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## USCS3P01:USCS303-Operating System (OS) Practical-09

### Practical – 09: Page Replacement Algorithm Least Recently Used (LRU)

Practical Date: 31-08-2021

Practical Aim: Page Replacement Algorithm (LRU)

Algorithm:

#### Page Replacement Algorithm

In demand paging memory management technique, if a page demanded for execution is present in main memory, then a page fault occurs.

To load the page in demand into main memory, a free page frame is searched in main memory and allocated.

If no page frame is free, memory manager has to free a frame by swapping its contents to secondary storage and thus make room for the required page.

To swap pages, many schemes or strategies are used.

#### Least Recently Used (LRU) Algorithm

The **Least Recently Used (LRU) algorithm** replaces the page that has not been used for the longest period of time.

It is based on the observation that pages that have not been used for long time will probably remain unused for the longest time and are to be replaced.

**Solved Example:**

**Example-01:**

Apply the LRU replacement algorithms for the following page-reference strings: 7,0,1,2,0,3,0,4,2,3,0,3,2

Indicate the number of page faults for LRU algorithm assuming demand paging with four frames.

Find the number of hits, number of faults and hit ratio

**Solution**

**Page Reference String:** 7,0,1,2,0,3,0,4,2,3,0,3,2

**Demand Paging or Number of Frames:** 4

7	7	7	7	7	3	3	3	3	3	3	3
-1	0	0	0	0	0	0	0	0	0	0	0

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-1	-1	1	1	1	1	4	4	4	4	4	4
-1	-1	-1	2	2	2	2	2	2	2	2	2

7	0	1		2	0	3	0	4	2	3	0	3	2
×	×	×		×		×		×					

**Number of Hits:** Count of no replacements = 7

**Number of Faults:** Count of replacements = 6×

**Hit Ratio:** Number of Hits/Len (Ref String) =  $7/13 = 0.53$

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## Example-02:

Consider the following example 3 frames with 1,3,0,3,5,6,3 page-reference strings.

Find the number of hits, number of faults and hit ratio using LRU Page Replacement Algorithm.

**Solution:**

**Page Reference String:** 1,3,0,3,5,6,3

**Demand Paging or Number of Frames:** 3

1	1	1	1	5	5	5
-1	3	3	3	3	3	3
-1	-1	0	0	0	6	6

1	3	0	3	5	6	3
×	×	×	×	×	×	

**Number of Hits:** Count of no replacements = 2

**Number of Faults:** Count of replacements = 5

**Hit Ratio:** Number of Hits/Len (Ref String) =  $2/7 = 0.28$

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## Example-03:

Consider the following example 3 frames with 7,0,1,2,0,3,0,4,2,3,0,3,2,1,2,0,1,7,0,1 page-reference strings.

Find the number of hits, number of faults and hit ratio using LRU Page Replacement Algorithm.

**Solution:**

**Page Reference String:** 7,0,1,2,0,3,0,4,2,3,0,3,2,1,2,0,1,7,0,1

**Demand Paging or Number of Frames:** 3

7	7	7	2	2	2	2	4	4	4	0	0	0	1	1	1	1	1	1	1
-1	0	0	0	0	0	0	0	0	3	3	3	3	3	3	0	0	0	0	0
-1	-1	1	1	1	3	3	3	2	2	2	2	2	2	2	2	2	7	7	7

7	0	1	2	0	3	0	4	2	3	0	3	2	1	2	0	1	7	0	1
×	×	×	×	×			×	×	×	×			×		×		×		

**Number of Hits:** Count of no replacements = 8

**Number of Faults:** Count of replacements = 12

**Hit Ratio:** Number of Hits/Len (Ref String) = 8/20 = 0.4

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## Question:

Write a Java program that implements the LRU page-replacement algorithm.

## Implementation:

```
//Name: Subrat Sahu
```

```
// Batch: B2
```

```
// PRN: 2020016400833692
```

```
// Date: 31 August,2021
```

```
// Prac-09: Page Replacement Algorithm(LRU)
```

```
import java.io.*;
```

```
import java.util.*;
```

```
public class P9_PR_LRU_SS
```

```
{
```

```
    public static void main(String[] args) throws IOException
```

```
    {
```

```
        Scanner scan = new Scanner(System.in);
```

```
        int frames,pointer = 0, hit = 0, fault = 0,ref_len;
```

```
        Boolean isFull = false;
```

```
        int buffer[];
```

```
        ArrayList<Integer>stack = new ArrayList<Integer>();
```

```
        int reference[];
```

```
        int mem_layout[][];
```

```
        System.out.print("Please enter the number of Frames: ");
```

```
        frames = scan.nextInt();
```

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```
System.out.print("Please enter the length of the References strings: ");
ref_len = scan.nextInt();
reference = new int[ref_len];
mem_layout = new int[ref_len][frames];
buffer = new int[frames];
for(int j = 0; j < frames; j++)
    buffer[j] = -1;
System.out.print("Please enter the references strings: ");
for(int i = 0; i < ref_len; i++)
{
    reference[i] = scan.nextInt();
}
System.out.println();
for(int i = 0; i < ref_len; i++)
{
    if(stack.contains(reference[i]))
    {
        stack.remove(stack.indexOf(reference[i]));
    }
    stack.add(reference[i]);
    int search = -1;
    for(int j = 0; j < frames; j++)
    {
        if(buffer[j] == reference[i])
        {
            search = j;
            hit++;
            break;
        }
    }
}
```

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```
    }
}
if(search == -1)
{
    if(isFull)
    {
        int min_loc = ref_len;
        for(int j = 0; j < frames; j++)
        {
            if(stack.contains(buffer[j]))
            {
                int temp =
stack.indexOf(buffer[j]);
                if(temp < min_loc)
                {
                    min_loc = temp;
                    pointer = j;
                }
            }
        }
    }
    buffer[pointer] = reference[i];
    fault++;
    pointer++;
    if(pointer == frames)
    {
        pointer = 0;
        isFull = true;
    }
}
```



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```
        }
        for(int j = 0; j < frames; j++)
            mem_layout[i][j] = buffer[j];
    }
    for(int i = 0; i < frames; i++)
    {
        for(int j = 0; j < ref_len; j++)
            System.out.printf("%3d",mem_layout[j][i]);
        System.out.println();
    }

    System.out.println("The number of Hits: " + hit);
    System.out.println("Hit Ratio: " +(float)((float)hit/ref_len));
    System.out.println("The number of Faults: " + fault);
}
}
```

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Input 01:

```
Please enter the number of Frames: 4
Please enter the length of the References strings: 13
Please enter the references strings:
7 0 1 2 0 3 0 4 2 3 0 3 2
```

Output 01:

```
7 7 7 7 7 3 3 3 3 3 3 3 3
-1 0 0 0 0 0 0 0 0 0 0 0 0
-1 -1 1 1 1 1 1 4 4 4 4 4 4
-1 -1 -1 2 2 2 2 2 2 2 2 2 2
The number of Hits: 7
Hit Ratio: 0.53846157
The number of Faults: 6
```

Sample Output 01:

```
Please enter the number of Frames: 4
Please enter the length of the References strings: 13
Please enter the references strings:
7 0 1 2 0 3 0 4 2 3 0 3 2

7 7 7 7 7 3 3 3 3 3 3 3 3
-1 0 0 0 0 0 0 0 0 0 0 0 0
-1 -1 1 1 1 1 1 4 4 4 4 4 4
-1 -1 -1 2 2 2 2 2 2 2 2 2 2
The number of Hits: 7
Hit Ratio: 0.53846157
The number of Faults: 6
```

Input 02:

```
Please enter the number of Frames: 3
Please enter the length of the References strings: 7
Please enter the references strings:
1 3 0 3 5 6 3
```

Output 02:

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```
1 1 1 1 5 5 5
-1 3 3 3 3 3 3
-1 -1 0 0 0 6 6
The number of Hits: 2
Hit Ratio: 0.2857143
The number of Faults: 5
```

## Sample Output 02:

```
Please enter the number of Frames: 3
Please enter the length of the References strings: 7
Please enter the references strings:
1 3 0 3 5 6 3

1 1 1 1 5 5 5
-1 3 3 3 3 3 3
-1 -1 0 0 0 6 6
The number of Hits: 2
Hit Ratio: 0.2857143
The number of Faults: 5
```

## Input 03:

```
Please enter the number of Frames: 3
Please enter the length of the References strings: 20
Please enter the references strings:
7 0 1 2 0 3 0 4 2 3 0 3 2 1 2 0 1 7 0 1
```

## Output 03:

```
7 7 7 2 2 2 2 4 4 4 0 0 0 1 1 1 1 1 1 1
-1 0 0 0 0 0 0 0 0 0 3 3 3 3 3 3 0 0 0 0
-1 -1 1 1 1 3 3 3 2 2 2 2 2 2 2 2 7 7 7
The number of Hits: 8
Hit Ratio: 0.4
The number of Faults: 12
```

## Sample Output 03:

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---

```
Please enter the number of Frames: 3
Please enter the length of the References strings: 20
Please enter the references strings:
7 0 1 2 0 3 0 4 2 3 0 3 2 1 2 0 1 7 0 1

  7 7 7 2 2 2 2 4 4 4 0 0 0 1 1 1 1 1 1 1
-1 0 0 0 0 0 0 0 0 0 3 3 3 3 3 3 0 0 0 0
-1 -1 1 1 1 3 3 3 2 2 2 2 2 2 2 2 7 7 7
The number of Hits: 8
Hit Ratio: 0.4
The number of Faults: 12
```