

# Operating System:

## Page Replacement: FIFO, Optimal, LRU

By: Vishvadeep Gothi



# VISHVADEEP GOTHI SIR

**AIR- 19, 119, 440, 682  
in GATE**



**ME from IISc Bangalore  
Mtech BITS Pilani in Data  
Science**



**14+ Years of Teaching Experience,  
10+ Years in GATE/IES**



**Subjects Taken:**  
Computer Organization & Architecture,  
data structure, operating system,  
C-Programming, Data science,  
Machine Learning, Python,  
coding interview problems,





# Vishvadeep Gothi

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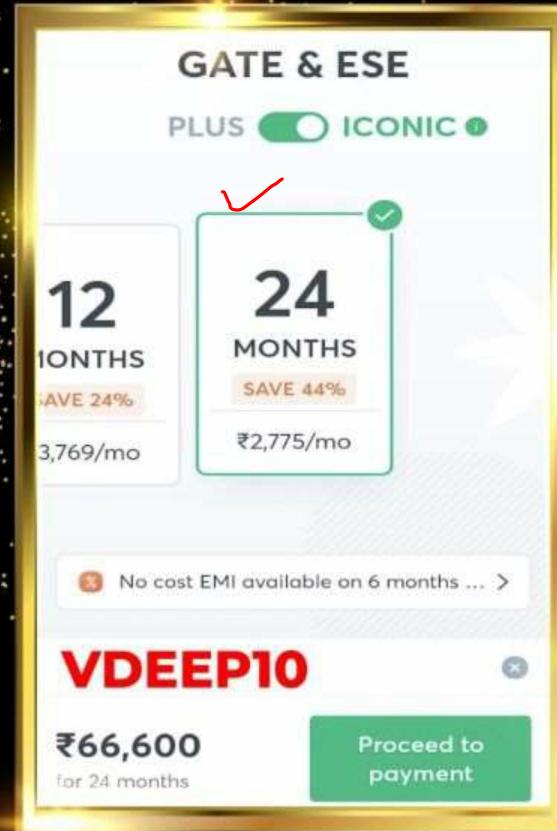
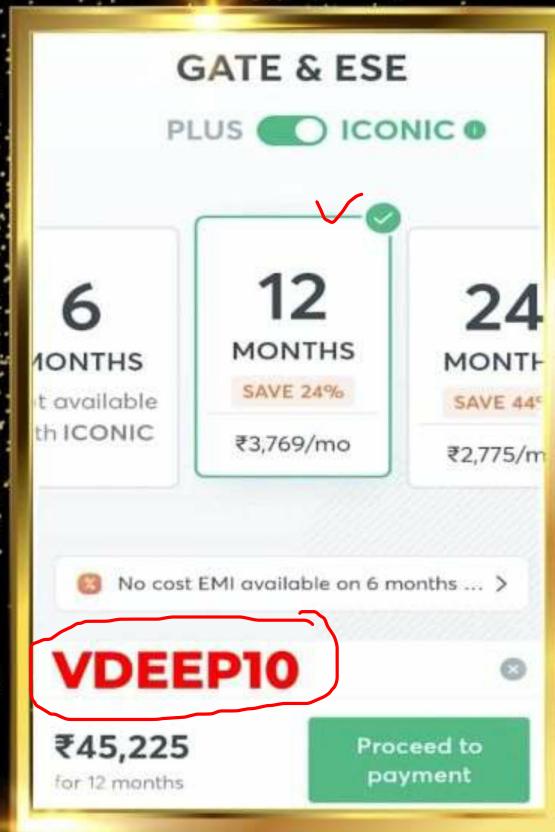
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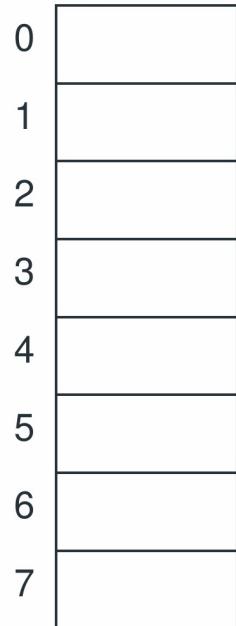
# Virtual Memory

- ◎ Feature of OS
- ◎ Enables to run larger process with smaller available memory



# Virtual Memory

Process



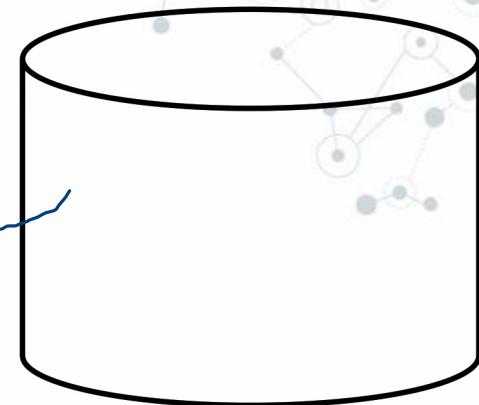
Page Table

0
1
2
3
4
5
6
7

Physical Memory

0
1
2
3
4
5
6
7

Secondary Memory



# Page Replacement Policies

1. First In First Out (FIFO)
2. Optimal Policy
3. Least Recently Used (LRU)
4. Least Frequently Used (LFU)
5. Most Frequently Used (MFU)
6. Last In First Out (LIFO)
7. Second Chance

most imp.

# First In First Out (FIFO)

↳ replace the page which is brought to mm first.

Assume:

- Number of frames = 3 (All empty initially)
- Page reference sequence: 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5

no. of page fault = 9

page fault rate =  $\frac{9}{12}$

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	4	4	4	5	1	1	5	5	5
2	2	2	2	1	1	1	2	2	3	3	3

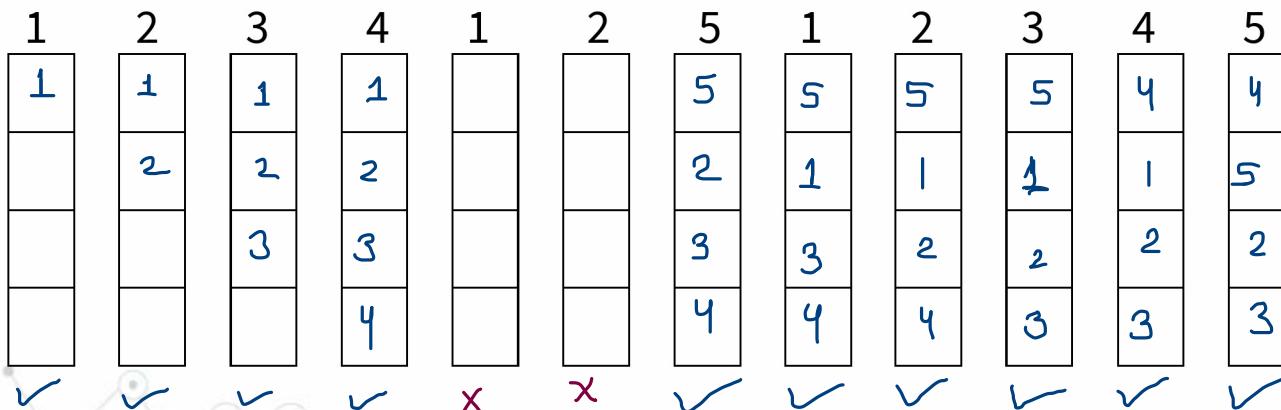
✓ ✓ ✓ ✓ ✓ ✓ ✗ ✗ ✓ ✓ ✗

# First In First Out (FIFO)

Assume:

- Number of frames = 4 (All empty initially)
- Page reference sequence: 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5

no. of page fault = 10



# Belady's Anomaly

- For some page reference sequence, increasing number of frames increases no. of page faults also.
- only FIFO suffers from this .



# First In First Out (FIFO)

## Advantages

1. Simple and easy to implement.
2. Low overhead.

Less time

## Disadvantages:

1. Poor performance. *more page faults*
2. Doesn't consider the frequency of use or last used time, simply replaces the oldest page.
3. Suffers from Belady's Anomaly

# Optimal Policy

→ replace page which is not (never) going to be referred in near future.

Assume:

- Number of frames = 3 (All empty initially)
- Page reference sequence: 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5

$$\text{no. of page faults} = 7$$
$$\text{page fault rate} = \frac{7}{12}$$

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	1	1	1	1	1	1	3	3	3
	2	2	2	2	2	2	2	2	2	4	4
		3		4		4		5		5	5

"It provides min. no. of page fault"

# Optimal Policy

## Advantages

1. Easy to Implement
2. Simple data structures are used
3. Highly efficient →  $\min$  page fault

## Disadvantages:

1. Requires future knowledge of the program  
→ hence  
practically  
not  
possible  
to implement
2. Time-consuming

# Least Recently Used (LRU)

↳ replace the page which CPU has not used since longest time.

Assume:

- Number of frames = 3 (All empty initially)
- Page reference sequence: 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5

$$\text{no. of page faults} = 10$$
$$\text{page fault rate} = \frac{10}{12}$$

1	2	3	4	1	2	5	1	2	3	4	5
1	1	1	4	4	4	5	5	5	3	3	3
2	2	2	2	1	1	1	1	1	4	4	4
3	3	3	3	3	2	2	2	2	2	2	5

# Least Recently Used (LRU)

## Advantages

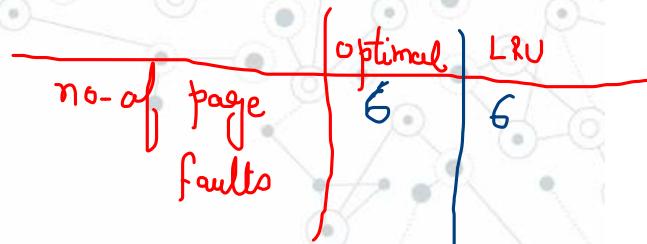
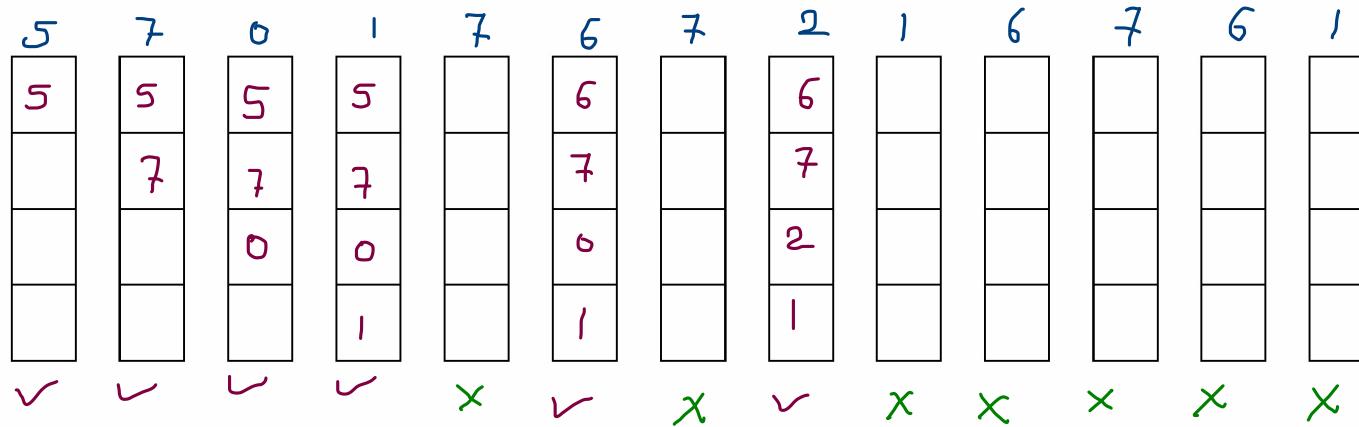
1. Efficient. (*in practical scenario*)
2. Doesn't suffer from Belady's Anomaly

## Disadvantages:

1. Complex Implementation
2. Expensive
3. Requires hardware support

# Question

- Number of frames = 4 (All empty initially)
- Page reference sequence: 5, 7, 0, 1, 7, 6, 7, 2, 1, 6, 7, 6, 1
- Number of page faults for optimal and LRU policies?



LRU

5	7	0	1	7	6	7	2	1	6	7	6	1
5	5	5	5	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7	7
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1
✓	✓	✓	✓	✗	✓	✗	✓	✓	✗	✗	✗	✗

no. of page faults = 6

# Question

no. of page faults = 5

A virtual memory system has only 2-page frames which are empty initially. Using demand paging the following sequence of page reference is passed through this system.

9, 8, 7, 8, 7, 9, 7, 9, 8, 9

Minimum possible number of page faults? *use optimal policy*

9 8 7 8 7 9 7 9 8 9

9 9 7 7 9

8 8 8 8

✓ ✓ ✓ ✗ ✗ ✓ ✗ ✗ ✗

# Question

H. ω.

A main memory can hold 3 page frames and initially all of them are vacant. Consider the following stream of page requests :

2, 3, 2, 4, 6, 2, 5, 6, 1, 4, 6

If the stream uses FIFO replacement policy, the hit ratio h will be?

- (a) 11/3
- (b) 1/11
- (c) 3/11
- (d) 2/11

# Question

H. W.

Consider the following page references:

2, 3, 4, 5, 6, 4, 5, 2, 7, 8, 9, 8, 9, 8, 9, 1, 6, 5, 6, 5, 3

Using optimal policy and 4 frames. Memory access time is 2ms and page fault service time is 40ms. The effective memory access time is?

# Next Class

Page Replacement Policies



✓ LIFO, LFU, MFU,  
Second Chance

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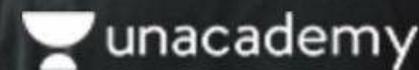
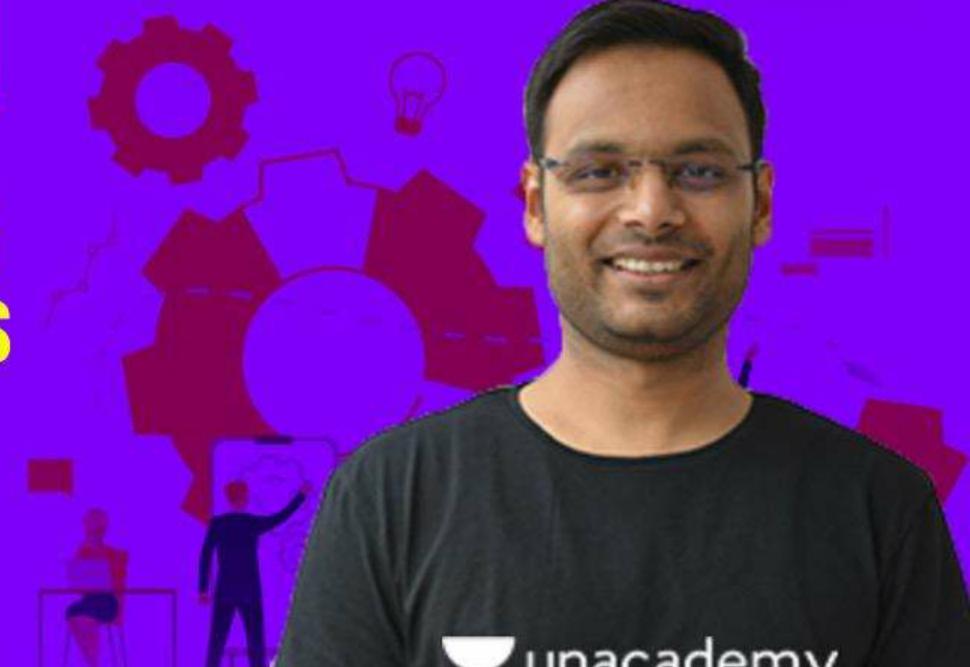
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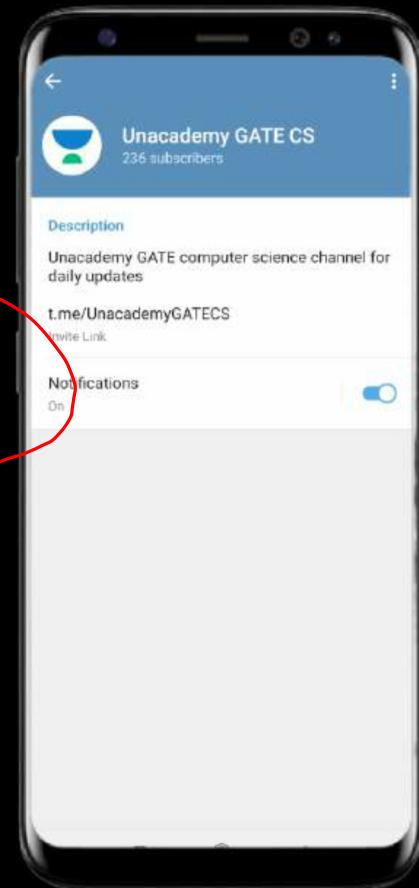
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