9367 | 5043 | 39903 | 39860 | 22753 | 6619 |
| 12 | 9408 | 5059 | 39906 | 39863 | 22724 | 6808 |
| 13 | 9543 | 5123 | 39902 | 39861 | 22585 | 6862 |
| 14 | 9482 | 5043 | 39901 | 39861 | 22494 | 6907 |
| 15 | 9458 | 5003 | 39901 | 39861 | 22362 | 6944 |

|  |  |  |
| --- | --- | --- |
| 8 Frames | Average | |
| **Refresh Period** | **Page Faults** | **Disk Writes** |
| 1 | 49940.33333 | 26686.3333 |
| 2 | 38060.33333 | 21921.3333 |
| 3 | 33500 | 20036 |
| 4 | 31314 | 17164 |
| 5 | 29529.66667 | 16836.6667 |
| 6 | 28496 | 16905.6667 |
| 7 | 27352.66667 | 16527.6667 |
| 8 | 23533.66667 | 16496.6667 |
| 9 | 23688 | 16555.6667 |
| 10 | 23758.33333 | 16868.6667 |
| 11 | 24007.66667 | 17174 |
| 12 | 24012.66667 | 17243.3333 |
| 13 | 24010 | 17282 |
| 14 | 23959 | 17270.3333 |
| 15 | 23907 | 17269.3333 |

As demonstrated in the chart and graph, when the number of frames was eight, a refresh period of 8 cycles yielded the lowest average number of both page faults and disk writes when testing all three trace files.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 16 Frames | Swim.trace | | Gzip.trace | | Gcc.trace | |
| **Refresh Period** | **Page Faults** | **Disk Writes** | **Page Faults** | **Disk Writes** | **Page Faults** | **Disk Writes** |
| 50 | 707 | 307 | 39884 | 39845 | 6839 | 2171 |
| 100 | 600 | 274 | 39882 | 39844 | 6049 | 2025 |
| 150 | 581 | 273 | 39882 | 39844 | 5921 | 1954 |
| 200 | 583 | 269 | 39887 | 39848 | 5857 | 1846 |
| 250 | 561 | 259 | 39888 | 39849 | 5911 | 1803 |
| 300 | 554 | 253 | 39898 | 39850 | 5957 | 1745 |
| 350 | 574 | 267 | 39891 | 39849 | 6015 | 1734 |
| 400 | 563 | 252 | 39930 | 39856 | 6069 | 1688 |
| 450 | 576 | 262 | 39930 | 39858 | 6140 | 1613 |
| 500 | 565 | 257 | 39928 | 39854 | 6235 | 1610 |

|  |  |  |
| --- | --- | --- |
| 16 Frames | Average | |
| **Refresh Period** | **Page Faults** | **Disk Writes** |
| 50 | 15810 | 14107.667 |
| 100 | 15510.3333 | 14047.667 |
| 150 | 15461.3333 | 14023.667 |
| 200 | 15442.3333 | 13987.667 |
| 250 | 15453.3333 | 13970.333 |
| 300 | 15469.6667 | 13949.333 |
| 350 | 15493.3333 | 13950 |
| 400 | 15520.6667 | 13932 |
| 450 | 15548.6667 | 13911 |
| 500 | 15576 | 13907 |

From the chart and graph, the average lowest number of page faults for 16 frames occurred when the refresh period was 200 cycles. It also had a rather low average number of disk writes.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 32 Frames | Swim.trace | | | | Gzip.trace | | Gcc.trace | |
| **Refresh Period** | **Page Faults** | | **Disk Writes** | | **Page Faults** | **Disk Writes** | **Page Faults** | **Disk Writes** |
| 50 | 544 | | 202 | | 39873 | 39821 | 4249 | 1076 |
| 100 | 439 | | 157 | | 39875 | 39823 | 2173 | 670 |
| 150 | 364 | | 124 | | 39874 | 39822 | 1582 | 539 |
| 200 | 322 | | 110 | | 39874 | 39822 | 1338 | 487 |
| 250 | 291 | | 104 | | 39874 | 39822 | 1123 | 432 |
| 300 | 268 | | 97 | | 39874 | 39822 | 968 | 413 |
| 350 | 241 | | 90 | | 39874 | 39822 | 910 | 384 |
| 400 | 237 | | 89 | | 39875 | 39823 | 858 | 382 |
| 450 | 225 | | 86 | | 39884 | 39825 | 827 | 367 |
| 500 | 219 | | 85 | | 39895 | 39829 | 809 | 367 |
| 32 Frames | Average | | |
| **Refresh Period** | **Page Faults** | **Disk Writes** | |
| 50 | 14888.6667 | 13699.667 | |
| 100 | 14162.3333 | 13550 | |
| 150 | 13940 | 13495 | |
| 200 | 13844.6667 | 13473 | |
| 250 | 13762.6667 | 13452.667 | |
| 300 | 13703.3333 | 13444 | |
| 350 | 13675 | 13432 | |
| 400 | 13656.6667 | 13431.333 | |
| 450 | 13645.3333 | 13426 | |
| 500 | 13641 | 13427 | |

With 32 frames, the lowest average number of page faults and disk writes occurred when the refresh cycle was at 500.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 64 Frames | Swim.trace | | Gzip.trace | | Gcc.trace | |
| **Refresh Period** | **Page Faults** | **Disk Writes** | **Page Faults** | **Disk Writes** | **Page Faults** | **Disk Writes** |
| 50 | 380 | 106 | 39873 | 39789 | 3131 | 641 |
| 100 | 187 | 35 | 39873 | 39789 | 1637 | 456 |
| 150 | 296 | 65 | 39872 | 39788 | 1221 | 374 |
| 200 | 270 | 59 | 39874 | 39790 | 1045 | 348 |
| 250 | 174 | 32 | 39874 | 39790 | 869 | 306 |
| 300 | 229 | 52 | 39874 | 39790 | 754 | 295 |
| 350 | 211 | 48 | 39874 | 39790 | 711 | 274 |
| 400 | 164 | 28 | 39874 | 39790 | 654 | 275 |
| 450 | 181 | 36 | 39874 | 39790 | 626 | 267 |
| 500 | 184 | 44 | 39874 | 39790 | 604 | 262 |
| 550 | 185 | 46 | 39874 | 39790 | 610 | 265 |
| 600 | 151 | 22 | 39874 | 39790 | 605 | 259 |
| 650 | 180 | 44 | 39874 | 39790 | 593 | 252 |
| 700 | 178 | 42 | 39874 | 39790 | 575 | 240 |
| 750 | 141 | 21 | 39874 | 39790 | 571 | 240 |
| 800 | 177 | 44 | 39874 | 39790 | 559 | 235 |
| 850 | 177 | 44 | 39874 | 39790 | 558 | 235 |
| 900 | 172 | 42 | 39876 | 39791 | 551 | 228 |
| 950 | 148 | 23 | 39882 | 39793 | 550 | 228 |
| 1000 | 173 | 43 | 39875 | 39791 | 539 | 220 |

|  |  |  |
| --- | --- | --- |
| 64 Frames | Average | |
| **Refresh Period** | **Page Faults** | **Disk Writes** |
| 50 | 14461.3333 | 13512 |
| 100 | 13899 | 13426.667 |
| 150 | 13796.3333 | 13409 |
| 200 | 13729.6667 | 13399 |
| 250 | 13639 | 13376 |
| 300 | 13619 | 13379 |
| 350 | 13598.6667 | 13370.667 |
| 400 | 13564 | 13364.333 |
| 450 | 13560.3333 | 13364.333 |
| 500 | 13554 | 13365.333 |
| 550 | 13556.3333 | 13367 |
| 600 | 13543.3333 | 13357 |
| 650 | 13549 | 13362 |
| 700 | 13542.3333 | 13357.333 |
| 750 | 13528.6667 | 13350.333 |
| 800 | 13536.6667 | 13356.333 |
| 850 | 13536.3333 | 13356.333 |
| 900 | 13533 | 13353.667 |
| 950 | 13526.6667 | 13348 |
| 1000 | 13529 | 13351.333 |

For 64 frames, the lowest average number of page faults and disk writes occurs when refresh cycles is 950.

**Part 2: Page Fault Statistics for Number of Frames among the Algorithms**

When number of frames was 8, the refresh cycles for the aging algorithm was 8 CPU cycles.

When number of frames was 16, the refresh cycles for the aging algorithm was 200 CPU cycles.

When number of frames was 32, the refresh cycles for the aging algorithm was 500 CPU cycles.

When number of frames was 64, the refresh cycles for the aging algorithm was 950 CPU cycles.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Swim.trace | | | Gzip.trace | | |
| **Frames** | **FIFO** | **OPT** | **Aging** | **FIFO** | **OPT** | **Aging** |
| 8 | 13893 | 4417 | 7919 | 44918 | 39874 | 39913 |
| 16 | 844 | 358 | 583 | 42384 | 39856 | 39887 |
| 32 | 326 | 144 | 219 | 41120 | 39856 | 39895 |
| 64 | 177 | 135 | 148 | 40496 | 39856 | 39882 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Gcc.trace | | | Average | | |
| **Frames** | **FIFO** | **OPT** | **Aging** | **FIFO** | **OPT** | **Aging** |
| 8 | 29011 | 13328 | 22769 | 29274 | 19206.333 | 23533.6667 |
| 16 | 8568 | 3020 | 5857 | 17265.3333 | 14411.333 | 15442.3333 |
| 32 | 1375 | 491 | 809 | 14273.6667 | 13497 | 13641 |
| 64 | 551 | 318 | 550 | 13741.3333 | 13436.333 | 13526.6667 |

Based on the table and graph, aging seems to be the best algorithm to use for an actual OS. Compared to FIFO, it has less page faults for each frame size and therefore is closer to the optimal number of page faults. In addition, compared to OPT, it’s more practical since a real-life OS won’t be able to predict what pages will be accessed in the future.

**Part 3: Instances of Belady’s Anomaly:**

There are two instances of Belady’s Anomaly which occurs when running FIFO on gcc.trace. For number of frames at 91, the number of page faults is 457. However, for number of frames at 92 and 93, the number of page faults is 458.