# PROJECT REPORT
# TOPIC : PAGING SIMULATION

**COURSE:**
**IT 308 : OPERATING SYSTEMS**

<u>**Team Details**</u>

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## INTRODUCTION

Paging is a memory management scheme that eliminates the need for contiguous allocation of physical memory. This scheme permits the physical address space of a process to be non – contiguous. We have attempted to simulate paging of operating system using three different page replacement algorithms, them being - Least Recently Used, First in First Out and Least Frequently Used. To give an insight to this page replacement process and page mapping that happens between logical memory space and physical memory space, we depict a Page Map Table to the user whenever a page fault takes place. Along with this, the empty frames present in the physical memory space are also shown.

## CODE EXPLANATION

### *vm.cpp*

```
#include<iostream>
#include "pagetable.h"
using namespace std;

bool checkNo(long long int);

int main()
{
  long long int log_memSize, phy_memSize,pgNum,n;
  int choice;

  //Size of logical memory space
  cout<<"Enter the number of pages in logical memory space \n";
  cin>>log_memSize;
  if(!checkNo(log_memSize))
  {
    cout<<"Error: the number of pages entered is invalid\n";
    exit(EXIT_FAILURE);
  }

  //Size of physical memory space
  cout<<"Enter the number of frames in physical memory space \n";
  cin>>phy_memSize;
  if(!checkNo(phy_memSize))
  {
    cout<<"Error: the number of frames entered is invalid\n";
    exit(EXIT_FAILURE);
  }

  do {
```

```
  //Create page table using the logical memory size and physical memory size obtained
  PageTable pgTable(log_memSize,phy_memSize);

  //Select the page replacement algorithm for paging simulation
  cout<<"Choose a page replacement algorithm for paging simulation (1 - 4):\n";
  cout<<"1. Least Recently Used\n";
  cout<<"2. First in First Out\n";
  cout<<"3. Least frequently used\n";
  cout<<"4. Exit\n";
  cin>>choice;
  if(choice==4)
    break;
  pgTable.setPageFaults(0);

  /*Pages that are there in the Logical Memory Space are entered by the
  User and the Page Table is used to get reference of the corresponding frames in
  Physical Memory Space*/
  cout<<"Enter the number of pages to be referred\n";
  cin>>n;
  long long int pgArr[n];
   cout<<"Enter all the page numbers to be referred each should belong to this range (0 -
   "<<log_memSize-1<<"):\n";
  for(long long int i=0;i<n;i++)
  {
        cin>>pgArr[i];
        pgNum=pgArr[i];
        if(pgNum<0 || pgNum>log_memSize-1)       //if the input is out of range
        {
            cout<<"Error! Enter the page number in range (0 - "<<log_memSize-1<<")\n";
            i=i-1;
        }
        else
        {
            if(pgTable.containsRef(pgNum))       //if the page is in physical memory
            {
              pgTable.accessPg(pgNum,choice);           //access the frame corresponding to
                                                        //that page
            }
            else                                 //if the page is not in physical memory
            {
              pgTable.addPg(pgNum,choice);       //add this page in physical memory
              pgTable.accessPg(pgNum,choice);           //access the frame corresponding to
                                                        //that page
            }
        }

    }    //the above loop will run till the end of input

cout<<"The page faults occurred are : "<<pgTable.getPageFaults()<<"\n";
```

```
}while(choice!=4);

  return 0;
}

//This function checks whether the number of pages or frames entered by the user is valid
bool checkNo(long long int size)
{
  if(size<0)
    return false;
    else
      return true;
}
```

- The user enters the number of pages in the logical memory space.
- The number of pages is checked whether it is valid or not using the *checkNo* function; if invalid, an error statement is printed and the program is exited.
- If the number of pages is valid, the user is asked to enter the number of frames in the physical memory space.
- The validity of the number of frames is also checked using the *checkNo* function and if invalid, an error statement is printed and program is exited.
- Since the number of pages and frames entered by the user are valid, a page table is created using the logical memory size and the physical memory size given as input using *pgTable* object of class PageTable.
- The user is asked to select a page replacement algorithm for the paging simulation from the available ones.
- Depending upon this choice of the user, the algorithm specific case will be executed when a page needs to be replaced in physical memory.
- The user enters the number of pages he/she wants to be referred.
- The user has to then enter the page numbers which he/she wants to be referred and that must be within the logical memory space, these pages are stored in an array *pgArr*.
- The page numbers entered by the user are checked if they are within the acceptable range, if not, an error statement is generated and the user has to give an input for that again.
- If the page number is valid and is present in the physical memory space, the concerned frame is accessed using *accessPg function* in *PgTable*.
- If the page number is valid and is not present, the page is added to the physical memory by *addPg function* and is then accessed by *accessPg*.
- The total page faults occurred are printed depending upon the algorithm selected.
- This process continues till the user chooses to exit.

*pagetable.h*

```
#ifndef _PAGE_TABLE_
#define _PAGE_TABLE_

#include<iostream>
#include<vector>
#include<iomanip>
using namespace std;

class PageTable
{
 long long int ts;               // Counter to increment the timeStamp
 long long int pgFaults;         // To store the number of page faults that occur
 long long int pgReplace(int choice); // Swap pages when there are no more available frames

 class PageTableEntry
 {
   public:
     long long int timeStamp;    //to keep track of pages referenced recently
     long long int frameNo;      //represents a frame of physical memory
     int checkFrame;             /*will have value 1 or 0 depending on whether
                                 the page is present in physical memory or not*/
     PageTableEntry()
     {
       timeStamp=0;
       frameNo=-1;
       checkFrame=0;
     }
 };

 vector<PageTableEntry> pgMap;   /*Represents all the Page table entries
                                 and is used to map logical address to physical address*/
 vector<long long int> emptyFrames;   //represents the empty frames in physical address space

 public:
   PageTable(long long int log_memSize,long long int phy_memSize);
   bool containsRef(long long int pgNum);
   void accessPg(long long int pgNum,int choice);
   void addPg(long long int pgNum,int choice);
   void displayPageTable();
   long long int getPageFaults();
   void setPageFaults(int pf);
   vector<long long int> fifo_framePgs;
  vector<pair<long long int,long long int> > lfu_framePgs;    //pair for keeping page and its
corresponding frequency of reference
};

/*Constructor to create the page table with number of pages equal to logical memory size
and allocate empty frames in physical memory*/
```

```
PageTable::PageTable(long long int log_memSize,long long int phy_memSize)
{
 emptyFrames.clear();
 pgMap.clear();
 fifo_framePgs.clear();
 for(long long int i=phy_memSize-1;i>=0;i--)
 {
    emptyFrames.push_back(i);
 }
 pgMap.resize(log_memSize);
 ts=1;                             //initially timestamp must be 0
}

//To check whether a page is present in physical memory
bool PageTable::containsRef(long long int pgNum)
{
 return pgMap[pgNum].checkFrame;
}

//To access the frame corresponding to page entered by user
void PageTable::accessPg(long long int pgNum,int choice)
{
 long long int frame=pgMap[pgNum].frameNo;

 if(choice==3)       //this loop is exclusively for lfu algorithm
 {
   for(long long int i=0;i<lfu_framePgs.size();i++)       //since the page is already present
                                                          //in physical memory, increment the
                                                          //frequency
   {
     if(lfu_framePgs[i].first==pgNum)
     {
       long long int freq=lfu_framePgs[i].second;
       lfu_framePgs[i].second=freq+1;
     }
   }
 }

 pgMap[pgNum].timeStamp=ts;
 displayPageTable();
 ++ts;
 cout<<"The page "<<pgNum<<" was found at frame "<<frame<<" in physical memory\n\n";
}

//To add this page in physical memory
void PageTable::addPg(long long int pgNum,int choice)
{

 //if there are empty frames in physical memory, then add the page in the empty frames
 if(!emptyFrames.empty())
 {
   long long int frame=emptyFrames.back();
   emptyFrames.pop_back();
   pgMap[pgNum].frameNo=frame;
   pgMap[pgNum].checkFrame=1;
   pgMap[pgNum].timeStamp=ts;
   //cout<<"time "<<ts<<"\n";
   cout<<"Page Fault: Adding "<<pgNum<<" at frame "<<frame<<"\n";
 }
 /*if there are no empty frames in physical memory, then swap a page present in Physical
 Memory with this page using the page replacement algorithm the user wants*/
 else
 {
   long long int frame=pgReplace(choice);
   pgMap[pgNum].frameNo=frame;
   pgMap[pgNum].checkFrame=1;
   pgMap[pgNum].timeStamp=ts;
   //cout<<"time "<<ts<<"\n";
   cout<<"Page Fault: Adding "<<pgNum<<" at frame "<<frame<<"\n";
 }
 ++pgFaults;
 fifo_framePgs.push_back(pgNum);
 lfu_framePgs.push_back(make_pair(pgNum,1));
}

/*use different page replacement algorithm depending on the choice entered by
the user and find a page that should be replaced*/
long long int PageTable::pgReplace(int choice)
{

 if(choice==1)         //Least Recently Used
 {
   long long int min=ts;
   long long int replacePg;
   for(long long int j=0;j<pgMap.size();j++)
   {
     if(pgMap[j].checkFrame==1)     //if the page is present in physical memory
     {
        if(pgMap[j].timeStamp<min)  //if this page is less recent compared to the previous page
in physical memory frame
       {
         min=pgMap[j].timeStamp;   //update the minimum timestamp
         replacePg=j;             //the page to be replaced is with this minimum timestamp now
       }
     }
   }
   long long int frame=pgMap[replacePg].frameNo;
   pgMap[replacePg].checkFrame=0;
   pgMap[replacePg].frameNo=-1;
   return frame;                   //return the frame where the new page will be inserted
 }

 else if(choice==2)    //First in First Out
 {
   long long int replacePg=fifo_framePgs.at(0);         //removing the first page that
   fifo_framePgs.erase(fifo_framePgs.begin()+0);         //was inserted in the physical
                                                           //memory
   pgMap[replacePg].checkFrame=0;
   long long int frame=pgMap[replacePg].frameNo;
   pgMap[replacePg].frameNo=-1;
   return frame;                    //return the frame where the new page will be inserted
 }


 else if(choice==3)    //Least frequently used
 {
   long long int min=0;
   for(long long int i=0;i<lfu_framePgs.size();i++)    //loop to find the page in physical
                                                           //memory with minimum frequency
   {
     if(lfu_framePgs[i].second<lfu_framePgs[min].second)
       min=i;
   }
   long long int replacePg=lfu_framePgs[min].first;
   lfu_framePgs.erase(lfu_framePgs.begin()+min);
   pgMap[replacePg].checkFrame=0;
   long long int frame=pgMap[replacePg].frameNo;
   pgMap[replacePg].frameNo=-1;
   return frame;                    //return the frame where the new page will be inserted
 }
 return 1;
}

//display the contents of the page table
void PageTable::displayPageTable()
{
  cout  <<  left  <<  setfill('-')  <<  setw(1)  <<  "+"  <<  setw(4)  <<  "-"  <<  setw(1)  <<  "+"  <<
setw(15)  <<  "-"  <<  setw(1)  <<  "+"  <<  setw(15)  <<  "-"  <<  setw(1)  <<  "+"  <<  setw(9)  <<
setfill('-')  <<  "-"  <<  right  <<  "+"  <<  setfill('  ')<<  setw(21)  <<  "+"  <<  setfill('-')  <<
setw(15) << "-" << endl;
  cout  <<  right  <<  setw(1)  <<  "|"  <<  "ADR"  <<  setfill('  ')  <<  setw(2)  <<  "|"  <<  left  <<
setw(15) << "Frame no." << setw(1) << "|" << setw(15)  << "Valid" << setw(1) << "|" << setw(5)
<< "TimeStamp" << setw(1) << "|" << setw(20) << setfill(' ') << " " << "|" << "Empty Frames"
<< setw(4) << right << "|" << endl;
  cout  <<  left  <<  setfill('-')  <<  setw(4)  <<  "+"  <<  setw(17)  <<  "-"  <<  setw(1)  <<  "+"  <<
setw(15) << "-" << setw(1) << "+" << setw(9) << "-" << setw(1) << "+" << setw(20) << setfill('
') << " " << setw(1) << setfill(' ') << "+" << setfill('-') << setw(15) << "-" << endl;
 for (unsigned int i = 0; i < pgMap.size(); i++)
 {
    cout << "|" << setfill(' ') << setw(3) << i << setfill(' ') << setw(1) << " " << "|" <<
setw(15) << pgMap.at(i).frameNo
     << setw(1) << "|" << setw(15) << pgMap.at(i).checkFrame << setw(1) << "|" << setw(5)
     << pgMap.at(i).timeStamp << setfill(' ') << setw(4) << " " << setw(1) << "|";
   if (i < emptyFrames.size()) {
      cout << left << setw(20) << setfill(' ') << " " << "|" << setw(5) << emptyFrames.at(i) <<
setfill(' ') << setw(9) << " " << setw(1) << "|" <<endl;
      cout << setfill('-') << setw(4) << "+" << setw(17) << "-" << setw(1) << "+" << setw(15)
<< "-" << setw(1) << "+" << setw(9) << "-" << setw(1) << "+" << setw(20) << setfill(' ') << "
" << setw(1) << setfill(' ') << "+" << setfill('-') << setw(15) << "-" << endl;
   }
      else {
      cout << endl << setfill('-') << setw(4) << "+" << setw(17) << "-" << setw(1) << "+" <<
setw(15) << "-" << setw(1) << "+" << setw(9) << "-" << setw(1) << "+" << endl;
   }
 }

}

//initialize page faults
void PageTable::setPageFaults(int pf)
{
 pgFaults=pf;
}

//Returns the number of page faults
long long int PageTable::getPageFaults()
{
 return pgFaults;
}

#endif
```

- The class *PageTable* has variables *ts* which is the counter to increment the timeStamp, *pgFaults* which stores the number of page faults which have occurred and it has a vector of *PageTableEntry* class called *pgMap* which stores the page table entries.
- The class *PageTableEntry* has variables *timeStamp* which corresponds to the timestamp of the a page, *frameNo* which represents the frame number from the physical memory where that page is present and has been initialised to -1 for all frames since initially none of the pages are present in physical memory space and *checkFrame* which is a boolean and indicates whether the page is present in the physical memory or not, which is initialised 0 because none of the page is present in physical memory .
- A constructor for *PageTable* is created with number of pages in logical space equal to the logical memory size entered by user and also it allocates empty frames in the physical memory based on the input entered for this by user.

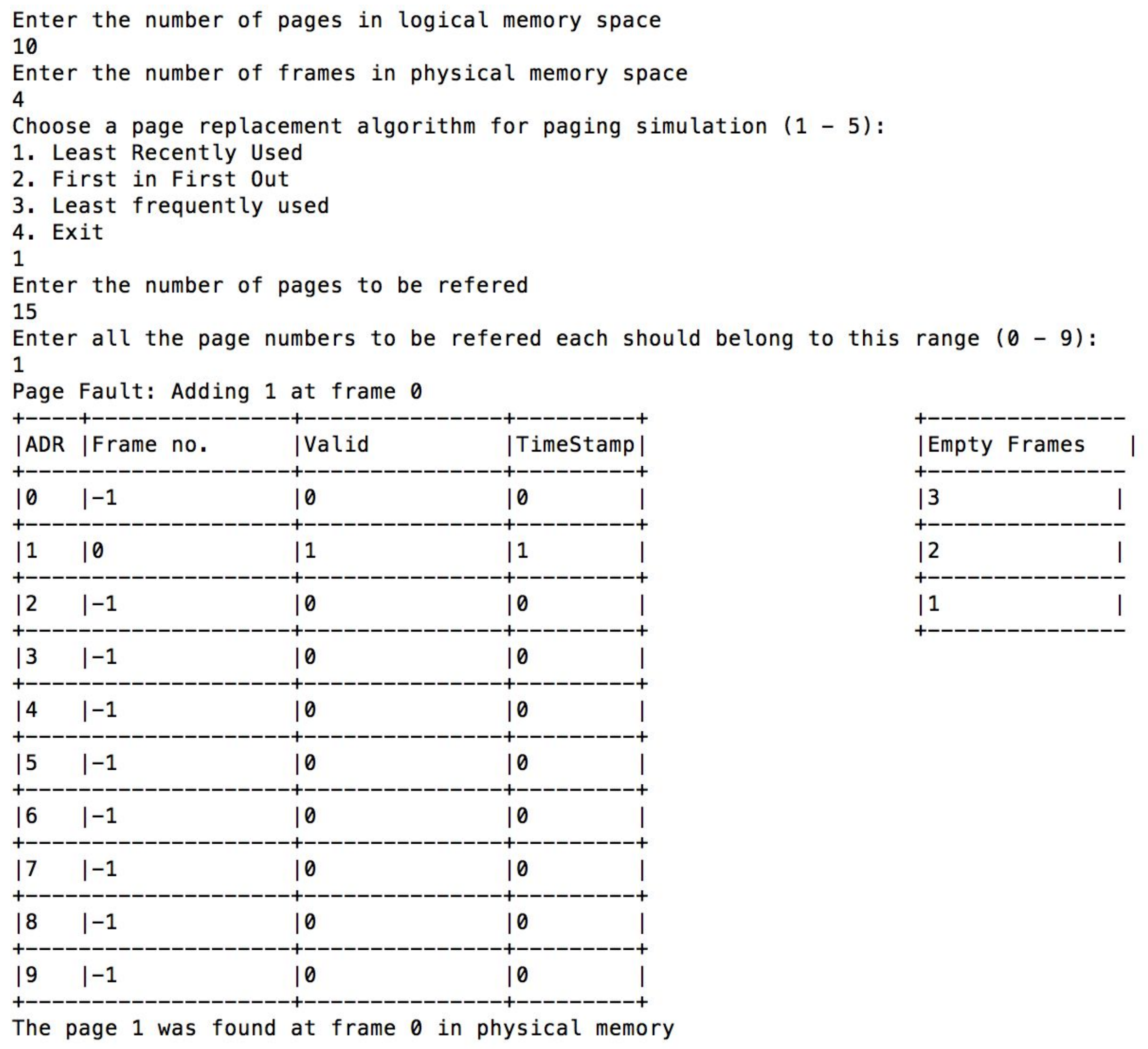
- Function *containsRef* of PageTable checks whether a page is present in the physical memory or not. This returns the checkFrame field which is either 1 or 0 of the page number which had been given as input.
- Function *accessPg* of PageTable is used to access the frame corresponding to the page number which had been entered by the user.
    - This function accesses the frame number of the page number entered and it prints this frame. It also increments the timestamp of the frame.
    - If the algorithm selected is least frequently used, the frequency of the page is updated by incrementing it in vector *lfu_framePgs* of the PageTable which contains pairs of page number and corresponding frequency of reference.
- The function *addPg* of PageTable is used to add a page to the physical memory.
    - If empty frames are present, the page is added to one of the empty frames by removing a frame from vector *emptyFrames* of PageTable and the variables of that page such as frameNo, checkFrame, timeStamp are updated.
    - If empty frames are not present, a page is swapped using the algorithm selected by the user and *pgFaults* is incremented. And the variables of that page such as frameNo, checkFrame, timeStamp are updated.
    - These page numbers are also added in the vector *fifo_framePgs* and *lfu_framePgs.*
- In the function *pgReplace* of PageTable *,* the selected page replacement algorithm is used to swap out a page creating a page fault.
    - If least recently used algorithm is selected, the page with the minimum *time stamp* is selected and it is replaced creating a page fault and the variables for it are updated. The frame where the new page will be inserted is returned.
    - If First in First Out is selected, the first page which was inserted in the physical memory is removed from the vector *fifo_framePgs* and the frame where the new page will be inserted is returned.
    - If least frequently used is selected, the page with the minimum frequency from the vector *lfu_framePgs* is found and removed and the frame where the new page will be inserted is returned.
- In the function *displayPageTable* of PageTable, the entire page map is displayed which contains values for logical space pages, the frame number of physical memory space corresponding to the page, the valid field to show the whether the page is present in physical memory or not by displaying value 1 or 0 and the timestamp of last access to the page . Also, the empty frames of Physical Memory are displayed.
- Function *setPageFaults* of PageTable is to initialize the page faults of the page to the parameter which is passed to the function.
- Function *getPageFaults* of PageTable returns the total number of page faults occured.

**TESTING**

**To run the above codes, open the terminal and run the following command**

- ➢ g++ -o main vm.cpp
- ➢ ./main

**The user and code interaction follows below**



```
Enter the number of pages in logical memory space
10
Enter the number of frames in physical memory space
4
Choose a page replacement algorithm for paging simulation (1 - 5):
1. Least Recently Used
2. First in First Out
3. Least frequently used
4. Exit
1
Enter the number of pages to be refered
15
Enter all the page numbers to be refered each should belong to this range (0 - 9):
1
Page Fault: Adding 1 at frame 0
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+--------------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+--------------------+---------------+---------+                    +---------------
|1   |0              |1              |1        |                    |2             |
+--------------------+---------------+---------+                    +---------------
|2   |-1             |0              |0        |                    |1             |
+--------------------+---------------+---------+                    +---------------
|3   |-1             |0              |0        |
+--------------------+---------------+---------+
|4   |-1             |0              |0        |
+--------------------+---------------+---------+
|5   |-1             |0              |0        |
+--------------------+---------------+---------+
|6   |-1             |0              |0        |
+--------------------+---------------+---------+
|7   |-1             |0              |0        |
+--------------------+---------------+---------+
|8   |-1             |0              |0        |
+--------------------+---------------+---------+
|9   |-1             |0              |0        |
+--------------------+---------------+---------+
The page 1 was found at frame 0 in physical memory
```

```
1
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+----+---------------+---------------+---------+                    +---------------
|1   |0              |1              |2        |                    |2             |
+----+---------------+---------------+---------+                    +---------------
|2   |-1             |0              |0        |                    |1             |
+----+---------------+---------------+---------+                    +---------------
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |-1             |0              |0        |
+----+---------------+---------------+---------+
|5   |-1             |0              |0        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

12345
Error! Enter the page number in range (0 - 9)
2
Page Fault: Adding 2 at frame 1
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+----+---------------+---------------+---------+                    +---------------
|1   |0              |1              |2        |                    |2             |
+----+---------------+---------------+---------+                    +---------------
|2   |1              |1              |3        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |-1             |0              |0        |
+----+---------------+---------------+---------+
|5   |-1             |0              |0        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 2 was found at frame 1 in physical memory

1
```

```
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+----+---------------+---------------+---------+                    +---------------
|1   |0              |1              |4        |                    |2             |
+----+---------------+---------------+---------+                    +---------------
|2   |1              |1              |3        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |-1             |0              |0        |
+----+---------------+---------------+---------+
|5   |-1             |0              |0        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

4
Page Fault: Adding 4 at frame 2
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+----+---------------+---------------+---------+                    +---------------
|1   |0              |1              |4        |
+----+---------------+---------------+---------+
|2   |1              |1              |3        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |-1             |0              |0        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 4 was found at frame 2 in physical memory

5
Page Fault: Adding 5 at frame 3
```

```
+----+----------------+----------------+----------+                +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                |Empty Frames    |
+----+----------------+----------------+----------+                +---------------
|0   |-1              |0               |0         |
+----+----------------+----------------+----------+
|1   |0               |1               |4         |
+----+----------------+----------------+----------+
|2   |1               |1               |3         |
+----+----------------+----------------+----------+
|3   |-1              |0               |0         |
+----+----------------+----------------+----------+
|4   |2               |1               |5         |
+----+----------------+----------------+----------+
|5   |3               |1               |6         |
+----+----------------+----------------+----------+
|6   |-1              |0               |0         |
+----+----------------+----------------+----------+
|7   |-1              |0               |0         |
+----+----------------+----------------+----------+
|8   |-1              |0               |0         |
+----+----------------+----------------+----------+
|9   |-1              |0               |0         |
+----+----------------+----------------+----------+
The page 5 was found at frame 3 in physical memory

2
+----+----------------+----------------+----------+                +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                |Empty Frames    |
+----+----------------+----------------+----------+                +---------------
|0   |-1              |0               |0         |
+----+----------------+----------------+----------+
|1   |0               |1               |4         |
+----+----------------+----------------+----------+
|2   |1               |1               |7         |
+----+----------------+----------------+----------+
|3   |-1              |0               |0         |
+----+----------------+----------------+----------+
|4   |2               |1               |5         |
+----+----------------+----------------+----------+
|5   |3               |1               |6         |
+----+----------------+----------------+----------+
|6   |-1              |0               |0         |
+----+----------------+----------------+----------+
|7   |-1              |0               |0         |
+----+----------------+----------------+----------+
|8   |-1              |0               |0         |
+----+----------------+----------------+----------+
|9   |-1              |0               |0         |
+----+----------------+----------------+----------+
The page 2 was found at frame 1 in physical memory
```

```
2
+----+---------------+---------------+---------+                +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                |Empty Frames    |
+----+---------------+---------------+---------+                +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |4        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 2 was found at frame 1 in physical memory

1
+----+---------------+---------------+---------+                +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                |Empty Frames    |
+----+---------------+---------------+---------+                +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |9        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

4
```

```
+----+----------------+----------------+----------+                    +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                    |Empty Frames   |
+----+----------------+----------------+----------+                    +---------------
|0   |-1              |0               |0         |
+----+----------------+----------------+----------+
|1   |0               |1               |9         |
+----+----------------+----------------+----------+
|2   |1               |1               |8         |
+----+----------------+----------------+----------+
|3   |-1              |0               |0         |
+----+----------------+----------------+----------+
|4   |2               |1               |10        |
+----+----------------+----------------+----------+
|5   |3               |1               |6         |
+----+----------------+----------------+----------+
|6   |-1              |0               |0         |
+----+----------------+----------------+----------+
|7   |-1              |0               |0         |
+----+----------------+----------------+----------+
|8   |-1              |0               |0         |
+----+----------------+----------------+----------+
|9   |-1              |0               |0         |
+----+----------------+----------------+----------+
The page 4 was found at frame 2 in physical memory

5
+----+----------------+----------------+----------+                    +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                    |Empty Frames   |
+----+----------------+----------------+----------+                    +---------------
|0   |-1              |0               |0         |
+----+----------------+----------------+----------+
|1   |0               |1               |9         |
+----+----------------+----------------+----------+
|2   |1               |1               |8         |
+----+----------------+----------------+----------+
|3   |-1              |0               |0         |
+----+----------------+----------------+----------+
|4   |2               |1               |10        |
+----+----------------+----------------+----------+
|5   |3               |1               |11        |
+----+----------------+----------------+----------+
|6   |-1              |0               |0         |
+----+----------------+----------------+----------+
|7   |-1              |0               |0         |
+----+----------------+----------------+----------+
|8   |-1              |0               |0         |
+----+----------------+----------------+----------+
|9   |-1              |0               |0         |
+----+----------------+----------------+----------+
The page 5 was found at frame 3 in physical memory
```

```
6
Page Fault: Adding 6 at frame 1
+----+-------------------+-------------------+---------+                          +---------------
|ADR |Frame no.          |Valid              |TimeStamp|                          |Empty Frames   |
+----+-------------------+-------------------+---------+                          +---------------
|0   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|1   |0                  |1                  |9        |
+----+-------------------+-------------------+---------+
|2   |-1                 |0                  |8        |
+----+-------------------+-------------------+---------+
|3   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|4   |2                  |1                  |10       |
+----+-------------------+-------------------+---------+
|5   |3                  |1                  |11       |
+----+-------------------+-------------------+---------+
|6   |1                  |1                  |12       |
+----+-------------------+-------------------+---------+
|7   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|8   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|9   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
The page 6 was found at frame 1 in physical memory

1
+----+-------------------+-------------------+---------+                          +---------------
|ADR |Frame no.          |Valid              |TimeStamp|                          |Empty Frames   |
+----+-------------------+-------------------+---------+                          +---------------
|0   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|1   |0                  |1                  |13       |
+----+-------------------+-------------------+---------+
|2   |-1                 |0                  |8        |
+----+-------------------+-------------------+---------+
|3   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|4   |2                  |1                  |10       |
+----+-------------------+-------------------+---------+
|5   |3                  |1                  |11       |
+----+-------------------+-------------------+---------+
|6   |1                  |1                  |12       |
+----+-------------------+-------------------+---------+
|7   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|8   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
|9   |-1                 |0                  |0        |
+----+-------------------+-------------------+---------+
The page 1 was found at frame 0 in physical memory
```

```
7
Page Fault: Adding 7 at frame 2
+----+----------------+----------------+----------+                +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                |Empty Frames   |
+----------------------+----------------+----------+               +---------------
|0   |-1              |0               |0         |
+----------------------+----------------+----------+
|1   |0               |1               |13        |
+----------------------+----------------+----------+
|2   |-1              |0               |8         |
+----------------------+----------------+----------+
|3   |-1              |0               |0         |
+----------------------+----------------+----------+
|4   |-1              |0               |10        |
+----------------------+----------------+----------+
|5   |3               |1               |11        |
+----------------------+----------------+----------+
|6   |1               |1               |12        |
+----------------------+----------------+----------+
|7   |2               |1               |14        |
+----------------------+----------------+----------+
|8   |-1              |0               |0         |
+----------------------+----------------+----------+
|9   |-1              |0               |0         |
+----------------------+----------------+----------+
The page 7 was found at frame 2 in physical memory

2
Page Fault: Adding 2 at frame 3
+----+----------------+----------------+----------+                +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                |Empty Frames   |
+----------------------+----------------+----------+               +---------------
|0   |-1              |0               |0         |
+----------------------+----------------+----------+
|1   |0               |1               |13        |
+----------------------+----------------+----------+
|2   |3               |1               |15        |
+----------------------+----------------+----------+
|3   |-1              |0               |0         |
+----------------------+----------------+----------+
|4   |-1              |0               |10        |
+----------------------+----------------+----------+
|5   |-1              |0               |11        |
+----------------------+----------------+----------+
|6   |1               |1               |12        |
+----------------------+----------------+----------+
|7   |2               |1               |14        |
+----------------------+----------------+----------+
|8   |-1              |0               |0         |
+----------------------+----------------+----------+
|9   |-1              |0               |0         |
+----------------------+----------------+----------+
The page 2 was found at frame 3 in physical memory

The page faults occured are : 7
```

```
Choose a page replacement algorithm for paging simulation (1 - 5):
1. Least Recently Used
2. First in First Out
3. Least frequently used
4. Exit
2
Enter the number of pages to be refered
15
Enter all the page numbers to be refered each should belong to this range (0 - 9):
1
Page Fault: Adding 1 at frame 0
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+--------------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3              |
+--------------------+---------------+---------+                    +---------------
|1   |0              |1              |1        |                    |2              |
+--------------------+---------------+---------+                    +---------------
|2   |-1             |0              |0        |                    |1              |
+--------------------+---------------+---------+                    +---------------
|3   |-1             |0              |0        |
+--------------------+---------------+---------+
|4   |-1             |0              |0        |
+--------------------+---------------+---------+
|5   |-1             |0              |0        |
+--------------------+---------------+---------+
|6   |-1             |0              |0        |
+--------------------+---------------+---------+
|7   |-1             |0              |0        |
+--------------------+---------------+---------+
|8   |-1             |0              |0        |
+--------------------+---------------+---------+
|9   |-1             |0              |0        |
+--------------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

1
```

```
+----+--------------------+--------------------+----------+                +----------------
|ADR |Frame no.           |Valid               |TimeStamp|                |Empty Frames    |
+--------------------------+--------------------+----------+                +----------------
|0   |-1                  |0                   |0         |                |3              |
+--------------------------+--------------------+----------+                +----------------
|1   |0                   |1                   |2         |                |2              |
+--------------------------+--------------------+----------+                +----------------
|2   |-1                  |0                   |0         |                |1              |
+--------------------------+--------------------+----------+                +----------------
|3   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|4   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|5   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|6   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|7   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|8   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|9   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
The page 1 was found at frame 0 in physical memory

2
Page Fault: Adding 2 at frame 1
+----+--------------------+--------------------+----------+                +----------------
|ADR |Frame no.           |Valid               |TimeStamp|                |Empty Frames    |
+--------------------------+--------------------+----------+                +----------------
|0   |-1                  |0                   |0         |                |3              |
+--------------------------+--------------------+----------+                +----------------
|1   |0                   |1                   |2         |                |2              |
+--------------------------+--------------------+----------+                +----------------
|2   |1                   |1                   |3         |
+--------------------------+--------------------+----------+
|3   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|4   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|5   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|6   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|7   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|8   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
|9   |-1                  |0                   |0         |
+--------------------------+--------------------+----------+
The page 2 was found at frame 1 in physical memory

1
```

```
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+----+---------------+---------------+---------+                    +---------------
|1   |0              |1              |4        |                    |2             |
+----+---------------+---------------+---------+                    +---------------
|2   |1              |1              |3        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |-1             |0              |0        |
+----+---------------+---------------+---------+
|5   |-1             |0              |0        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

4
Page Fault: Adding 4 at frame 2
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+----+---------------+---------------+---------+                    +---------------
|1   |0              |1              |4        |
+----+---------------+---------------+---------+
|2   |1              |1              |3        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |-1             |0              |0        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 4 was found at frame 2 in physical memory

5
Page Fault: Adding 5 at frame 3
```

```
+----+---------------+---------------+---------+                    +----------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+----+---------------+---------------+---------+                    +----------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |4        |
+----+---------------+---------------+---------+
|2   |1              |1              |3        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 5 was found at frame 3 in physical memory

2
+----+---------------+---------------+---------+                    +----------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+----+---------------+---------------+---------+                    +----------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |4        |
+----+---------------+---------------+---------+
|2   |1              |1              |7        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 2 was found at frame 1 in physical memory

2
```

```
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |4        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 2 was found at frame 1 in physical memory

1
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |9        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

4
```

```
+----+----------------+----------------+---------+                                  +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                                  |Empty Frames   |
+----+----------------+----------------+---------+                                  +---------------
|0   |-1              |0               |0        |
+----+----------------+----------------+---------+
|1   |0               |1               |9        |
+----+----------------+----------------+---------+
|2   |1               |1               |8        |
+----+----------------+----------------+---------+
|3   |-1              |0               |0        |
+----+----------------+----------------+---------+
|4   |2               |1               |10       |
+----+----------------+----------------+---------+
|5   |3               |1               |6        |
+----+----------------+----------------+---------+
|6   |-1              |0               |0        |
+----+----------------+----------------+---------+
|7   |-1              |0               |0        |
+----+----------------+----------------+---------+
|8   |-1              |0               |0        |
+----+----------------+----------------+---------+
|9   |-1              |0               |0        |
+----+----------------+----------------+---------+
The page 4 was found at frame 2 in physical memory

5
+----+----------------+----------------+---------+                                  +---------------
|ADR |Frame no.       |Valid           |TimeStamp|                                  |Empty Frames   |
+----+----------------+----------------+---------+                                  +---------------
|0   |-1              |0               |0        |
+----+----------------+----------------+---------+
|1   |0               |1               |9        |
+----+----------------+----------------+---------+
|2   |1               |1               |8        |
+----+----------------+----------------+---------+
|3   |-1              |0               |0        |
+----+----------------+----------------+---------+
|4   |2               |1               |10       |
+----+----------------+----------------+---------+
|5   |3               |1               |11       |
+----+----------------+----------------+---------+
|6   |-1              |0               |0        |
+----+----------------+----------------+---------+
|7   |-1              |0               |0        |
+----+----------------+----------------+---------+
|8   |-1              |0               |0        |
+----+----------------+----------------+---------+
|9   |-1              |0               |0        |
+----+----------------+----------------+---------+
The page 5 was found at frame 3 in physical memory

6
Page Fault: Adding 6 at frame 0
```

```
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+--------------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |
+--------------------+---------------+---------+
|1   |-1             |0              |9        |
+--------------------+---------------+---------+
|2   |1              |1              |8        |
+--------------------+---------------+---------+
|3   |-1             |0              |0        |
+--------------------+---------------+---------+
|4   |2              |1              |10       |
+--------------------+---------------+---------+
|5   |3              |1              |11       |
+--------------------+---------------+---------+
|6   |0              |1              |12       |
+--------------------+---------------+---------+
|7   |-1             |0              |0        |
+--------------------+---------------+---------+
|8   |-1             |0              |0        |
+--------------------+---------------+---------+
|9   |-1             |0              |0        |
+--------------------+---------------+---------+
The page 6 was found at frame 0 in physical memory

1
Page Fault: Adding 1 at frame 1
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+--------------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |
+--------------------+---------------+---------+
|1   |1              |1              |13       |
+--------------------+---------------+---------+
|2   |-1             |0              |8        |
+--------------------+---------------+---------+
|3   |-1             |0              |0        |
+--------------------+---------------+---------+
|4   |2              |1              |10       |
+--------------------+---------------+---------+
|5   |3              |1              |11       |
+--------------------+---------------+---------+
|6   |0              |1              |12       |
+--------------------+---------------+---------+
|7   |-1             |0              |0        |
+--------------------+---------------+---------+
|8   |-1             |0              |0        |
+--------------------+---------------+---------+
|9   |-1             |0              |0        |
+--------------------+---------------+---------+
The page 1 was found at frame 1 in physical memory

7
Page Fault: Adding 7 at frame 2
```

```
+----+----------------+---------------+----------+                    +---------------
|ADR |Frame no.       |Valid          |TimeStamp|                    |Empty Frames    |
+----+----------------+---------------+----------+                    +---------------
|0   |-1              |0              |0         |
+----+----------------+---------------+----------+
|1   |1               |1              |13        |
+----+----------------+---------------+----------+
|2   |-1              |0              |8         |
+----+----------------+---------------+----------+
|3   |-1              |0              |0         |
+----+----------------+---------------+----------+
|4   |-1              |0              |10        |
+----+----------------+---------------+----------+
|5   |3               |1              |11        |
+----+----------------+---------------+----------+
|6   |0               |1              |12        |
+----+----------------+---------------+----------+
|7   |2               |1              |14        |
+----+----------------+---------------+----------+
|8   |-1              |0              |0         |
+----+----------------+---------------+----------+
|9   |-1              |0              |0         |
+----+----------------+---------------+----------+
The page 7 was found at frame 2 in physical memory

2
Page Fault: Adding 2 at frame 3
+----+----------------+---------------+----------+                    +---------------
|ADR |Frame no.       |Valid          |TimeStamp|                    |Empty Frames    |
+----+----------------+---------------+----------+                    +---------------
|0   |-1              |0              |0         |
+----+----------------+---------------+----------+
|1   |1               |1              |13        |
+----+----------------+---------------+----------+
|2   |3               |1              |15        |
+----+----------------+---------------+----------+
|3   |-1              |0              |0         |
+----+----------------+---------------+----------+
|4   |-1              |0              |10        |
+----+----------------+---------------+----------+
|5   |-1              |0              |11        |
+----+----------------+---------------+----------+
|6   |0               |1              |12        |
+----+----------------+---------------+----------+
|7   |2               |1              |14        |
+----+----------------+---------------+----------+
|8   |-1              |0              |0         |
+----+----------------+---------------+----------+
|9   |-1              |0              |0         |
+----+----------------+---------------+----------+
The page 2 was found at frame 3 in physical memory

The page faults occured are : 8
```

```
Choose a page replacement algorithm for paging simulation (1 - 5):
1. Least Recently Used
2. First in First Out
3. Least frequently used
4. Exit
3
Enter the number of pages to be refered
15
Enter all the page numbers to be refered each should belong to this range (0 - 9):
1
Page Fault: Adding 1 at frame 0
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+--------------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3              |
+--------------------+---------------+---------+                    +---------------
|1   |0              |1              |1        |                    |2              |
+--------------------+---------------+---------+                    +---------------
|2   |-1             |0              |0        |                    |1              |
+--------------------+---------------+---------+                    +---------------
|3   |-1             |0              |0        |
+--------------------+---------------+---------+
|4   |-1             |0              |0        |
+--------------------+---------------+---------+
|5   |-1             |0              |0        |
+--------------------+---------------+---------+
|6   |-1             |0              |0        |
+--------------------+---------------+---------+
|7   |-1             |0              |0        |
+--------------------+---------------+---------+
|8   |-1             |0              |0        |
+--------------------+---------------+---------+
|9   |-1             |0              |0        |
+--------------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

1
```

```
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+--------------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+--------------------+---------------+---------+                    +---------------
|1   |0              |1              |2        |                    |2             |
+--------------------+---------------+---------+                    +---------------
|2   |-1             |0              |0        |                    |1             |
+--------------------+---------------+---------+                    +---------------
|3   |-1             |0              |0        |
+--------------------+---------------+---------+
|4   |-1             |0              |0        |
+--------------------+---------------+---------+
|5   |-1             |0              |0        |
+--------------------+---------------+---------+
|6   |-1             |0              |0        |
+--------------------+---------------+---------+
|7   |-1             |0              |0        |
+--------------------+---------------+---------+
|8   |-1             |0              |0        |
+--------------------+---------------+---------+
|9   |-1             |0              |0        |
+--------------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

2
Page Fault: Adding 2 at frame 1
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+--------------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |                    |3             |
+--------------------+---------------+---------+                    +---------------
|1   |0              |1              |2        |                    |2             |
+--------------------+---------------+---------+                    +---------------
|2   |1              |1              |3        |
+--------------------+---------------+---------+
|3   |-1             |0              |0        |
+--------------------+---------------+---------+
|4   |-1             |0              |0        |
+--------------------+---------------+---------+
|5   |-1             |0              |0        |
+--------------------+---------------+---------+
|6   |-1             |0              |0        |
+--------------------+---------------+---------+
|7   |-1             |0              |0        |
+--------------------+---------------+---------+
|8   |-1             |0              |0        |
+--------------------+---------------+---------+
|9   |-1             |0              |0        |
+--------------------+---------------+---------+
The page 2 was found at frame 1 in physical memory

1
```

```
+----+---------------+---------------+----------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+----+---------------+---------------+----------+                    +---------------
|0   |-1             |0              |0         |                    |3              |
+----+---------------+---------------+----------+                    +---------------
|1   |0              |1              |4         |                    |2              |
+----+---------------+---------------+----------+                    +---------------
|2   |1              |1              |3         |
+----+---------------+---------------+----------+
|3   |-1             |0              |0         |
+----+---------------+---------------+----------+
|4   |-1             |0              |0         |
+----+---------------+---------------+----------+
|5   |-1             |0              |0         |
+----+---------------+---------------+----------+
|6   |-1             |0              |0         |
+----+---------------+---------------+----------+
|7   |-1             |0              |0         |
+----+---------------+---------------+----------+
|8   |-1             |0              |0         |
+----+---------------+---------------+----------+
|9   |-1             |0              |0         |
+----+---------------+---------------+----------+
The page 1 was found at frame 0 in physical memory

4
Page Fault: Adding 4 at frame 2
+----+---------------+---------------+----------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames    |
+----+---------------+---------------+----------+                    +---------------
|0   |-1             |0              |0         |                    |3              |
+----+---------------+---------------+----------+                    +---------------
|1   |0              |1              |4         |
+----+---------------+---------------+----------+
|2   |1              |1              |3         |
+----+---------------+---------------+----------+
|3   |-1             |0              |0         |
+----+---------------+---------------+----------+
|4   |2              |1              |5         |
+----+---------------+---------------+----------+
|5   |-1             |0              |0         |
+----+---------------+---------------+----------+
|6   |-1             |0              |0         |
+----+---------------+---------------+----------+
|7   |-1             |0              |0         |
+----+---------------+---------------+----------+
|8   |-1             |0              |0         |
+----+---------------+---------------+----------+
|9   |-1             |0              |0         |
+----+---------------+---------------+----------+
The page 4 was found at frame 2 in physical memory

5
Page Fault: Adding 5 at frame 3
```

```
+----+---------------+---------------+----------+                   +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                   |Empty Frames   |
+----+---------------+---------------+----------+                   +---------------
|0   |-1             |0              |0         |
+----+---------------+---------------+----------+
|1   |0              |1              |4         |
+----+---------------+---------------+----------+
|2   |1              |1              |3         |
+----+---------------+---------------+----------+
|3   |-1             |0              |0         |
+----+---------------+---------------+----------+
|4   |2              |1              |5         |
+----+---------------+---------------+----------+
|5   |3              |1              |6         |
+----+---------------+---------------+----------+
|6   |-1             |0              |0         |
+----+---------------+---------------+----------+
|7   |-1             |0              |0         |
+----+---------------+---------------+----------+
|8   |-1             |0              |0         |
+----+---------------+---------------+----------+
|9   |-1             |0              |0         |
+----+---------------+---------------+----------+
The page 5 was found at frame 3 in physical memory

2
+----+---------------+---------------+----------+                   +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                   |Empty Frames   |
+----+---------------+---------------+----------+                   +---------------
|0   |-1             |0              |0         |
+----+---------------+---------------+----------+
|1   |0              |1              |4         |
+----+---------------+---------------+----------+
|2   |1              |1              |7         |
+----+---------------+---------------+----------+
|3   |-1             |0              |0         |
+----+---------------+---------------+----------+
|4   |2              |1              |5         |
+----+---------------+---------------+----------+
|5   |3              |1              |6         |
+----+---------------+---------------+----------+
|6   |-1             |0              |0         |
+----+---------------+---------------+----------+
|7   |-1             |0              |0         |
+----+---------------+---------------+----------+
|8   |-1             |0              |0         |
+----+---------------+---------------+----------+
|9   |-1             |0              |0         |
+----+---------------+---------------+----------+
The page 2 was found at frame 1 in physical memory

2
```

```
+----+---------------+---------------+---------+                   +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                   |Empty Frames   |
+----+---------------+---------------+---------+                   +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |4        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 2 was found at frame 1 in physical memory

1
+----+---------------+---------------+---------+                   +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                   |Empty Frames   |
+----+---------------+---------------+---------+                   +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |9        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |5        |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 1 was found at frame 0 in physical memory

4
```

```
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |9        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |10       |
+----+---------------+---------------+---------+
|5   |3              |1              |6        |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 4 was found at frame 2 in physical memory

5
+----+---------------+---------------+---------+                    +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+---------+                    +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+---------+
|1   |0              |1              |9        |
+----+---------------+---------------+---------+
|2   |1              |1              |8        |
+----+---------------+---------------+---------+
|3   |-1             |0              |0        |
+----+---------------+---------------+---------+
|4   |2              |1              |10       |
+----+---------------+---------------+---------+
|5   |3              |1              |11       |
+----+---------------+---------------+---------+
|6   |-1             |0              |0        |
+----+---------------+---------------+---------+
|7   |-1             |0              |0        |
+----+---------------+---------------+---------+
|8   |-1             |0              |0        |
+----+---------------+---------------+---------+
|9   |-1             |0              |0        |
+----+---------------+---------------+---------+
The page 5 was found at frame 3 in physical memory

6
Page Fault: Adding 6 at frame 2
```

```
+----+---------------+---------------+----------+                   +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+----------+                   +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+----------+
|1   |0              |1              |9        |
+----+---------------+---------------+----------+
|2   |1              |1              |8        |
+----+---------------+---------------+----------+
|3   |-1             |0              |0        |
+----+---------------+---------------+----------+
|4   |-1             |0              |10       |
+----+---------------+---------------+----------+
|5   |3              |1              |11       |
+----+---------------+---------------+----------+
|6   |2              |1              |12       |
+----+---------------+---------------+----------+
|7   |-1             |0              |0        |
+----+---------------+---------------+----------+
|8   |-1             |0              |0        |
+----+---------------+---------------+----------+
|9   |-1             |0              |0        |
+----+---------------+---------------+----------+
The page 6 was found at frame 2 in physical memory

1
+----+---------------+---------------+----------+                   +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+----------+                   +---------------
|0   |-1             |0              |0        |
+----+---------------+---------------+----------+
|1   |0              |1              |13       |
+----+---------------+---------------+----------+
|2   |1              |1              |8        |
+----+---------------+---------------+----------+
|3   |-1             |0              |0        |
+----+---------------+---------------+----------+
|4   |-1             |0              |10       |
+----+---------------+---------------+----------+
|5   |3              |1              |11       |
+----+---------------+---------------+----------+
|6   |2              |1              |12       |
+----+---------------+---------------+----------+
|7   |-1             |0              |0        |
+----+---------------+---------------+----------+
|8   |-1             |0              |0        |
+----+---------------+---------------+----------+
|9   |-1             |0              |0        |
+----+---------------+---------------+----------+
The page 1 was found at frame 0 in physical memory

7
Page Fault: Adding 7 at frame 2
+----+---------------+---------------+----------+                   +---------------
|ADR |Frame no.      |Valid          |TimeStamp|                    |Empty Frames   |
+----+---------------+---------------+----------+                   +---------------
```

```
+------------------+---------------+---------+                          +---------------
|0   |-1           |0              |0        |
+------------------+---------------+---------+
|1   |0            |1              |13       |
+------------------+---------------+---------+
|2   |1            |1              |8        |
+------------------+---------------+---------+
|3   |-1           |0              |0        |
+------------------+---------------+---------+
|4   |-1           |0              |10       |
+------------------+---------------+---------+
|5   |3            |1              |11       |
+------------------+---------------+---------+
|6   |-1           |0              |12       |
+------------------+---------------+---------+
|7   |2            |1              |14       |
+------------------+---------------+---------+
|8   |-1           |0              |0        |
+------------------+---------------+---------+
|9   |-1           |0              |0        |
+------------------+---------------+---------+
The page 7 was found at frame 2 in physical memory

2
+----+-------------+---------------+---------+                          +---------------
|ADR |Frame no.    |Valid          |TimeStamp|                          |Empty Frames   |
+------------------+---------------+---------+                          +---------------
|0   |-1           |0              |0        |
+------------------+---------------+---------+
|1   |0            |1              |13       |
+------------------+---------------+---------+
|2   |1            |1              |15       |
+------------------+---------------+---------+
|3   |-1           |0              |0        |
+------------------+---------------+---------+
|4   |-1           |0              |10       |
+------------------+---------------+---------+
|5   |3            |1              |11       |
+------------------+---------------+---------+
|6   |-1           |0              |12       |
+------------------+---------------+---------+
|7   |2            |1              |14       |
+------------------+---------------+---------+
|8   |-1           |0              |0        |
+------------------+---------------+---------+
|9   |-1           |0              |0        |
+------------------+---------------+---------+
The page 2 was found at frame 1 in physical memory

The page faults occured are : 6
Choose a page replacement algorithm for paging simulation (1 - 5):
1. Least Recently Used
2. First in First Out
3. Least frequently used
4. Exit
4
```

The test case above had a logical memory space size of 10 pages and physical memory space size of 4. The number of pages to be referenced were 15 and the page numbers were as follows 1,1,2,1,4,5,2,2,1,4,5,6,1,7,2.

To demonstrate paging simulation of operating system, this logical page input was mapped to physical space input using 3 different Page Replacement Algorithms, them being - *Least Recently Used, First in First Out, Least Frequently Used.*

The Page Faults and Page Accesses occuring after every page reference have been clearly depicted using a Page Map Table. The currently empty frames in Physical Memory have also been shown beside the table.

It is seen that the page faults vary with the page replacement algorithm selected. That is:-

- Least Recently Used: 7 page faults
- First in, First Out: 8 page faults
- Least Frequently Used: 6 page faults