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**Analysis Overview:**

Figure 1 – gcc.trace analysis of several page replacement algorithms. WSClock uses 100 as its refresh rate parameter.

Figure 2 - swim.trace analysis of several page replacement algorithms. WSClock uses 100 as its refresh rate parameter

**Aging Analysis:**

Figure 3 - Aging Algorithm analysis for gcc.trace using different refresh rates.

Figure 4 - Aging Algorithm analysis for swim.trace using different refresh rates.

**WSClock Analysis:**

Figure 5 - WSClock Algorithm analysis for gcc.trace using different tau rates.

Figure 6 - WSClock Algorithm analysis for swim.trace using different tau rates.

According to the data for both trace files, the clock algorithm generates the least page faults on average for any number of frames given as the parameter. However, as noted in Figure 2 for both the 8 frames and 16 frames run, the clock simulation is not the preferred algorithm. In this case, the WSClock is preferred. Furthermore, according to the data having higher frames always generates less page faults. Across both Figure 1 and Figure 2, having 64 frames significantly decreases the number of page faults compared to 8 frames. Practically, this would not be a good choice as the memory overhead increases proportionately to the number of frames. The developer should make an informed and consistent approach should the developer have the choice on the number of frames to use in virtual memory implementation. Interestingly, the WSClock implementation for both trace files did not dramatically decrease or increase the number of page faults. Additionally, relative to the other algorithms, aging does not seem like a good choice for virtual memory management.

Looking at the aging analysis for Figure 3 and Figure 4, it seems that having a low refresh rate negatively impacts the performance of the aging algorithm. The data shows that using a refresh rate somewhere between 50 and 250 gives the least number of page faults. However, when using a low number of frames, having even a lower refresh rate is preferred. Anything more than 500 as a refresh rate shows an increase number of page faults for 8, 16, and 32 frames. Logically this makes sense as having a longer refresh rate increases the chances of encountering an invalid page, or a page fault. For 8 frames, anything lower than 100 is preferred.

Looking at the WSClock analysis for Figure 5 and Figure 6, surprisingly there was no dramatic change of page faults regardless of the tau parameter set at a refresh rate of 100. This leads me to two conclusions. Either there is an implementation error or the refresh rate to tau ratio is not optimal. The data shows a faulty logic in the way that page faults are generated when tau surpasses the set refresh rate. This leads me to believe that there is an implementation error as the page faults should largely be the same for any tau set at equal to or greater than the refresh rate as no page will ever be older than tau. However, I also believe that choosing the right refresh rate to tau ratio is important in determining a good choice for tau. According to the data, any tau set between 50 and 100 seems to be a good choice for this implementation. Having a low tau would accrue unnecessary work and having a tau greater than the refresh rate would be pointless.

In conclusion, the WSClock is the preferred choice for swim.trace whereas the Clock algorithm is the preferred choice for gcc.trace. The challenge with WSClock comes with determining a good ratio between the refresh rate and tau, and the data shows that it is inconsistent between different trace files. A virtual memory developer would need to be conscientious on how different refresh rates to tau might affect the performance for different task which would incur extra work overhead. In short, I believe the second chance variant Clock algorithm to be the best algorithm supported by the data.

**Appendix A – gcc.trace data**

OPT

|  |  |  |
| --- | --- | --- |
| Frames | Page Faults | Disk Writes |
| 8 | 118480 | 15032 |
| 16 | 80307 | 11319 |
| 32 | 55802 | 8279 |
| 64 | 38050 | 5746 |

Clock

|  |  |  |
| --- | --- | --- |
| Frames | Page Faults | Disk Writes |
| 8 | 205377 | 37529 |
| 16 | 138703 | 24109 |
| 32 | 97907 | 16745 |
| 64 | 69778 | 12044 |

Aging

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 100 | 257852 | 26791 |
| 16 | 100 | 190390 | 24016 |
| 32 | 100 | 148523 | 21540 |
| 64 | 100 | 145539 | 21321 |

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 200 | 290462 | 22414 |
| 16 | 200 | 192121 | 20278 |
| 32 | 200 | 118252 | 17104 |
| 64 | 200 | 112971 | 16461 |

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 500 | 324714 | 20391 |
| 16 | 500 | 245743 | 16670 |
| 32 | 500 | 142737 | 15076 |
| 64 | 500 | 84743 | 12770 |

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 800 | 350037 | 23827 |
| 16 | 800 | 265894 | 15316 |
| 32 | 800 | 177347 | 13874 |
| 64 | 800 | 82459 | 11731 |

WSClock

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 25 | 337330 | 39594 |
| 16 | 100 | 25 | 254825 | 22786 |
| 32 | 100 | 25 | 189779 | 13435 |
| 64 | 100 | 25 | 128388 | 6903 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 50 | 259054 | 31350 |
| 16 | 100 | 50 | 212858 | 22630 |
| 32 | 100 | 50 | 163759 | 13607 |
| 64 | 100 | 50 | 118640 | 6875 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 100 | 233374 | 38642 |
| 16 | 100 | 100 | 169187 | 17634 |
| 32 | 100 | 100 | 142809 | 12517 |
| 64 | 100 | 100 | 106199 | 6993 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 250 | 210187 | 38445 |
| 16 | 100 | 250 | 158140 | 24230 |
| 32 | 100 | 250 | 120551 | 13239 |
| 64 | 100 | 250 | 92852 | 7319 |

**Appendix B – swim.trace data**

OPT

|  |  |  |
| --- | --- | --- |
| Frames | Page Faults | Disk Writes |
| 8 | 171244 | 46452 |
| 16 | 78312 | 18134 |
| 32 | 28826 | 6916 |
| 64 | 14289 | 4114 |

Clock

|  |  |  |
| --- | --- | --- |
| Frames | Page Faults | Disk Writes |
| 8 | 330879 | 55464 |
| 16 | 212795 | 46956 |
| 32 | 81498 | 18217 |
| 64 | 30368 | 7662 |

Aging

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 100 | 343419 | 45152 |
| 16 | 100 | 200675 | 34685 |
| 32 | 100 | 170477 | 30451 |
| 64 | 100 | 165984 | 29735 |

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 200 | 400652 | 31621 |
| 16 | 200 | 198018 | 29601 |
| 32 | 200 | 118348 | 20998 |
| 64 | 200 | 110965 | 20072 |

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 500 | 497998 | 21028 |
| 16 | 500 | 218758 | 17970 |
| 32 | 500 | 90960 | 14788 |
| 64 | 500 | 69591 | 12189 |

|  |  |  |  |
| --- | --- | --- | --- |
| Frames | Refresh Rate | Page Faults | Disk Writes |
| 8 | 800 | 547742 | 20128 |
| 16 | 800 | 245245 | 14412 |
| 32 | 800 | 100640 | 13093 |
| 64 | 800 | 60619 | 10088 |

WSClock

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 25 | 320489 | 50795 |
| 16 | 100 | 25 | 192518 | 37708 |
| 32 | 100 | 25 | 93031 | 9877 |
| 64 | 100 | 25 | 34194 | 8052 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 50 | 321995 | 50811 |
| 16 | 100 | 50 | 192459 | 38789 |
| 32 | 100 | 50 | 88703 | 11013 |
| 64 | 100 | 50 | 34327 | 8089 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 100 | 322170 | 50860 |
| 16 | 100 | 100 | 193842 | 39729 |
| 32 | 100 | 100 | 83971 | 12863 |
| 64 | 100 | 100 | 33883 | 7927 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frames | Refresh Rate | Tau | Page Faults | Disk Writes |
| 8 | 100 | 250 | 322146 | 50854 |
| 16 | 100 | 250 | 193783 | 39704 |
| 32 | 100 | 250 | 82008 | 16804 |
| 64 | 100 | 250 | 32813 | 7832 |