# COEN-383
# Advanced Operating System
# Project 4 Report
# Group 4

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## Objective :

The objective of this project is to gain hands-on experience in exploring the various memory management algorithms for swapping and paging. This will be achieved by using a C program to operate various page replacement algorithms such as First-In-First-Out (FIFO), Least Recently Used (LRU), Least Frequently Used (LFU), Most Frequently Used (MFU), and Random Pick. The project involves generating random processes with varied sizes and durations, and organizing them into a Job Queue based on arrival time. The program will also manage the physical memory frames and disk pages, allocating memory to processes from the free pages list. Additionally, the program will generate the appropriate record whenever a job starts or completes. The key aspect of the project is the implementation of the chosen page replacement algorithm to select a victim page to evict, so that the needed page can be brought into memory. The program will track the hit and miss statistics for every run, and calculate the average number of processes successfully swapped-in for each replacement algorithm over multiple runs, and print the results. By completing this project, the student will gain valuable hands-on experience in understanding and implementing memory management algorithms, which are essential in the field of operating systems and computer architecture.

## Theory:

In understanding the dynamics of page replacement algorithms, it's crucial to delve into the distinct strategies they employ. The FCFS Algorithm, standing for First-Come-First-Served, adheres strictly to the principle of chronology, opting to replace the page that arrived earliest. Conversely, the LRU Algorithm, which stands for Least Recently Used, operates on the principle of recency, choosing to replace the page that has remained untouched for the longest duration. The LFU Algorithm, denoting Least Frequently Used, prioritizes the replacement of pages with the least number of references, aiming to optimize memory usage by eliminating infrequently accessed pages. In contrast, the MFU Algorithm, or Most Frequently Used, targets pages that have been referenced most often, favoring those with higher utilization rates to maintain

efficiency. Lastly, the R Algorithm introduces an element of randomness into the replacement process, selecting pages for eviction arbitrarily. Each of these algorithms offers a unique approach to managing memory resources, catering to various scenarios and optimizing system performance accordingly.

Each process does start at page-0 then every 100 msec it references a random page from its own address space.

- Locality of reference, after referencing a page i, there is a 70% probability that the next reference will be to page i, i-1, or i+1. It wraps around from 10 to 0. In other words, there is a 70% probability that for a given i, $\Delta i$ will be -1, 0, or +1. Otherwise, $|\Delta i| > 1$.
- We will be generating 150 jobs.
- Sort the random jobs generation based on arrival time and have them structured as a linked list.
- Processes have randomly and evenly distributed sizes of 5, 11, 17, and 31 MB.
- Processes have randomly and evenly distributed service durations of 1, 2, 3, 4, or 5 seconds.

## Code Execution

- A Makefile has been created to compile all the files and showcase the output. To execute the code, use the following command

#code execution:

make run

- To remove the object files and clean up the project directory, employ the command

#code clean:

make clean

# Result & Conclusion:

The Swapping and Paging Simulation project offers insightful information about how different page replacement methods impact an operating system's memory management and page swapping. Through a series of simulations using various

methods, the code facilitates performance comparison and analysis. The best performance in terms of Hit Ratio - we get is Least Recently Used Algorithm (LRU).

| Algorithm | Hit Ratio | Pages Swapped |
|---|---|---|
| FCFS | 2.6926 | 174 |
| LFU | 1.6255 | 163 |
| LRU | 2.7095 | 166 |
| MFU | 1.6576 | 149 |
| Random | 2.0306 | 143 |

## Outputs:

Screenshots from a Run on a Linux Machine:

```
********************************************************************************
Process id 117 is done. Memory is getting free
********************************************************************************
Average number of processes that were successfully swapped in: 181
The Hit-Miss Ratio: 1.948579

The Hit Ratio: 0.660854

The Miss Ratio: 0.339146
```

| Simulator | Hit-Miss Ratio | Hit Ratio | Miss Ratio | Average Swapped Processes |
|---|---|---|---|---|
| FCFS | 2.252583 | 0.692552 | 0.307448 | 174 |
| LRU | 2.442840 | 0.709542 | 0.290458 | 166 |
| LFU | 1.670343 | 0.625516 | 0.374484 | 163 |
| MFU | 1.920912 | 0.657641 | 0.342359 | 149 |
| Random | 2.030598 | 0.670032 | 0.329968 | 143 |

## First Come First Serve

```
------======= Running simulator   1 ========-------
Page::: 0 for process id::: 79 brought in at ::: 0.000000
Page::: 0 for process id::: 138 brought in at ::: 0.000000
Page::: 0 for process id::: 57 brought in at ::: 0.000000
Page::: 3 for process 79 brought in at 0.000000
Page::: 1 for process 138 brought in at 0.100000
Page::: 1 for process 57 brought in at 0.100000
Page::: 4 for process 79 brought in at 0.200000
Page::: 7 for process 57 brought in at 0.200000
Page::: 2 for process 79 brought in at 0.400000
Page::: 2 for process 138 brought in at 0.400000
Page::: 3 for process 57 brought in at 0.400000
Page::: 6 for process 57 brought in at 0.700000
Page::: 1 for process 79 brought in at 0.900000
Page::: 0 for process id::: 8 brought in at ::: 1.000000
Page::: 0 for process id::: 1 brought in at ::: 1.000000
Page::: 0 for process id::: 29 brought in at ::: 1.000000
Page::: 12 for process 8 brought in at 1.000000
Page::: 1 for process 1 brought in at 1.000000
Page::: 11 for process 57 brought in at 1.100000
Page::: 12 for process 29 brought in at 1.100000
Page::: 1 for process 8 brought in at 1.200000
Page::: 5 for process 29 brought in at 1.300000
Page::: 3 for process 1 brought in at 1.400000
Page::: 2 for process 57 brought in at 1.500000
Page::: 26 for process 8 brought in at 1.500000
Page::: 4 for process 29 brought in at 1.500000
Page::: 1 for process 29 brought in at 1.800000
Page::: 28 for process 29 brought in at 1.900000
######################################################################
Process id 138 is done. Memory is getting free ...
######################################################################
######################################################################
Process id 29 is done. Memory is getting free ...
######################################################################
Page::: 0 for process id::: 33 brought in at ::: 2.000000
Page::: 0 for process id::: 49 brought in at ::: 2.000000
Page::: 0 for process id::: 105 brought in at ::: 2.000000
Page::: 0 for process id::: 13 brought in at ::: 2.000000
Page::: 1 for process 13 brought in at 2.000000
Page::: 21 for process 33 brought in at 2.100000
Page::: 9 for process 105 brought in at 2.100000
Page::: 18 for process 8 brought in at 2.200000
Page::: 4 for process 1 brought in at 2.300000
Page::: 30 for process 33 brought in at 2.300000
Page::: 6 for process 105 brought in at 2.400000
Page::: 16 for process 57 brought in at 2.500000
Page::: 13 for process 8 brought in at 2.500000
Page::: 3 for process 49 brought in at 2.500000
Page::: 2 for process 13 brought in at 2.500000
Page::: 25 for process 33 brought in at 2.600000
Page::: 10 for process 49 brought in at 2.600000
Page::: 7 for process 13 brought in at 2.600000
Page::: 15 for process 33 brought in at 2.700000
Page::: 8 for process 105 brought in at 2.700000
Page::: 11 for process 13 brought in at 2.700000
Page::: 8 for process 33 brought in at 2.800000
Page::: 1 for process 105 brought in at 2.900000
Page::: 0 for process id::: 23 brought in at ::: 3.000000
Page::: 0 for process id::: 84 brought in at ::: 3.000000
Page::: 0 for process id::: 73 brought in at ::: 3.000000
Page::: 20 for process 8 brought in at 3.000000
Page::: 25 for process 23 brought in at 3.000000
Page::: 1 for process 73 brought in at 3.000000
Page::: 10 for process 57 brought in at 3.100000
Page::: 3 for process 84 brought in at 3.100000
Page::: 8 for process 57 brought in at 3.200000
Page::: 9 for process 33 brought in at 3.200000
```

## Least Frequently Used

```
./SIMULATION LFU
------======= Running simulator   1 ========-------
Page::: 0 for process id::: 5 brought in at ::: 0.000000
Page::: 0 for process id::: 30 brought in at ::: 0.000000
Page::: 0 for process id::: 85 brought in at ::: 0.000000
Page::: 0 for process id::: 113 brought in at ::: 0.000000
Page::: 1 for process 30 brought in at 0.000000
Page::: 10 for process 85 brought in at 0.000000
Page::: 6 for process 113 brought in at 0.000000
Page::: 9 for process 5 brought in at 0.100000
Page::: 2 for process 85 brought in at 0.100000
Page::: 16 for process 113 brought in at 0.200000
Page::: 3 for process 30 brought in at 0.300000
Page::: 1 for process 85 brought in at 0.300000
Page::: 14 for process 113 brought in at 0.400000
Page::: 1 for process 5 brought in at 0.600000
Page::: 1 for process 113 brought in at 0.600000
Page::: 4 for process 30 brought in at 0.700000
Page::: 9 for process 85 brought in at 0.900000
######################################################################
Process id 5 is done. Memory is getting free ...
######################################################################
Page::: 0 for process id::: 37 brought in at ::: 1.000000
Page::: 0 for process id::: 38 brought in at ::: 1.000000
Page::: 0 for process id::: 62 brought in at ::: 1.000000
Page::: 0 for process id::: 129 brought in at ::: 1.000000
Page::: 0 for process id::: 132 brought in at ::: 1.000000
Page::: 1 for process 132 brought in at 1.000000
Page::: 6 for process 85 brought in at 1.100000
Page::: 1 for process 37 brought in at 1.100000
Page::: 4 for process 129 brought in at 1.100000
Page::: 4 for process 132 brought in at 1.100000
Page::: 11 for process 113 brought in at 1.200000
Page::: 8 for process 129 brought in at 1.200000
Page::: 1 for process 129 brought in at 1.300000
Page::: 3 for process 132 brought in at 1.300000
Page::: 5 for process 113 brought in at 1.400000
Page::: 5 for process 129 brought in at 1.500000
Page::: 4 for process 85 brought in at 1.700000
Page::: 2 for process 30 brought in at 1.800000
Page::: 2 for process 132 brought in at 1.800000
Page::: 4 for process 37 brought in at 1.900000
Page::: 0 for process id::: 3 brought in at ::: 2.000000
Page::: 9 for process 113 brought in at 2.000000
Page::: 1 for process 3 brought in at 2.000000
Page::: 3 for process 37 brought in at 2.200000
Page::: 9 for process 129 brought in at 2.400000
Page::: 6 for process 3 brought in at 2.500000
Page::: 7 for process 113 brought in at 2.700000
Page::: 10 for process 3 brought in at 2.700000
######################################################################
Process id 85 is done. Memory is getting free ...
######################################################################
######################################################################
Process id 113 is done. Memory is getting free ...
######################################################################
######################################################################
Process id 37 is done. Memory is getting free ...
######################################################################
Page::: 0 for process id::: 65 brought in at ::: 3.000000
Page::: 0 for process id::: 72 brought in at ::: 3.000000
Page::: 9 for process 3 brought in at 3.000000
Page::: 1 for process 65 brought in at 3.000000
Page::: 1 for process 72 brought in at 3.000000
Page::: 6 for process 129 brought in at 3.100000
Page::: 3 for process 65 brought in at 3.100000
Page::: 3 for process 72 brought in at 3.100000
Page::: 10 for process 129 brought in at 3.200000
```

## Least Recently Used

```
------======= Running simulator   1 ========-------
Page::: 0 for process id::: 5 brought in at ::: 0.000000
Page::: 0 for process id::: 30 brought in at ::: 0.000000
Page::: 0 for process id::: 85 brought in at ::: 0.000000
Page::: 0 for process id::: 113 brought in at ::: 0.000000
Page::: 1 for process 30 brought in at 0.000000
Page::: 10 for process 85 brought in at 0.000000
Page::: 6 for process 113 brought in at 0.000000
Page::: 9 for process 5 brought in at 0.100000
Page::: 2 for process 85 brought in at 0.100000
Page::: 16 for process 113 brought in at 0.200000
Page::: 3 for process 30 brought in at 0.300000
Page::: 1 for process 85 brought in at 0.300000
Page::: 14 for process 113 brought in at 0.400000
Page::: 1 for process 5 brought in at 0.600000
Page::: 1 for process 113 brought in at 0.600000
Page::: 4 for process 30 brought in at 0.700000
Page::: 9 for process 85 brought in at 0.900000
########################################################################
Process id 5 is done. Memory is getting free ...
########################################################################
Page::: 0 for process id::: 37 brought in at ::: 1.000000
Page::: 0 for process id::: 38 brought in at ::: 1.000000
Page::: 0 for process id::: 62 brought in at ::: 1.000000
Page::: 0 for process id::: 129 brought in at ::: 1.000000
Page::: 0 for process id::: 132 brought in at ::: 1.000000
Page::: 1 for process 132 brought in at 1.000000
Page::: 6 for process 85 brought in at 1.100000
Page::: 1 for process 37 brought in at 1.100000
Page::: 4 for process 129 brought in at 1.100000
Page::: 4 for process 132 brought in at 1.100000
Page::: 11 for process 113 brought in at 1.200000
Page::: 8 for process 129 brought in at 1.200000
Page::: 1 for process 129 brought in at 1.300000
Page::: 3 for process 132 brought in at 1.300000
Page::: 5 for process 113 brought in at 1.400000
Page::: 5 for process 129 brought in at 1.500000
Page::: 4 for process 85 brought in at 1.700000
Page::: 2 for process 30 brought in at 1.800000
Page::: 2 for process 132 brought in at 1.800000
Page::: 4 for process 37 brought in at 1.900000
Page::: 0 for process id::: 3 brought in at ::: 2.000000
Page::: 9 for process 113 brought in at 2.000000
Page::: 1 for process 3 brought in at 2.000000
Page::: 3 for process 37 brought in at 2.200000
Page::: 9 for process 129 brought in at 2.400000
Page::: 6 for process 3 brought in at 2.500000
Page::: 7 for process 113 brought in at 2.700000
Page::: 10 for process 3 brought in at 2.700000
########################################################################
Process id 85 is done. Memory is getting free ...
########################################################################
########################################################################
Process id 113 is done. Memory is getting free ...
########################################################################
########################################################################
Process id 37 is done. Memory is getting free ...
########################################################################
```

## Most Frequently Used

```
./SIMULATION MFU
------======= Running simulator   1 ========-------
Page::: 0 for process id::: 5 brought in at ::: 0.000000
Page::: 0 for process id::: 30 brought in at ::: 0.000000
Page::: 0 for process id::: 85 brought in at ::: 0.000000
Page::: 0 for process id::: 113 brought in at ::: 0.000000
Page::: 1 for process 30 brought in at 0.000000
Page::: 10 for process 85 brought in at 0.000000
Page::: 6 for process 113 brought in at 0.000000
Page::: 9 for process 5 brought in at 0.100000
Page::: 2 for process 85 brought in at 0.100000
Page::: 16 for process 113 brought in at 0.200000
Page::: 3 for process 30 brought in at 0.300000
Page::: 1 for process 85 brought in at 0.300000
Page::: 14 for process 113 brought in at 0.400000
Page::: 1 for process 5 brought in at 0.600000
Page::: 1 for process 113 brought in at 0.600000
Page::: 4 for process 30 brought in at 0.700000
Page::: 9 for process 85 brought in at 0.900000
########################################################################
Process id 5 is done. Memory is getting free ...
########################################################################
Page::: 0 for process id::: 37 brought in at ::: 1.000000
Page::: 0 for process id::: 38 brought in at ::: 1.000000
Page::: 0 for process id::: 62 brought in at ::: 1.000000
Page::: 0 for process id::: 129 brought in at ::: 1.000000
Page::: 0 for process id::: 132 brought in at ::: 1.000000
Page::: 1 for process 132 brought in at 1.000000
Page::: 6 for process 85 brought in at 1.100000
Page::: 1 for process 37 brought in at 1.100000
Page::: 4 for process 129 brought in at 1.100000
Page::: 4 for process 132 brought in at 1.100000
Page::: 11 for process 113 brought in at 1.200000
Page::: 8 for process 129 brought in at 1.200000
Page::: 1 for process 129 brought in at 1.300000
Page::: 3 for process 132 brought in at 1.300000
Page::: 5 for process 113 brought in at 1.400000
Page::: 5 for process 129 brought in at 1.500000
Page::: 4 for process 85 brought in at 1.700000
Page::: 2 for process 30 brought in at 1.800000
Page::: 2 for process 132 brought in at 1.800000
Page::: 4 for process 37 brought in at 1.900000
Page::: 0 for process id::: 3 brought in at ::: 2.000000
Page::: 9 for process 113 brought in at 2.000000
Page::: 1 for process 3 brought in at 2.000000
Page::: 3 for process 37 brought in at 2.200000
Page::: 9 for process 129 brought in at 2.400000
Page::: 6 for process 3 brought in at 2.500000
Page::: 7 for process 113 brought in at 2.700000
Page::: 10 for process 3 brought in at 2.700000
########################################################################
Process id 85 is done. Memory is getting free ...
########################################################################
########################################################################
Process id 113 is done. Memory is getting free ...
########################################################################
########################################################################
```

## Random

```
./SIMULATION Random
------======= Running simulator   1 ========-------
Page::: 0 for process id::: 5 brought in at ::: 0.000000
Page::: 0 for process id::: 30 brought in at ::: 0.000000
Page::: 0 for process id::: 85 brought in at ::: 0.000000
Page::: 0 for process id::: 113 brought in at ::: 0.000000
Page::: 1 for process 30 brought in at 0.000000
Page::: 10 for process 85 brought in at 0.000000
Page::: 6 for process 113 brought in at 0.000000
Page::: 9 for process 5 brought in at 0.100000
Page::: 2 for process 85 brought in at 0.100000
Page::: 16 for process 113 brought in at 0.200000
Page::: 3 for process 30 brought in at 0.300000
Page::: 1 for process 85 brought in at 0.300000
Page::: 14 for process 113 brought in at 0.400000
Page::: 1 for process 5 brought in at 0.600000
Page::: 1 for process 113 brought in at 0.600000
Page::: 4 for process 30 brought in at 0.700000
Page::: 9 for process 85 brought in at 0.900000
######################################################################
Process id 5 is done. Memory is getting free ...
######################################################################
Page::: 0 for process id::: 37 brought in at ::: 1.000000
Page::: 0 for process id::: 38 brought in at ::: 1.000000
Page::: 0 for process id::: 62 brought in at ::: 1.000000
Page::: 0 for process id::: 129 brought in at ::: 1.000000
Page::: 0 for process id::: 132 brought in at ::: 1.000000
Page::: 1 for process 132 brought in at 1.000000
Page::: 6 for process 85 brought in at 1.100000
Page::: 1 for process 37 brought in at 1.100000
Page::: 4 for process 129 brought in at 1.100000
Page::: 4 for process 132 brought in at 1.100000
Page::: 11 for process 113 brought in at 1.200000
Page::: 8 for process 129 brought in at 1.200000
Page::: 1 for process 129 brought in at 1.300000
Page::: 3 for process 132 brought in at 1.300000
Page::: 5 for process 113 brought in at 1.400000
Page::: 5 for process 129 brought in at 1.500000
Page::: 4 for process 85 brought in at 1.700000
Page::: 2 for process 30 brought in at 1.800000
Page::: 2 for process 132 brought in at 1.800000
Page::: 4 for process 37 brought in at 1.900000
Page::: 0 for process id::: 3 brought in at ::: 2.000000
Page::: 9 for process 113 brought in at 2.000000
Page::: 1 for process 3 brought in at 2.000000
Page::: 3 for process 37 brought in at 2.200000
Page::: 9 for process 129 brought in at 2.400000
Page::: 6 for process 3 brought in at 2.500000
Page::: 7 for process 113 brought in at 2.700000
Page::: 10 for process 3 brought in at 2.700000
######################################################################
Process id 85 is done. Memory is getting free ...
######################################################################
######################################################################
Process id 113 is done. Memory is getting free ...
######################################################################
######################################################################
Process id 37 is done. Memory is getting free ...
######################################################################
```