Republic of the Philippines
Tarlac State University
COLLEGE OF COMPUTER STUDIES
Tarlac City, Tarlac
Tel. No. (045) 6068173

Implementation of Page Replacement Algorithms (FIFO, LRU, OPT) in Go

Github Link: https://github.com/pj-pj-pj/page-replacement-algorithms

A Case Study
Submitted to the Faculty of the College of Computer Studies
San Isidro Campus, Tarlac City,
Tarlac State University

In Partial Fulfillment of the Requirements for the Subject
Operating Systems
A.Y. 2024-2025

Paula Joyce S. Ucol

Instructor:
Jo Anne S. Cura

Date: May 21, 2025

Table of Contents

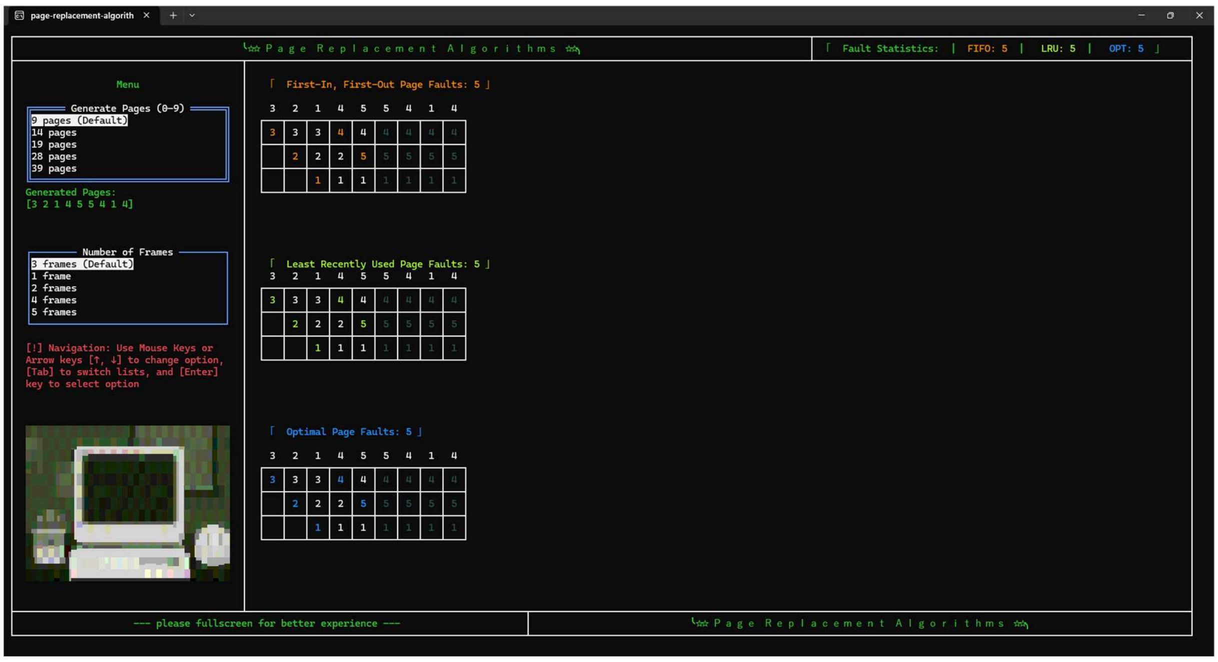
I. Introduction

This document demonstrates the implementation of three page-replacement algorithms in the Go programming language, which are the First-In, First-Out (FIFO), Least Recently Used (LRU), and Optimal Replacement (OPT) algorithms. The created program simulates how these algorithms handle page faults for a randomly generated page-reference string in the selected frame count. The user selects the number of page frames among the options given in the program, and the program outputs the total page faults for each algorithm.

II. Sample Inputs and Outputs

The program generates a random page-reference string (e.g. 7 0 1 2 0 3 0 4 2 3) with values ranging from 0-9 where it applies each of the three page replacement algorithms, displaying its process in a tabular format and the total number of page faults incurred by each algorithm. The FIFO strategy replaced the oldest pages first, while LRU selected the least recently used page, and OPT replaced the page that wouldn't be used for the longest time in the future.

1.1 Sample 1

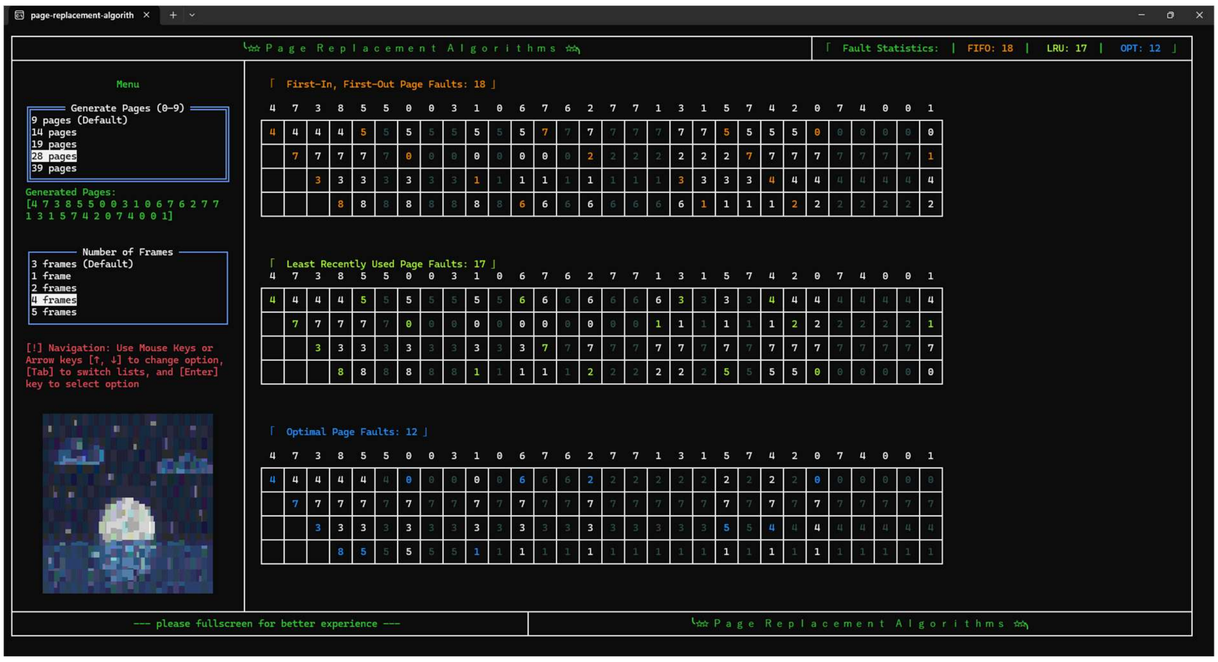


```
                    ╰☆☆ P a g e  R e p l a c e m e n t  A l g o r i t h m s ☆☆╮    ⌈ Fault Statistics: | FIFO: 5 | LRU: 5 | OPT: 5 ⌋

          Menu                      ⌈ First-In, First-Out Page Faults: 5 ⌋

   ═══ Generate Pages (0-9) ═══       3   2   1   4   5   5   4   1   4
   9 pages (Default)                ┌───┬───┬───┬───┬───┬───┬───┬───┬───┐
   14 pages                         │ 3 │ 3 │ 3 │ 4 │ 4 │ 4 │ 4 │ 4 │ 4 │
   19 pages                         ├───┼───┼───┼───┼───┼───┼───┼───┼───┤
   28 pages                         │   │ 2 │ 2 │ 2 │ 5 │ 5 │ 5 │ 5 │ 5 │
   39 pages                         ├───┼───┼───┼───┼───┼───┼───┼───┼───┤
                                    │   │   │ 1 │ 1 │ 1 │ 1 │ 1 │ 1 │ 1 │
  Generated Pages:                  └───┴───┴───┴───┴───┴───┴───┴───┴───┘
  [3 2 1 4 5 5 4 1 4]


   ──── Number of Frames ────       ⌈ Least Recently Used Page Faults: 5 ⌋
   3 frames (Default)                 3   2   1   4   5   5   4   1   4
   1 frame                          ┌───┬───┬───┬───┬───┬───┬───┬───┬───┐
   2 frames                         │ 3 │ 3 │ 3 │ 4 │ 4 │ 4 │ 4 │ 4 │ 4 │
   4 frames                         ├───┼───┼───┼───┼───┼───┼───┼───┼───┤
   5 frames                         │   │ 2 │ 2 │ 2 │ 5 │ 5 │ 5 │ 5 │ 5 │
                                    ├───┼───┼───┼───┼───┼───┼───┼───┼───┤
  [!] Navigation: Use Mouse Keys or │   │   │ 1 │ 1 │ 1 │ 1 │ 1 │ 1 │ 1 │
  Arrow keys [↑, ↓] to change option,└───┴───┴───┴───┴───┴───┴───┴───┴───┘
  [Tab] to switch lists, and [Enter]
  key to select option

                                    ⌈ Optimal Page Faults: 5 ⌋

                                      3   2   1   4   5   5   4   1   4
                                    ┌───┬───┬───┬───┬───┬───┬───┬───┬───┐
                                    │ 3 │ 3 │ 3 │ 4 │ 4 │ 4 │ 4 │ 4 │ 4 │
                                    ├───┼───┼───┼───┼───┼───┼───┼───┼───┤
                                    │   │ 2 │ 2 │ 2 │ 5 │ 5 │ 5 │ 5 │ 5 │
                                    ├───┼───┼───┼───┼───┼───┼───┼───┼───┤
                                    │   │   │ 1 │ 1 │ 1 │ 1 │ 1 │ 1 │ 1 │
                                    └───┴───┴───┴───┴───┴───┴───┴───┴───┘

      --- please fullscreen for better experience ---      ╰☆☆ P a g e  R e p l a c e m e n t  A l g o r i t h m s ☆☆╮
```

Figure 1. Sample output with 9-page reference string [3 2 1 4 5 5 4 1 4] and 3 page frames.

Figure 1 demonstrates a sample output of the program where the generated page-reference string is [3 2 1 4 5 5 4 1 4], and the number of page frames was set to 3. All three algorithms resulted in the same number of page faults incurred, which is 5.

1.2 Sample 2

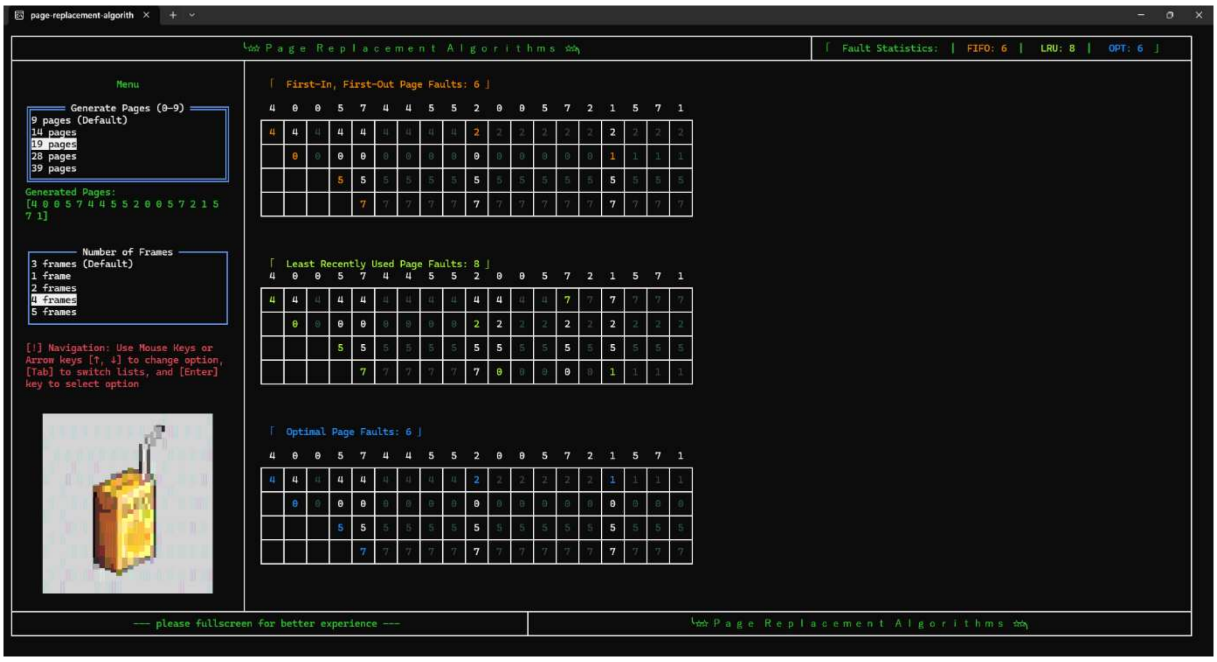


```
page-replacement-algorith

╰☆☆ Page Replacement Algorithms ☆☆╮      ⌈ Fault Statistics: | FIFO: 18 | LRU: 17 | OPT: 12 ⌋

Menu

═══ Generate Pages (0-9) ═══
9 pages (Default)
14 pages
19 pages
28 pages
39 pages

Generated Pages:
[4 7 3 8 5 5 0 0 3 1 0 6 7 6 2 7 7
1 3 1 5 7 4 2 0 7 4 0 0 1]

── Number of Frames ──
3 frames (Default)
1 frame
2 frames
4 frames
5 frames

[!] Navigation: Use Mouse Keys or
Arrow keys [↑, ↓] to change option,
[Tab] to switch lists, and [Enter]
key to select option

⌈ First-In, First-Out Page Faults: 18 ⌋

4  7  3  8  5  5  0  0  3  1  0  6  7  6  2  7  7  1  3  1  5  7  4  2  0  7  4  0  0  1
4  4  4  4  5  5  5  5  5  5  5  5  7  7  7  7  7  7  7  7  5  5  5  5  0  0  0  0  0  0
   7  7  7  7  7  0  0  0  0  0  0  0  0  2  2  2  2  2  2  2  7  7  7  7  7  7  7  7  1
      3  3  3  3  3  3  3  1  1  1  1  1  1  1  1  1  3  3  3  3  4  4  4  4  4  4  4  4
         8  8  8  8  8  8  8  8  6  6  6  6  6  6  6  6  1  1  1  1  2  2  2  2  2  2  2

⌈ Least Recently Used Page Faults: 17 ⌋
4  7  3  8  5  5  0  0  3  1  0  6  7  6  2  7  7  1  3  1  5  7  4  2  0  7  4  0  0  1
4  4  4  4  5  5  5  5  5  5  5  6  6  6  6  6  6  6  3  3  3  3  4  4  4  4  4  4  4  4
   7  7  7  7  7  0  0  0  0  0  0  0  0  0  0  0  1  1  1  1  1  1  2  2  2  2  2  2  1
      3  3  3  3  3  3  3  3  3  3  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7
         8  8  8  8  8  8  1  1  1  1  1  2  2  2  2  2  2  5  5  5  5  0  0  0  0  0  0

⌈ Optimal Page Faults: 12 ⌋

4  7  3  8  5  5  0  0  3  1  0  6  7  6  2  7  7  1  3  1  5  7  4  2  0  7  4  0  0  1
4  4  4  4  4  4  0  0  0  0  0  6  6  6  2  2  2  2  2  2  2  2  2  2  0  0  0  0  0  0
   7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7
      3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  5  5  4  4  4  4  4  4  4  4
         8  5  5  5  5  5  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1

--- please fullscreen for better experience ---      ╰☆☆ Page Replacement Algorithms ☆☆╮
```

Figure 2. Sample output of reference string [4 7 3 8 5 5 0 0 3 1 0 6 7 6 2 7 7 1 3 1 5 7 4 2 0 7 4 0 0 1] and 4 frames.

Figure 2 demonstrates a sample output of the program where the generated page-reference string is [4 7 3 8 5 5 0 0 3 1 0 6 7 6 2 7 7 1 3 1 5 7 4 2 0 7 4 0 0 1], and the number of page frames was set to 4. The FIFO incurred a total of 18 page faults, LRU has 17, while OPT algorithm incurred a significantly lesser number with 12 page faults.

1.3 Sample 3



```
page-replacement-algorith

╰☆☆ Page Replacement Algorithms ☆☆╮      ⌈ Fault Statistics: | FIFO: 6 | LRU: 8 | OPT: 6 ⌋

Menu

═══ Generate Pages (0-9) ═══
9 pages (Default)
14 pages
19 pages
28 pages
39 pages

Generated Pages:
[4 0 0 5 7 4 4 5 5 2 0 0 5 7 2 1 5
7 1]

── Number of Frames ──
3 frames (Default)
1 frame
2 frames
4 frames
5 frames

[!] Navigation: Use Mouse Keys or
Arrow keys [↑, ↓] to change option,
[Tab] to switch lists, and [Enter]
key to select option

⌈ First-In, First-Out Page Faults: 6 ⌋

4  0  0  5  7  4  4  5  5  2  0  0  5  7  2  1  5  7  1
4  4  4  4  4  4  4  4  4  2  2  2  2  2  2  2  2  2  2
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  1  1  1
         5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
            7  7  7  7  7  7  7  7  7  7  7  7  7  7  7

⌈ Least Recently Used Page Faults: 8 ⌋
4  0  0  5  7  4  4  5  5  2  0  0  5  7  2  1  5  7  1
4  4  4  4  4  4  4  4  4  4  4  4  4  7  7  7  7  7  7
   0  0  0  0  0  0  0  0  2  2  2  2  2  2  2  2  2  2
         5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
            7  7  7  7  7  7  0  0  0  0  0  1  1  1  1

⌈ Optimal Page Faults: 6 ⌋

4  0  0  5  7  4  4  5  5  2  0  0  5  7  2  1  5  7  1
4  4  4  4  4  4  4  4  4  2  2  2  2  2  2  1  1  1  1
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
         5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
            7  7  7  7  7  7  7  7  7  7  7  7  7  7  7

--- please fullscreen for better experience ---      ╰☆☆ Page Replacement Algorithms ☆☆╮
```

Figure 3. Sample output with 19-page reference string [4 0 0 5 7 4 4 5 5 2 0 0 5 7 2 1 5 7 1] and 4 page frames.

Figure 3 demonstrates a sample output of the program where the generated page-reference string is [4 7 3 8 5 5 0 0 3 1 0 6 7 6 2 7 7 1 3 1 5 7 4 2 0 7 4 0 0 1], and the number of page frames was set to 4. The FIFO algorithm incurred a total of number 6 page faults, LRU has 8, and the OPT algorithm with the same page faults incurred as

FIFO with also 6.

1.4 Sample 4

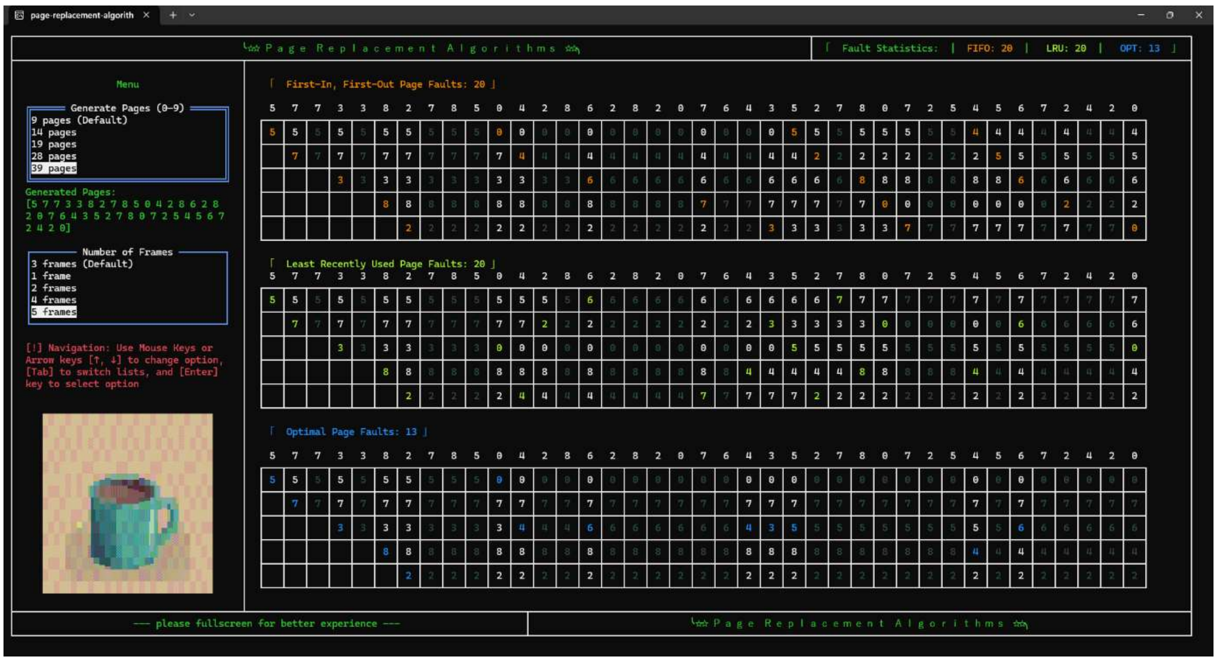

```
page-replacement-algorith

Page Replacement Algorithms          ⌈ Fault Statistics: | FIFO: 20 | LRU: 20 | OPT: 13 ⌋

Menu

Generate Pages (0-9)
9 pages (Default)
14 pages
19 pages
28 pages
39 pages

Generated Pages:
[5 7 7 3 3 8 2 7 8 5 0 4 2 8 6 2 8
2 0 7 6 4 3 5 2 7 8 0 7 2 5 4 5 6 7
2 4 2 0]

Number of Frames
3 frames (Default)
1 frame
2 frames
4 frames
5 frames

[!] Navigation: Use Mouse Keys or
Arrow keys [↑, ↓] to change option,
[Tab] to switch lists, and [Enter]
key to select option

⌈ First-In, First-Out Page Faults: 20 ⌋
5 7 7 3 3 8 2 7 8 5 0 4 2 8 6 2 8 2 0 7 6 4 3 5 2 7 8 0 7 2 5 4 5 6 7 2 4 2 0
5 5 5 5 5 5 5 5 5 5 0 0 0 0 0 0 0 0 0 0 0 0 0 5 5 5 5 5 5 5 5 4 4 4 4 4 4 4 4
  7 7 7 7 7 7 7 7 7 7 4 4 4 4 4 4 4 4 4 4 4 4 4 2 2 2 2 2 2 2 2 5 5 5 5 5 5 5
      3 3 3 3 3 3 3 3 3 3 3 6 6 6 6 6 6 6 6 6 6 6 6 8 8 8 8 8 8 8 6 6 6 6 6 6
          8 8 8 8 8 8 8 8 8 8 8 8 8 8 7 7 7 7 7 7 7 7 0 0 0 0 0 0 0 0 2 2 2 2
            2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 7 7 7 7 7 7 7 7 7 7 0

⌈ Least Recently Used Page Faults: 20 ⌋
5 7 7 3 3 8 2 7 8 5 0 4 2 8 6 2 8 2 0 7 6 4 3 5 2 7 8 0 7 2 5 4 5 6 7 2 4 2 0
5 5 5 5 5 5 5 5 5 5 5 5 5 5 6 6 6 6 6 6 6 6 6 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7
  7 7 7 7 7 7 7 7 7 7 7 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 0 0 0 0 0 0 6 6 6 6 6 6
      3 3 3 3 3 3 3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 5 5 5 5 5 5 5 5 5 5 5 5 5 5 0
          8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 4 4 4 4 4 8 8 8 8 8 4 4 4 4 4 4 4 4
            2 2 2 2 2 4 4 4 4 4 4 4 4 7 7 7 7 7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2

⌈ Optimal Page Faults: 13 ⌋
5 7 7 3 3 8 2 7 8 5 0 4 2 8 6 2 8 2 0 7 6 4 3 5 2 7 8 0 7 2 5 4 5 6 7 2 4 2 0
5 5 5 5 5 5 5 5 5 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7
      3 3 3 3 3 3 3 3 4 4 4 6 6 6 6 6 6 6 4 3 5 5 5 5 5 5 5 5 5 5 6 6 6 6 6 6
          8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 4 4 4 4 4 4 4 4
            2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2

--- please fullscreen for better experience ---          Page Replacement Algorithms
```

Figure 4. Sample output with 39-page reference string [5 7 7 3 3 8 2 7 8 5 0 4 2 8 6 2 8 2 0 7 6 4 3 5 2 7 8 0 7 2 5 4 5 6 7 2 4 2 0] and 5 page frames.

Figure 4 demonstrates a sample output of the program where the generated page-reference string is [5 7 7 3 3 8 2 7 8 5 0 4 2 8 6 2 8 2 0 7 6 4 3 5 2 7 8 0 7 2 5 4 5 6 7 2 4 2 0], and the number of page frames was set to 4. The FIFO and LRU algorithms both incurred a total of 20 page faults, while the OPT algorithm incurred a number of 13 page faults.

1.5 Sample 5

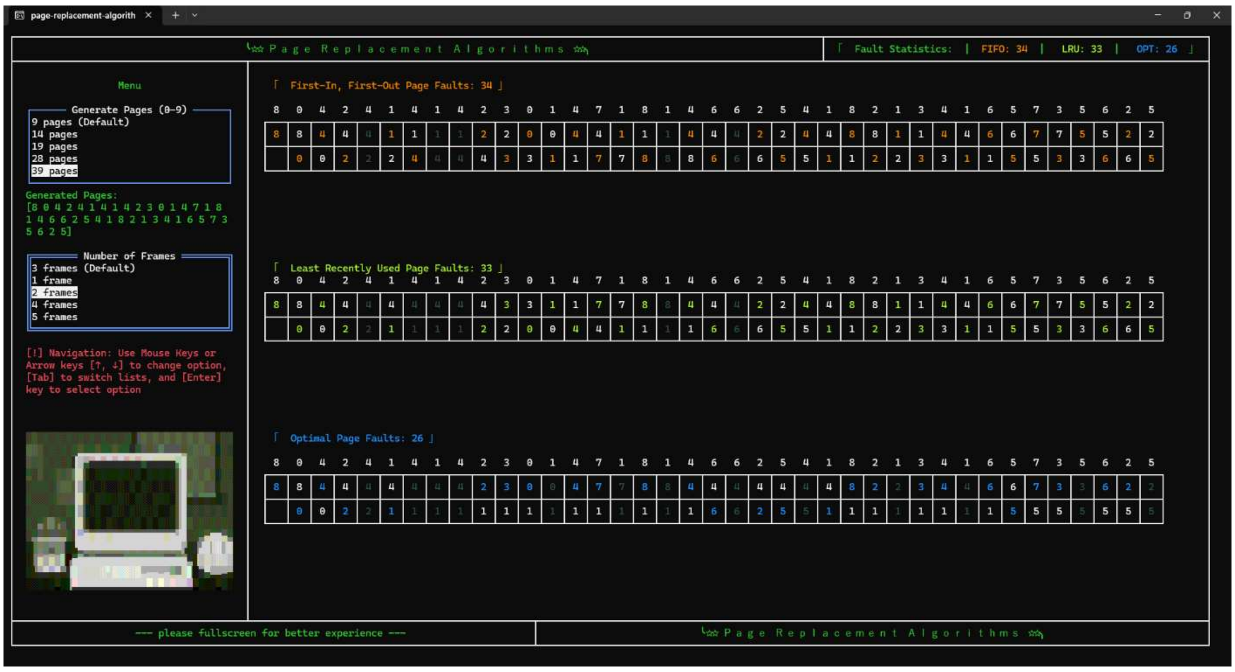

```
page-replacement-algorith

Page Replacement Algorithms          ⌈ Fault Statistics: | FIFO: 34 | LRU: 33 | OPT: 26 ⌋

Menu

Generate Pages (0-9)
9 pages (Default)
14 pages
19 pages
28 pages
39 pages

Generated Pages:
[8 0 4 2 4 1 4 1 4 2 3 0 1 4 7 1 8
1 4 6 6 2 5 4 1 8 2 1 3 4 1 6 5 7 3
5 6 2 5]

Number of Frames
3 frames (Default)
1 frame
2 frames
4 frames
5 frames

[!] Navigation: Use Mouse Keys or
Arrow keys [↑, ↓] to change option,
[Tab] to switch lists, and [Enter]
key to select option

⌈ First-In, First-Out Page Faults: 34 ⌋
8 0 4 2 4 1 4 1 4 2 3 0 1 4 7 1 8 1 4 6 6 2 5 4 1 8 2 1 3 4 1 6 5 7 3 5 6 2 5
8 8 4 4 4 1 1 1 1 2 2 0 0 4 4 1 1 1 4 4 4 2 2 4 4 8 8 1 1 4 4 6 6 7 7 5 5 2 2
  0 0 2 2 2 4 4 4 4 3 3 1 1 7 7 8 8 8 6 6 6 5 5 1 1 2 2 3 3 1 1 5 5 3 3 6 6 5

⌈ Least Recently Used Page Faults: 33 ⌋
8 0 4 2 4 1 4 1 4 2 3 0 1 4 7 1 8 1 4 6 6 2 5 4 1 8 2 1 3 4 1 6 5 7 3 5 6 2 5
8 8 4 4 4 4 4 4 4 4 3 3 1 1 7 7 8 8 4 4 4 2 2 4 4 8 8 1 1 4 4 6 6 7 7 5 5 2 2
  0 0 2 2 1 1 1 1 2 2 0 0 4 4 1 1 1 1 6 6 6 5 5 1 1 2 2 3 3 1 1 5 5 3 3 6 6 5

⌈ Optimal Page Faults: 26 ⌋
8 0 4 2 4 1 4 1 4 2 3 0 1 4 7 1 8 1 4 6 6 2 5 4 1 8 2 1 3 4 1 6 5 7 3 5 6 2 5
8 8 4 4 4 4 4 4 4 2 3 0 0 4 7 7 8 8 4 4 4 4 4 4 4 8 2 2 3 4 4 6 6 7 3 3 6 2 2
  0 0 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 6 6 2 5 5 1 1 1 1 1 1 1 1 5 5 5 5 5 5 5

--- please fullscreen for better experience ---          Page Replacement Algorithms
```

Figure 5. Sample output with 39-page reference string [8 0 4 2 4 1 4 1 4 2 3 0 1 4 7 1 8 1 4 6 6 2 5 4 1 8 2 1 3 4 1 6 5 7 3 5 6 2 5] and 2 page frames.

Figure 5 demonstrates a sample output of the program where the page-reference string is [8 0 4 2 4 1 4 1 4 2 3 0 1 4 7 1 8 1 4 6 6 2 5 4 1 8 2 1 3 4 1 6 5 7 3 5 6 2 5], and the number of page frames was set to 4. The FIFO and LRU algorithms both incurred a total of 20 page faults, while the OPT algorithm incurred a number of 13 page faults.

III. Conclusion

This document demonstrated the implementation of the three page replacement algorithms (FIFO, LRU, and OPT) using different page reference strings (with values ranging from 0 to 9) and varying frame sizes. The process of each algorithm was shown using a tabular format allowing observation of how the number of page faults can vary depending on the algorithms and selected inputs.

IV. Code and Downloads

- Github Repository: https://github.com/pj-pj-pj/page-replacement-algorithms
  - Main Algorithm File: See the */algorithms/algorithms.go*
- Executable Program:
  - Download from the Github repository under the releases section: https://github.com/pj-pj-pj/page-replacement-algorithms/releases/tag/v1.1.0