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Project 8 - Page Replacement Algorithms

Abstract:

In this project, our goal was to implement three page replacement algorithms including: first in, first out, least recently used, and optimal page replacement. Then we compared all three algorithms and which is the best to prevent the least number of page faults.

Results:

Example run:

FIFO:	31 [73, 19, 92, 42, 31] Miss	LRU:	31 [34, 19, 92, 42, 31] Miss
34 [34] Miss	92 [73, 19, 92, 42, 31] Hit	34 [34] Miss	92 [34, 19, 92, 42, 31] Hit
51 [34, 51] Miss	16 [19, 92, 42, 31, 16] Miss	51 [34, 51] Miss	16 [34, 92, 42, 31, 16] Miss
97 [34, 51, 97] Miss	62 [92, 42, 31, 16, 62] Miss	97 [34, 51, 97] Miss	62 [34, 42, 31, 16, 62] Miss
36 [34, 51, 97, 36] Miss	73 [42, 31, 16, 62, 73] Miss	36 [34, 51, 97, 36] Miss	73 [34, 31, 16, 62, 73] Miss
7 [34, 51, 97, 36, 7] Miss	7 [31, 16, 62, 73, 7] Miss	7 [34, 51, 97, 36, 7] Miss	7 [34, 16, 62, 73, 7] Miss
38 [51, 97, 36, 7, 38] Miss	22 [16, 62, 73, 7, 22] Miss	38 [34, 97, 36, 7, 38] Miss	22 [34, 62, 73, 7, 22] Miss
68 [97, 36, 7, 38, 68] Miss	60 [62, 73, 7, 22, 60] Miss	68 [34, 36, 7, 38, 68] Miss	60 [34, 73, 7, 22, 60] Miss
31 [36, 7, 38, 68, 31] Miss	18 [73, 7, 22, 60, 18] Miss	31 [34, 7, 38, 68, 31] Miss	18 [34, 7, 22, 60, 18] Miss
6 [7, 38, 68, 31, 6] Miss	1 [7, 22, 60, 18, 1] Miss	6 [34, 38, 68, 31, 6] Miss	1 [34, 22, 60, 18, 1] Miss
8 [38, 68, 31, 6, 8] Miss	80 [22, 60, 18, 1, 80] Miss	8 [34, 68, 31, 6, 8] Miss	80 [34, 60, 18, 1, 80] Miss
10 [68, 31, 6, 8, 10] Miss	94 [60, 18, 1, 80, 94] Miss	10 [34, 31, 6, 8, 10] Miss	94 [34, 18, 1, 80, 94] Miss
41 [31, 6, 8, 10, 41] Miss	15 [18, 1, 80, 94, 15] Miss	41 [34, 6, 8, 10, 41] Miss	15 [34, 1, 80, 94, 15] Miss
99 [6, 8, 10, 41, 99] Miss	37 [1, 80, 94, 15, 37] Miss	99 [34, 8, 10, 41, 99] Miss	37 [34, 80, 94, 15, 37] Miss
91 [8, 10, 41, 99, 91] Miss	39 [80, 94, 15, 37, 39] Miss	91 [34, 10, 41, 99, 91] Miss	39 [34, 94, 15, 37, 39] Miss
65 [10, 41, 99, 91, 65] Miss	98 [94, 15, 37, 39, 98] Miss	65 [34, 41, 99, 91, 65] Miss	98 [34, 15, 37, 39, 98] Miss
73 [41, 99, 91, 65, 73] Miss	56 [15, 37, 39, 98, 56] Miss	73 [34, 99, 91, 65, 73] Miss	56 [34, 37, 39, 98, 56] Miss
92 [99, 91, 65, 73, 92] Miss	94 [37, 39, 98, 56, 94] Miss	92 [34, 91, 65, 73, 92] Miss	94 [34, 39, 98, 56, 94] Miss
92 [99, 91, 65, 73, 92] Hit	49 [39, 98, 56, 94, 49] Miss	92 [34, 91, 65, 73, 92] Hit	49 [34, 98, 56, 94, 49] Miss
46 [91, 65, 73, 92, 46] Miss	94 [39, 98, 56, 94, 49] Hit	46 [34, 65, 73, 92, 46] Miss	94 [34, 98, 56, 94, 49] Hit
6 [65, 73, 92, 46, 6] Miss	41 [98, 56, 94, 49, 41] Miss	6 [34, 73, 92, 46, 6] Miss	41 [34, 56, 94, 49, 41] Miss
26 [73, 92, 46, 6, 26] Miss	89 [56, 94, 49, 41, 89] Miss	26 [34, 92, 46, 6, 26] Miss	89 [34, 94, 49, 41, 89] Miss
31 [92, 46, 6, 26, 31] Miss	78 [94, 49, 41, 89, 78] Miss	31 [34, 46, 6, 26, 31] Miss	78 [34, 49, 41, 89, 78] Miss
32 [46, 6, 26, 31, 32] Miss	1 [49, 41, 89, 78, 1] Miss	32 [34, 6, 26, 31, 32] Miss	1 [34, 41, 89, 78, 1] Miss
74 [6, 26, 31, 32, 74] Miss	19 [41, 89, 78, 1, 19] Miss	74 [34, 26, 31, 32, 74] Miss	19 [34, 89, 78, 1, 19] Miss
61 [26, 31, 32, 74, 61] Miss	58 [89, 78, 1, 19, 58] Miss	61 [34, 31, 32, 74, 61] Miss	58 [34, 78, 1, 19, 58] Miss
93 [31, 32, 74, 61, 93] Miss	53 [78, 1, 19, 58, 53] Miss	93 [34, 32, 74, 61, 93] Miss	53 [34, 1, 19, 58, 53] Miss
54 [32, 74, 61, 93, 54] Miss	45 [1, 19, 58, 53, 45] Miss	54 [34, 74, 61, 93, 54] Miss	45 [34, 19, 58, 53, 45] Miss
56 [74, 61, 93, 54, 56] Miss	70 [19, 58, 53, 45, 70] Miss	56 [34, 61, 93, 54, 56] Miss	70 [34, 58, 53, 45, 70] Miss
90 [61, 93, 54, 56, 90] Miss	40 [58, 53, 45, 70, 40] Miss	90 [34, 93, 54, 56, 90] Miss	40 [34, 53, 45, 70, 40] Miss
	8 [53, 45, 70, 40, 8] Miss	68 [34, 54, 56, 90, 68] Miss	8 [34, 45, 70, 40, 8] Miss
	69 [45, 70, 40, 8, 69] Miss	32 [34, 56, 90, 68, 32] Miss	69 [34, 70, 40, 8, 69] Miss
	# of Page Faults: 95		# of Page Faults: 96

Optimal: 34 [34] Miss 51 [34, 51] Miss 97 [34, 51, 97] Miss 36 [34, 51, 97, 36] Miss 7 [34, 51, 97, 36, 7] Miss 38 [51, 97, 36, 7, 38] Miss 68 [97, 36, 7, 38, 68] Miss 31 [36, 7, 38, 68, 31] Miss 6 [7, 38, 68, 31, 6] Miss 8 [7, 68, 31, 8, 8] Miss 10 [7, 31, 8, 10, 10] Miss 41 [7, 31, 8, 41, 41] Miss 99 [7, 31, 8, 41, 99] Miss 91 [7, 31, 8, 41, 91] Miss 65 [7, 31, 8, 41, 65] Miss 73 [7, 8, 41, 73, 73] Miss 92 [7, 8, 41, 73, 92] Miss 92 [7, 8, 41, 73, 92] Hit 46 [7, 8, 41, 73, 46] Miss 6 [7, 8, 41, 73, 6] Miss 26 [7, 8, 41, 73, 26] Miss 31 [7, 8, 41, 73, 31] Miss 32 [7, 8, 41, 73, 32] Miss 74 [7, 8, 41, 73, 74] Miss 61 [7, 8, 41, 73, 61] Miss 93 [7, 8, 41, 73, 93] Miss 54 [7, 8, 41, 73, 54] Miss 56 [7, 8, 41, 56, 65] Miss 90 [7, 8, 41, 56, 90] Miss 68 [7, 8, 41, 56, 68] Miss	22 [8, 58, 78, 19, 22] Miss 60 [8, 58, 78, 19, 60] Miss 18 [8, 58, 78, 19, 18] Miss 1 [8, 58, 19, 1, 1] Miss 80 [8, 58, 19, 1, 80] Miss 94 [8, 58, 19, 1, 94] Miss 15 [8, 58, 19, 1, 15] Miss 37 [8, 58, 19, 1, 37] Miss 39 [8, 58, 19, 1, 39] Miss 98 [8, 58, 19, 1, 98] Miss 56 [8, 58, 19, 1, 56] Miss 94 [8, 58, 19, 1, 94] Miss 49 [8, 58, 19, 1, 49] Miss 94 [8, 58, 19, 1, 94] Miss 41 [8, 58, 19, 1, 41] Miss 89 [8, 58, 19, 1, 89] Miss 78 [8, 58, 19, 78, 78] Miss 1 [8, 58, 19, 1, 1] Miss 19 [8, 58, 19, 1, 1] Hit 58 [8, 58, 19, 1, 1] Hit 53 [8, 1, 1, 53, 53] Miss 45 [8, 53, 53, 45, 45] Miss 70 [8, 45, 45, 70, 70] Miss 40 [45, 70, 70, 40, 40] Miss 8 [45, 70, 40, 8, 8] Miss 69 [70, 40, 8, 8, 69] Miss # of Page Faults: 96	FIFO: 1 [1] Miss 2 [1, 2] Miss 1 [1, 2] Hit 5 [1, 2, 5] Miss 1 [1, 2, 5] Hit 2 [1, 2, 5] Hit 5 [1, 2, 5] Hit 8 [1, 2, 5, 8] Miss 10 [1, 2, 5, 8, 10] Miss 9 [2, 5, 8, 10, 9] Miss 9 [2, 5, 8, 10, 9] Hit 9 [2, 5, 8, 10, 9] Hit 12 [5, 8, 10, 9, 12] Miss 15 [8, 10, 9, 12, 15] Miss 11 [10, 9, 12, 15, 11] Miss 15 [10, 9, 12, 15, 11] Hit 13 [9, 12, 15, 11, 13] Miss 18 [12, 15, 11, 13, 18] Miss 15 [12, 15, 11, 13, 18] Hit 20 [15, 11, 13, 18, 20] Miss 22 [11, 13, 18, 20, 22] Miss 22 [11, 13, 18, 20, 22] Hit 19 [13, 18, 20, 22, 19] Miss 23 [18, 20, 22, 19, 23] Miss 24 [20, 22, 19, 23, 24] Miss 22 [20, 22, 19, 23, 24] Hit 25 [22, 19, 23, 24, 25] Miss 28 [19, 23, 24, 25, 28] Miss	77 [73, 76, 75, 74, 77] Miss 78 [76, 75, 74, 77, 78] Miss 78 [76, 75, 74, 77, 78] Hit 77 [76, 75, 74, 77, 78] Hit 83 [75, 74, 77, 78, 83] Miss 82 [74, 77, 78, 83, 82] Miss 82 [74, 77, 78, 83, 82] Hit 85 [77, 78, 83, 82, 85] Miss 85 [77, 78, 83, 82, 85] Hit 87 [78, 83, 82, 85, 87] Miss 84 [83, 82, 85, 87, 84] Miss 88 [82, 85, 87, 84, 88] Miss 90 [85, 87, 84, 88, 90] Miss 91 [87, 84, 88, 90, 91] Miss 88 [87, 84, 88, 90, 91] Hit 92 [84, 88, 90, 91, 92] Miss 93 [88, 90, 91, 92, 93] Miss 91 [88, 90, 91, 92, 93] Hit 94 [90, 91, 92, 93, 94] Miss 97 [91, 92, 93, 94, 97] Miss 96 [92, 93, 94, 97, 96] Miss 96 [92, 93, 94, 97, 96] Hit 99 [93, 94, 97, 96, 99] Miss # of Page Faults: 67
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Reference String (No locality, length of 100): [26, 56, 63, 51, 14, 23, 99, 71, 40, 55, 82, 97, 47, 14, 7, 56, 44, 28, 58, 34, 4, 48, 44, 72, 92, 22, 61, 78, 51, 68, 43, 60, 64, 1, 60, 12, 96, 30, 61, 46, 38, 34, 49, 30, 18, 60, 4, 61, 22, 35, 72, 83, 59, 13, 87, 36, 17, 57, 66, 0, 18, 5, 20, 19, 14, 58, 56, 19, 95, 94, 14, 83, 43, 37, 75, 92, 61, 21, 24, 68, 92, 56, 44, 77, 95, 88, 48, 64, 37, 49, 39, 27, 12, 16, 86, 64, 44, 89, 19, 14]

Reference String (Locality, length of 100): [2, 1, 3, 2, 2, 2, 6, 4, 10, 6, 8, 8, 13, 15, 16, 13, 13, 14, 18, 18, 19, 18, 22, 25, 21, 23, 26, 24, 26, 30, 28, 30, 32, 34, 36, 33, 36, 39, 37, 41, 41, 40, 41, 41, 46, 43, 46, 48, 46, 51, 51, 49, 51, 55, 56, 56, 56, 55, 56, 61, 57, 63, 63, 60, 66, 66, 63, 68, 69, 70, 67, 68, 69, 73, 76, 75, 75, 78, 79, 76, 81, 82, 81, 85, 82, 82, 84, 87, 85, 86, 92, 91, 89, 95, 91, 94, 97, 96, 95, 97]

Run 1	No Locality (# of Page Faults)	Locality (# of Page Faults)
First in, First Out (Fifo)	96	63
Least Recently Used (LRU)	98	63
Optimal Page Replacement	90	63

Reference String (No locality, length of 100): [1, 44, 6, 33, 23, 23, 5, 89, 5, 52, 56, 88, 96, 85, 90, 24, 16, 59, 96, 29, 48, 79, 60, 60, 36, 76, 46, 65, 65, 27, 45, 49, 33, 43, 63, 17, 44, 24, 23, 34, 35, 34, 17, 49, 50, 6, 79, 83, 79, 73, 20, 27, 26, 55, 21, 99, 47, 85, 55, 27, 55, 8, 51, 41, 44, 46, 34, 34, 33, 88, 18, 36, 40, 56, 7, 1, 96, 58, 47, 80, 86, 33, 7, 93, 30, 57, 12, 9, 92, 60, 96, 8, 59, 33, 37, 21, 31, 26, 89, 73]

Reference String (Locality, length of 100): [2, 2, 4, 1, 3, 4, 8, 5, 10, 7, 12, 8, 10, 10, 15, 15, 15, 16, 15, 18, 21, 19, 19, 24, 25, 23, 26, 28, 28, 27, 29, 31, 31, 32, 36, 33, 35, 39, 36, 36, 39, 38, 41, 42, 46, 43, 47, 45, 47, 48, 52, 49, 52, 51, 54, 55, 53, 57, 57, 61, 57, 60, 60, 65, 62, 65, 68, 68, 65, 67, 70, 71, 74, 70, 71, 72, 75, 75, 77, 77, 82, 79, 79, 82, 82, 87, 86, 88, 87, 90, 92, 88, 91, 91, 93, 95, 97, 96, 99, 96]

Run 2	No Locality (# of Page Faults)	Locality (# of Page Faults)
First in, First Out (Fifo)	92	67
Least Recently Used (LRU)	91	68
Optimal Page Replacement	92	67

Reference String (No locality, length of 100): [56, 50, 13, 83, 90, 25, 76, 35, 55, 54, 1, 20, 17, 41, 59, 25, 92, 21, 23, 97, 2, 13, 32, 4, 27, 82, 38, 54, 83, 99, 63, 29, 38, 63, 68, 15, 41, 96, 29, 43, 92, 20, 41, 61, 92, 43, 87, 46, 32, 30, 28, 7, 4, 16, 26, 85, 80, 97, 24, 85, 67, 67, 73, 78, 22, 36, 76, 32, 77, 96, 78, 89, 29, 22, 66, 79, 60, 86, 96, 65, 34, 41, 37, 14, 69, 90, 43, 63, 53, 7, 38, 36, 46, 21, 32, 28, 5, 4, 58, 91]

Reference String (Locality, length of 100): [1, 2, 1, 2, 2, 4, 8, 8, 7, 8, 8, 10, 9, 13, 11, 16, 18, 16, 18, 19, 20, 21, 22, 22, 24, 23, 26, 25, 30, 29, 28, 33, 32, 34, 36, 36, 33, 38, 40, 36, 42, 41, 43, 43, 41, 43, 48, 47, 48, 46, 47, 50, 54, 50, 54, 55, 53, 57, 60, 59, 59, 58, 61, 63, 66, 63, 64, 66, 67, 67, 68, 72, 70, 72, 76, 73, 77, 74, 79, 80, 79, 82, 79, 80, 81, 87, 85, 87, 88, 89, 87, 90, 92, 90, 93, 94, 96, 97, 98, 99]

Run 3	No Locality (# of Page Faults)	Locality (# of Page Faults)
First in, First Out (Fifo)	95	70
Least Recently Used (LRU)	96	70
Optimal Page Replacement	92	70

Reference String (No locality, length of 100): [99, 79, 32, 69, 52, 12, 39, 42, 65, 60, 70, 62, 44, 90, 60, 50, 83, 30, 15, 11, 41, 34, 42, 60, 2, 44, 34, 18, 12, 72, 25, 9, 54, 66, 12, 33, 42, 98, 21, 38, 78, 75, 61, 7, 80, 72, 96, 69, 32, 90, 63, 97, 68, 58, 83, 37, 10, 89, 97, 82, 27, 94, 61, 47, 52, 49, 37, 26, 1, 29, 4, 27, 79, 17, 25, 79, 76, 9, 60, 91, 42, 64, 53, 78, 87, 90, 48, 74, 68, 59, 25, 75, 95, 65, 56, 5, 32, 68, 97, 63]

Reference String (Locality, length of 100): [1, 2, 1, 2, 3, 6, 3, 9, 6, 10, 12, 10, 10, 10, 12, 14, 14, 17, 20, 17, 18, 23, 22, 21, 24, 22, 26, 28, 26, 31, 28, 33, 33, 32, 32, 37, 35, 36, 36, 41, 37, 40, 39, 42, 46, 47, 45, 49, 46, 51, 52, 49, 51, 54, 56, 56, 54, 55, 55, 61, 61, 59, 62, 65, 62, 63, 65, 67, 66, 68, 70, 68, 71, 73, 76, 72, 74, 74, 76, 80, 81, 78, 82, 81, 85, 86, 84, 86, 87, 88, 88, 93, 94, 90, 93, 93, 95, 97, 96, 97]

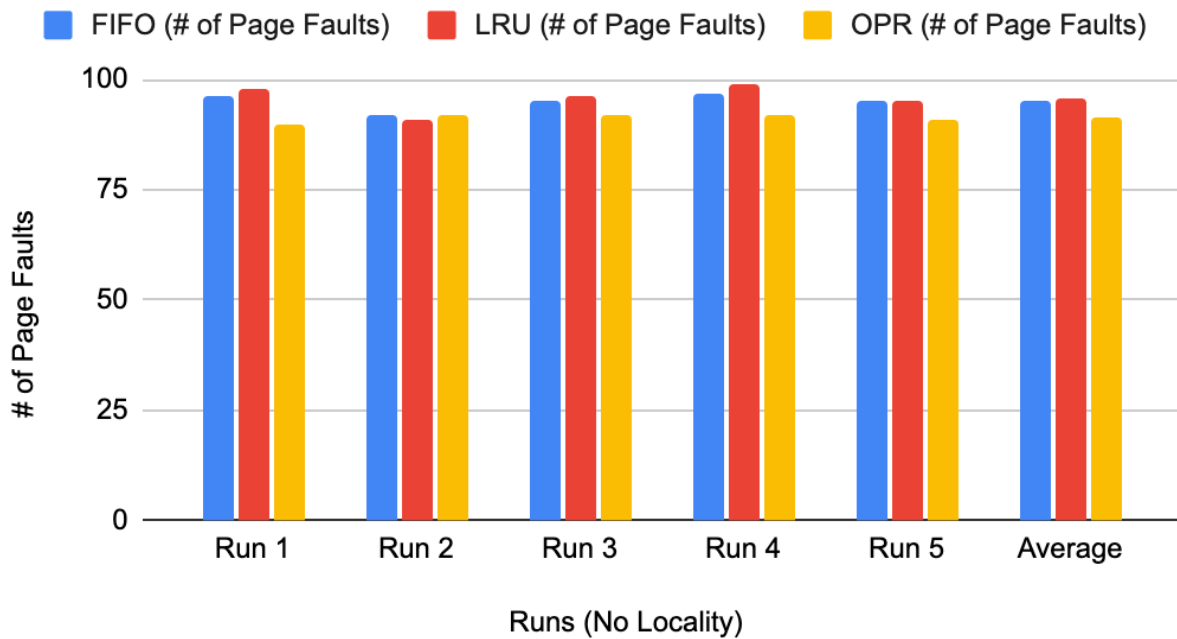
Run 4	No Locality (# of Page Faults)	Locality (# of Page Faults)
First in, First Out (Fifo)	97	63
Least Recently Used (LRU)	99	63
Optimal Page Replacement	92	63

[44, 63, 12, 2, 22, 93, 6, 78, 95, 0, 96, 94, 58, 72, 96, 64, 69, 77, 61, 86, 72, 5, 86, 85, 81, 77, 23, 42, 48, 59, 1, 70, 63, 52, 65, 21, 29, 56, 43, 44, 91, 56, 71, 95, 8, 80, 45, 86, 77, 14, 6, 95, 70, 72, 40, 82, 56, 32, 3, 10, 67, 79, 60, 52, 18, 88, 73, 89, 70, 29, 10, 78, 13, 11, 81, 86, 58, 80, 87, 58, 37, 53, 52, 22, 75, 63, 6, 24, 97, 56, 84, 6, 89, 99, 32, 51, 6, 63, 18, 45]

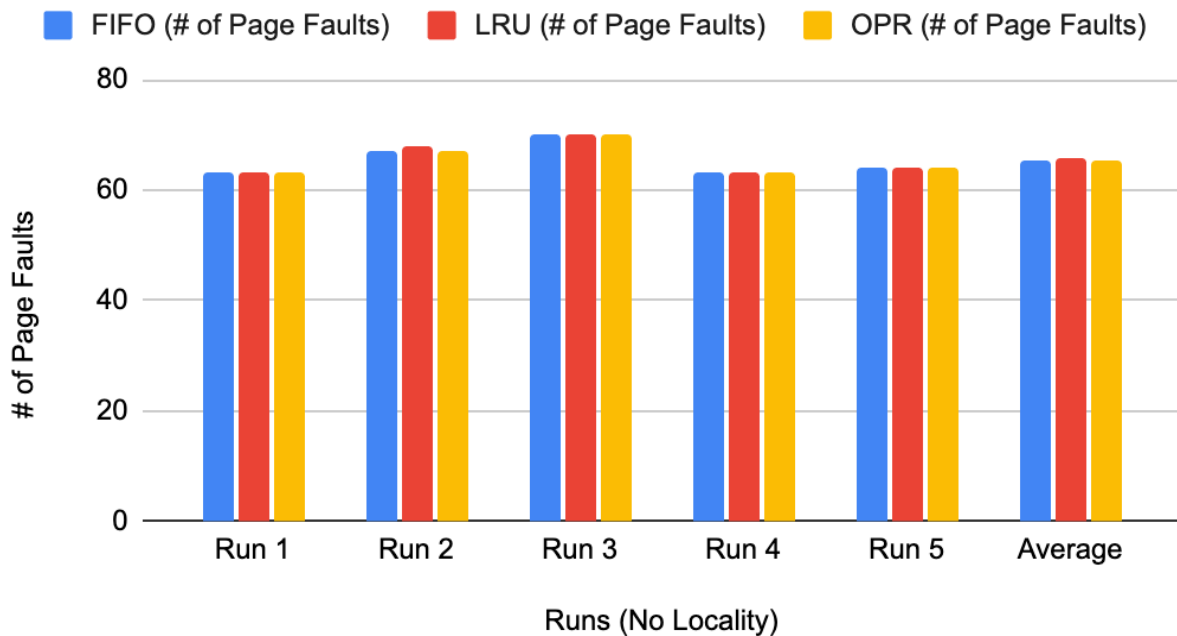
[1, 1, 3, 3, 5, 4, 8, 8, 10, 9, 8, 8, 10, 15, 11, 14, 18, 14, 17, 20, 21, 18, 23, 25, 24, 25, 27, 28, 25, 31, 27, 29, 29, 32, 36, 34, 38, 35, 36, 41, 40, 43, 42, 42, 45, 47, 47, 47, 50, 48, 51, 53, 49, 53, 52, 52, 53, 54, 60, 57, 62, 63, 63, 65, 62, 65, 67, 67, 66, 71, 69, 69, 74, 75, 75, 75, 74, 78, 75, 78, 77, 82, 82, 83, 84, 84, 84, 86, 88, 88, 87, 89, 93, 94, 95, 96, 93, 95, 96, 98]

Run 5	No Locality (# of Page Faults)	Locality (# of Page Faults)
First in, First Out (Fifo)	95	64
Least Recently Used (LRU)	95	64
Optimal Page Replacement	91	64

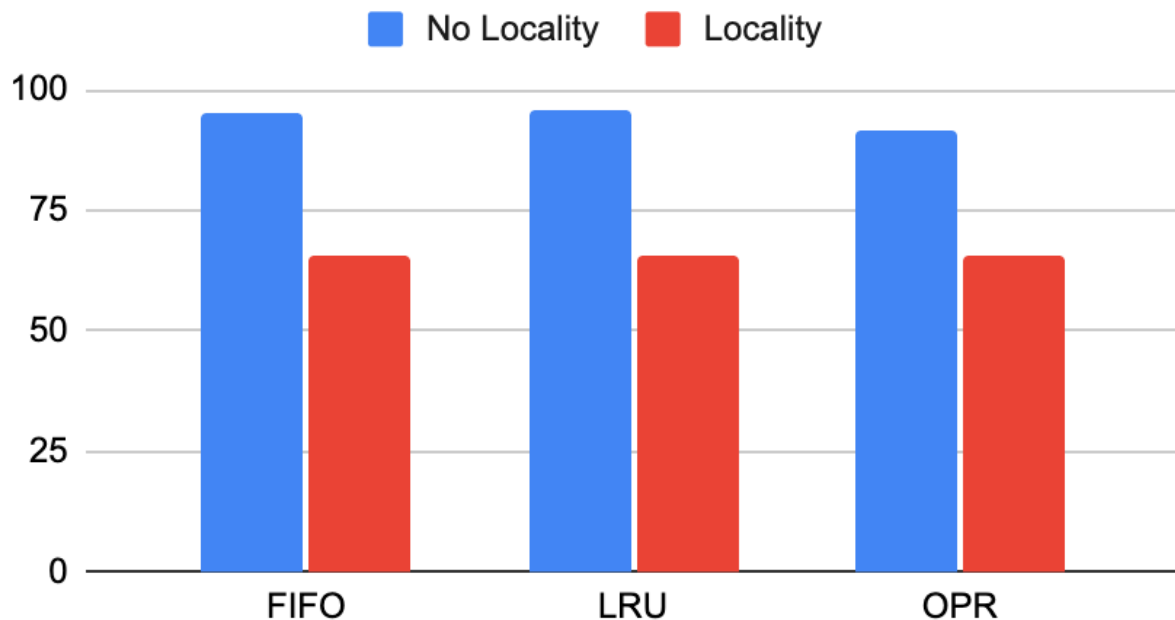
FIFO, LRU and OPR (No Locality)



FIFO, LRU and OPR (Locality)



No Locality vs Locality



Discussion:

Based on the data, we can see that when there is no locality, optimal page replacement always out-performs FIFO and LRU. When comparing FIFO and LRU for no locality, we can see that their performance is fairly similar, and their number of page faults do not vary too much.

As for when using locality, all three page replacement algorithms basically perform identically, so when using locality, whichever page replacement algorithm you use, it ultimately will not affect performance.

Extensions:

I did not do any extensions for this project.

Acknowledgements:

I did not get any help for this project.