EOPSY

Lab 4: Memory Management

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Introduction

Memory management is the functionality of the operating system which handles the processes allocation in memory.
The processes are moved back and forth between the parts of the memory. When it happens, the free memory space is divided further and further into little pieces. At some point these free pieces can be too small and remain not used at all – this problem is called **fragmentation**.
A solution to fragmentation can be **paging**, in which process address space is divided into equally-sized blocks called pages. The pages which belong to a specific process are loaded into available memory frames. To reiterate, frames are used to divide the physical memory, and pages are used to divide the processes' virtual address space.

Paging mechanism is important in implementing virtual memory and it is responsible for:
- mapping virtual addresses onto physical addresses (locating the referenced page and frame used by that page),
- sending pages from external memory to operating memory and sending back pages which are not required anymore.

The goal of this task was to configure the Memory Management simulator to map any 8 pages of physical memory to the first 8 pages of virtual memory, and then read from one virtual memory address on each of the 64 virtual pages.

memory.conf

```
// memset  virt page #  physical page #  R (read from)  M (modified) inMemTime (ns) lastTouchTime (ns)
memset 0 0 0 0 0 0
memset 1 1 0 0 0 0
memset 2 2 0 0 0 0
memset 3 3 0 0 0 0
memset 4 4 0 0 0 0
memset 5 5 0 0 0 0
memset 6 6 0 0 0 0
memset 7 7 0 0 0 0


// enable_logging 'true' or 'false'
// When true specify a log_file or leave blank for stdout
enable_logging true

// log_file <FILENAME>
// Where <FILENAME> is the name of the file you want output
// to be print to.
log_file tracefile

// page size, defaults to 2^14 and cannot be greater than 2^26
// pagesize <single page size (base 10)> or <'power' num (base 2)>
pagesize 16384

// addressradix sets the radix in which numerical values are displayed
// 2 is the default value
// addressradix <radix>
addressradix 10

// numpages sets the number of pages (physical and virtual)
// 64 is the default value
// numpages must be at least 2 and no more than 64
// numpages <num>
numpages 64
```

I edited the `memory.conf` file so that only 8 pages are mapped accordingly to our task's specifications (`memset` commands at the top which map respective pages between physical and virtual memory).
I also changed the address radix to 10, so that the numerical values are displayed in decimal.
The rest was left unchanged.

Then, in the `commands` file, I specified that the simulator should execute the `READ` command 64 times to addresses being the multiples of 16384, in order to read from one virtual memory address on each of the 64 virtual pages.

Part of the **commands** file:

```
READ 0
READ 16384         // 64 addresses being the multiples of 16384
READ 32768
READ 49152
READ 65536
READ 81920
…
READ 999424
READ 1015808
READ 1032192
```

Comments about the simulation results

After stepping through the simulator one operation at a time, it became clear that the first 8 pages were mapped correctly as was specified in the memory.conf file. Moreover, the pages 8-31 were also mapped correctly (probably by default by the simulator).

A **page fault** occurs when a virtual page which has not been mapped to a physical page yet is being referenced.
It turned out that the address 524288 caused the first page fault. It occurred at the 32nd virtual page and the simulator showed it was mapped to physical page -1 (so it was not mapped to any physical page). From that moment, each further address caused page faults up until 64th page, so the last one.

When a page fault happens, this page is being mapped to the first physical page in queue (depending on which page replacement algorithm is used).

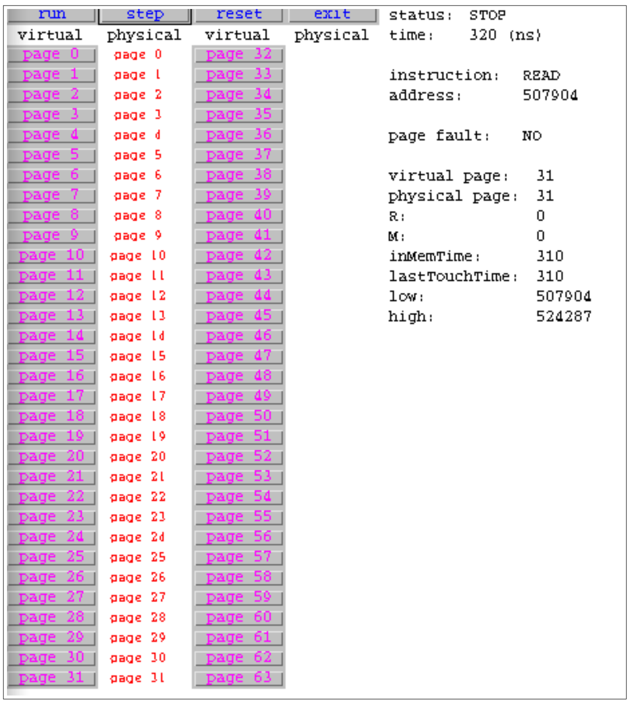
Part of `tracefile` file:

```
READ 0 ... okay
READ 16384 ... okay
READ 32768 ... okay
READ 49152 ... okay
…
READ 507904 ... okay
READ 524288 ... page fault
READ 540672 ... page fault
…
READ 1032192 ... page fault
```

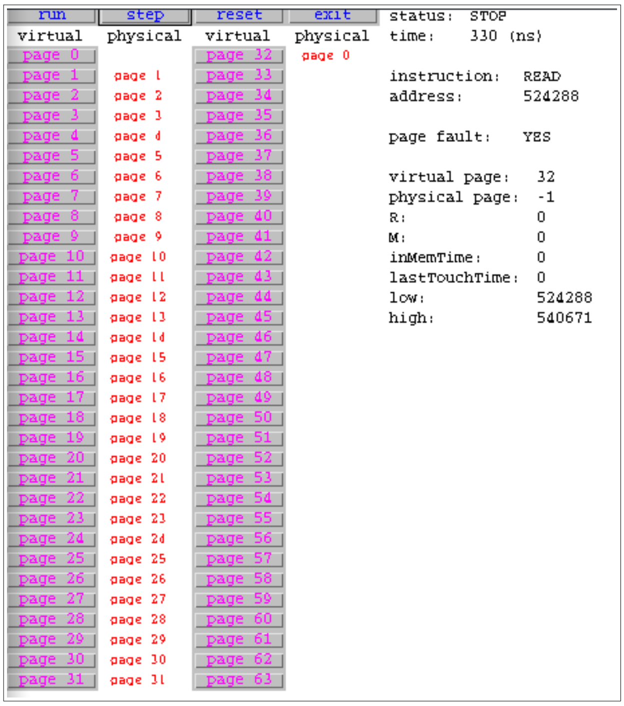
Information about the page replacement algorithm could be found in `PageFault.java` file (it's highlighted on the screenshot below).

```java
/* It is in this file, specifically the replacePage function that will
   be called by MemoryManagement when there is a page fault.  The
   users of this program should rewrite PageFault to implement the
   page replacement algorithm.
*/

  // This PageFault file is an example of the FIFO Page Replacement
  // Algorithm as described in the Memory Management section.

import java.util.*;

public class PageFault {

  /**
   * The page replacement algorithm for the memory management sumulator.
   * This method gets called whenever a page needs to be replaced.
   * <p>
   * The page replacement algorithm included with the simulator is
   * FIFO (first-in first-out).  A while or for loop should be used
   * to search through the current memory contents for a canidate
   * replacement page.  In the case of FIFO the while loop is used
   * to find the proper page while making sure that virtPageNum is
   * not exceeded.
   * <pre>
   *   Page page = ( Page ) mem.elementAt( oldestPage )
   * </pre>
```

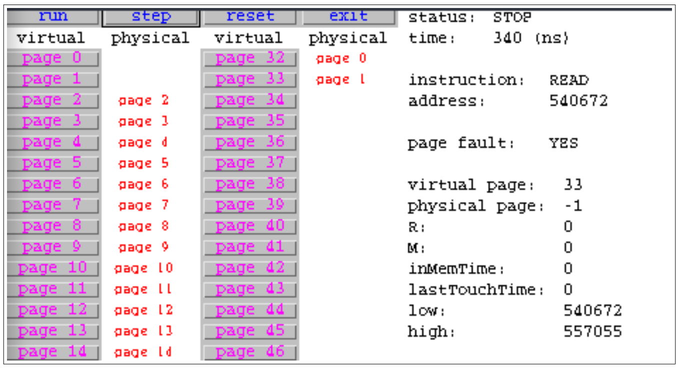
The page replacement algorithm used here is **FIFO (First-In First-Out)**. So, the first page mapped (first in) is used as replacement in the first place (first out).

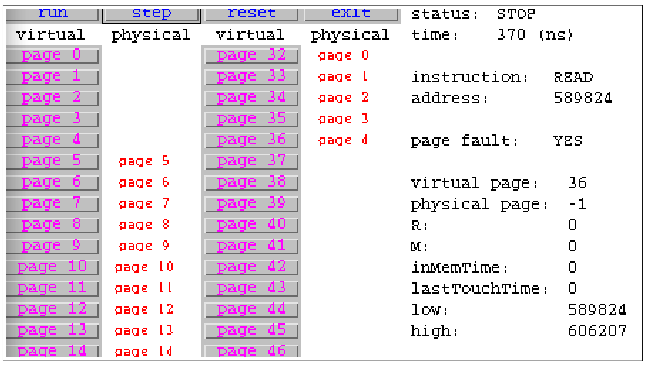


Last mapped page (31st)



First page fault





The screenshots above show the simulator step by step around the important point of the first page fault. It is visible that when the first page fault occurs at the 32nd page, page number 0 (which was first in) is first taken as replacement. After that, consecutive pages are taken by the replacement algorithm – at 33rd page, page number 1 is taken (which is the next "first in" after page 0) and so on.