Operating System 2 Programming Assignment 6

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- There are 2 files in the folder
    - xv6modified.tar.gz
    - Assn6_CS20BTECH11063_Report.pdf
- To compile and run the entire xv6 operating system

```
$ make
$ make qemu
```

To run `pgtprint function`

```
$ pgtprint
```

To run `demandpaging`

```
$ demandpaging
```

- The entire repository of xv6 has been cloned from the following github link
    - xv6-public
- To add a new system call which prints current date and time
    - In `syscall.h` the following changes are made
        - `#define SYS_pgtprint 23` is added
    - In `syscall.c` the following changes are made
        - `extern int sys_pgtprint(void);` is added which is an external system call defined elsewhere
        - `[SYS_pgtprint] sys_pgtprint` is added inside `static int (*syscalls[])(void)`
        - Inside `sysproc.c` a system call `sys_pgtprint()` is added to print page table entires
        - Inside `user.h` a function which would be called by user to print date and time is added, `int pgtprint()`
        - Inside `usys.S` , `SYSCALL(pgtprint)` is added, so that the user can now call this function to print the date and time
        - Added `_pgtprint` to the `UPROGS` definition in `Makefile`
        - A file `pgtprint.c` has been created which calls `pgtprint()` to print the page tables
- The working and design of the program:

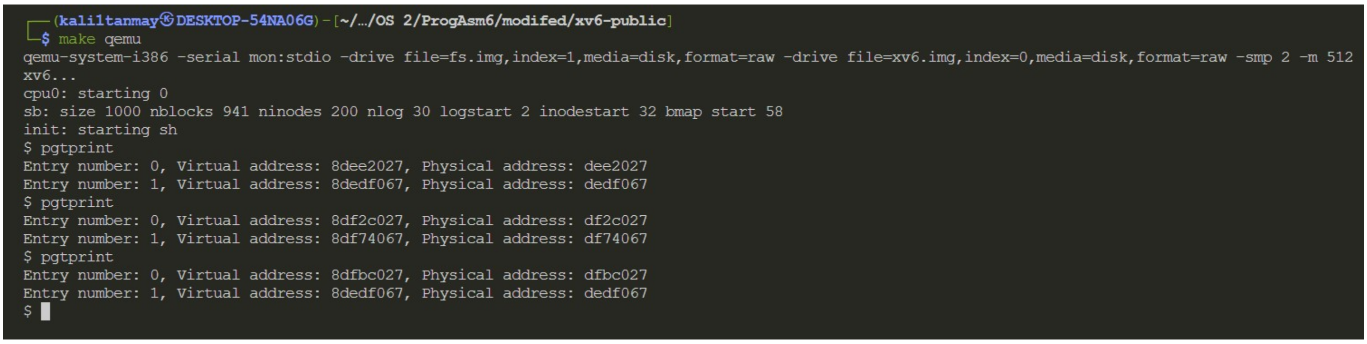
  - To create a system call, we first should assign a system call number to our new system call
  - When the user inputs the name of the system call in xv6, the console reads the name of the function and find the relevant number which corresponds to the function
  - A system call is executed in kernel mode as the program needs access low level functions
  - The program generates a trap
  - During a system call, the processor switches from user mode to kernel mode, then it completes the process and returns to user mode
  - Traps are handled in `trapasm.S`
  - The file makes a call `trap(struct trapframe *)` in `trap.c`
  - A system call can also take arguments to kernel mode or take return value back to user mode
  - `syscall.c` stores an array of function pointers that return `int`
  - There is a `sys_` prefix so that assembly instructions for each syscall are not written
  - A particular syscall takes `eax` register value that we placed on `usys.S` with its corresponding syscall number and then calls `sys_<name of syscall>` and puts the return value into `eax` register
  - When a user function is passed with any parameters, they are stored in the user stack and are accessed using `argint` `argstr` and `argptr` given in `syscall.c`
  - Pointers to the memory location are passed to avoid unnecessary overhead

- Important Points to note

  - To use pgtprint call, enter `pgtprint` in the console and press Enter
  - The entire page table entry will be printed as per requirements mentioned in the assignment

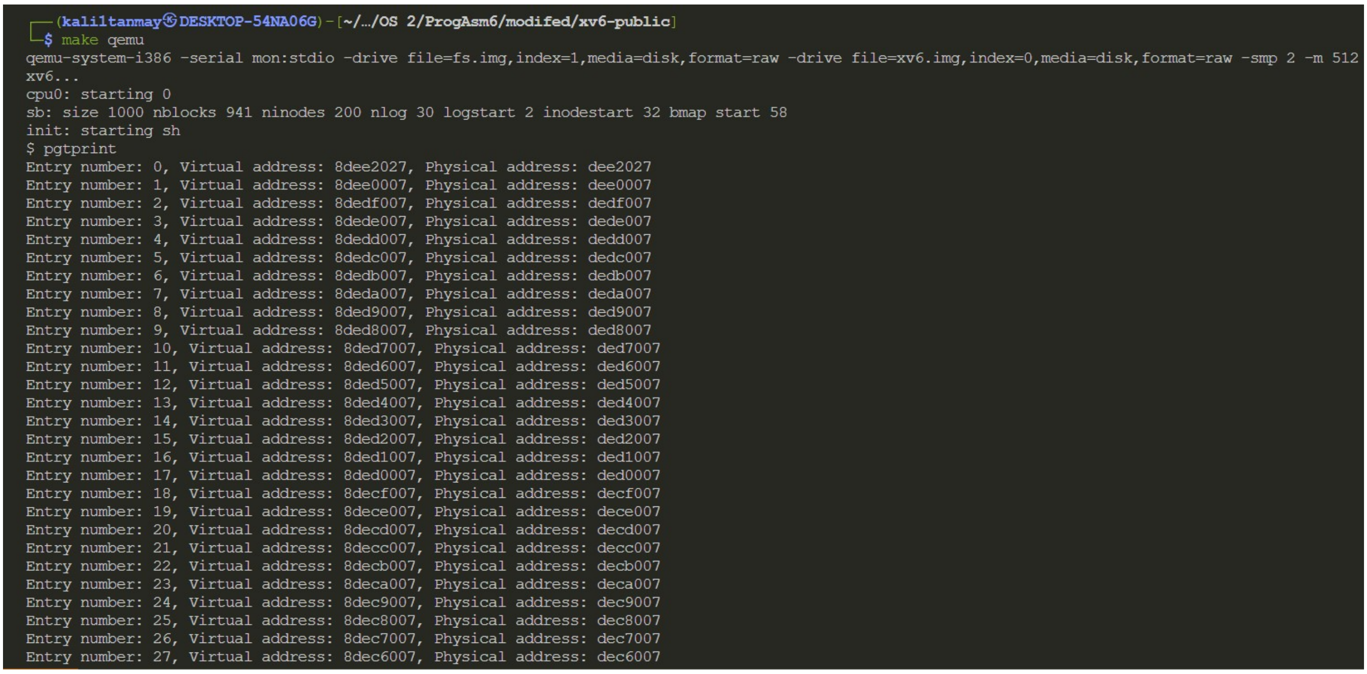
Here are some of the sample outputs for various situations as mentioned in the assignment

- Normal pgtprint without any arrays



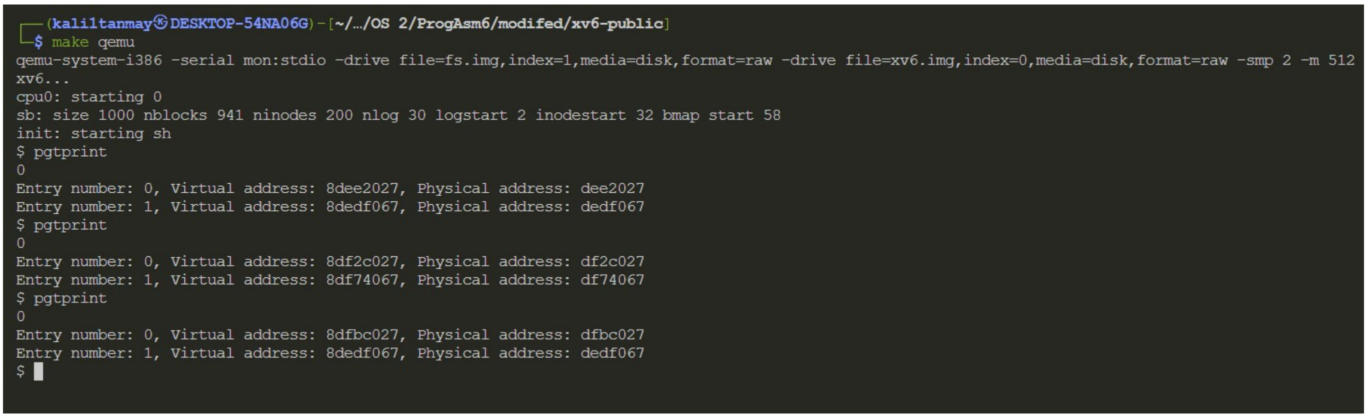
```
┌──(kali1tanmay㉿DESKTOP-54NA06G)-[~/…/OS 2/ProgAsm6/modifed/xv6-public]
└─$ make qemu
qemu-system-i386 -serial mon:stdio -drive file=fs.img,index=1,media=disk,format=raw -drive file=xv6.img,index=0,media=disk,format=raw -smp 2 -m 512
xv6...
cpu0: starting 0
sb: size 1000 nblocks 941 ninodes 200 nlog 30 logstart 2 inodestart 32 bmap start 58
init: starting sh
$ pgtprint
Entry number: 0, Virtual address: 8dee2027, Physical address: dee2027
Entry number: 1, Virtual address: 8dedf067, Physical address: dedf067
$ pgtprint
Entry number: 0, Virtual address: 8df2c027, Physical address: df2c027
Entry number: 1, Virtual address: 8df74067, Physical address: df74067
$ pgtprint
Entry number: 0, Virtual address: 8dfbc027, Physical address: dfbc027
Entry number: 1, Virtual address: 8dedf067, Physical address: dedf067
$ █
```

- pgtprint with `int arrGlobal[100000];`



```
┌──(kali1tanmay㉿DESKTOP-54NA06G)-[~/…/OS 2/ProgAsm6/modifed/xv6-public]
└─$ make qemu
qemu-system-i386 -serial mon:stdio -drive file=fs.img,index=1,media=disk,format=raw -drive file=xv6.img,index=0,media=disk,format=raw -smp 2 -m 512
xv6...
cpu0: starting 0
sb: size 1000 nblocks 941 ninodes 200 nlog 30 logstart 2 inodestart 32 bmap start 58
init: starting sh
$ pgtprint
Entry number: 0, Virtual address: 8dee2027, Physical address: dee2027
Entry number: 1, Virtual address: 8dee0007, Physical address: dee0007
Entry number: 2, Virtual address: 8dedf007, Physical address: dedf007
Entry number: 3, Virtual address: 8dede007, Physical address: dede007
Entry number: 4, Virtual address: 8dedd007, Physical address: dedd007
Entry number: 5, Virtual address: 8dedc007, Physical address: dedc007
Entry number: 6, Virtual address: 8dedb007, Physical address: dedb007
Entry number: 7, Virtual address: 8deda007, Physical address: deda007
Entry number: 8, Virtual address: 8ded9007, Physical address: ded9007
Entry number: 9, Virtual address: 8ded8007, Physical address: ded8007
Entry number: 10, Virtual address: 8ded7007, Physical address: ded7007
Entry number: 11, Virtual address: 8ded6007, Physical address: ded6007
Entry number: 12, Virtual address: 8ded5007, Physical address: ded5007
Entry number: 13, Virtual address: 8ded4007, Physical address: ded4007
Entry number: 14, Virtual address: 8ded3007, Physical address: ded3007
Entry number: 15, Virtual address: 8ded2007, Physical address: ded2007
Entry number: 16, Virtual address: 8ded1007, Physical address: ded1007
Entry number: 17, Virtual address: 8ded0007, Physical address: ded0007
Entry number: 18, Virtual address: 8decf007, Physical address: decf007
Entry number: 19, Virtual address: 8dece007, Physical address: dece007
Entry number: 20, Virtual address: 8decd007, Physical address: decd007
Entry number: 21, Virtual address: 8decc007, Physical address: decc007
Entry number: 22, Virtual address: 8decb007, Physical address: decb007
Entry number: 23, Virtual address: 8deca007, Physical address: deca007
Entry number: 24, Virtual address: 8dec9007, Physical address: dec9007
Entry number: 25, Virtual address: 8dec8007, Physical address: dec8007
Entry number: 26, Virtual address: 8dec7007, Physical address: dec7007
Entry number: 27, Virtual address: 8dec6007, Physical address: dec6007
```

- pgtprint with `int arrLocal[100000];`



```
┌──(kali1tanmay㉿DESKTOP-54NA06G)-[~/…/OS 2/ProgAsm6/modifed/xv6-public]
└─$ make qemu
qemu-system-i386 -serial mon:stdio -drive file=fs.img,index=1,media=disk,format=raw -drive file=xv6.img,index=0,media=disk,format=raw -smp 2 -m 512
xv6...
cpu0: starting 0
sb: size 1000 nblocks 941 ninodes 200 nlog 30 logstart 2 inodestart 32 bmap start 58
init: starting sh
$ pgtprint
0
Entry number: 0, Virtual address: 8dee2027, Physical address: dee2027
Entry number: 1, Virtual address: 8dedf067, Physical address: dedf067
$ pgtprint
0
Entry number: 0, Virtual address: 8df2c027, Physical address: df2c027
Entry number: 1, Virtual address: 8df74067, Physical address: df74067
$ pgtprint
0
Entry number: 0, Virtual address: 8dfbc027, Physical address: dfbc027
Entry number: 1, Virtual address: 8dedf067, Physical address: dedf067
$ █
```

In the case of using local array the pagetable printing does not change while in the case of using global array we can see that many pagetable entries are being printed

In the case of global variables values were assigned statically on compile time and in the case of local variables it is assigned on the heap dynamically

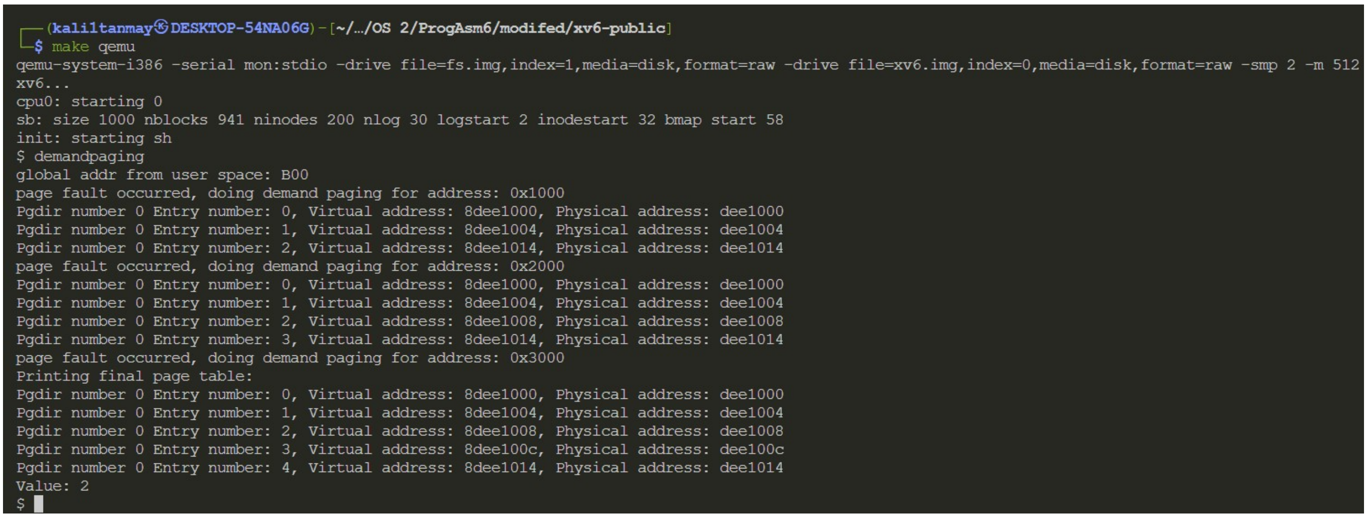
Assignment part 2

The following changes have been made for part 2 of the assignment

- `exec.c`
    - `if((sz = allocuvm(pgdir, sz, ph.vaddr + ph.filesz)) == 0)`
    - `sz += ph.memsz - ph.filesz;`
    - The above changes have been made at line 54-70
- `trap.c`
    - switch case for `T_PGFLT` has been added at line 80
    - The code has been taken from `allocuvm` function

- `demandpaging.c`
    - The following file has been added to give user program functionality
- `defs.h`
    - `int map_to_page(pde_t *pgdir, void *va, uint size, uint pa, int perm);`
    - The declaration of function has been made in the file to map memory to pages
- `vm.c`
    - `int map_to_page(pde_t *pgdir, void *va, uint size, uint pa, int perm)`
    - This function is same as `mapppages`
    - Both the functions are exactly same
- Added `_demandpaging` to the `UPROGS` definition in `Makefile`
- Working and Design of the code
    - The changes in `exec.c` does not allocate memory to dynamic variables when calling `allocuvm` but `sz` is still same as before
    - Then when the program gets a trap or a page fault occurs
    - It goes into page fault case in `trap.c`
    - It gets the address of the register where the page fault has occured
    - It then assigns memory, if it able to allocate, then it does `memset`
    - It then maps the page to physical and virtual memory and then continues with the program

Here are some of the sample outputs for `demandpaging` in the operating system



```
┌──(kali1tanmay㉿DESKTOP-54NA06G)-[~/…/OS 2/ProgAsm6/modifed/xv6-public]
└─$ make qemu
qemu-system-i386 -serial mon:stdio -drive file=fs.img,index=1,media=disk,format=raw -drive file=xv6.img,index=0,media=disk,format=raw -smp 2 -m 512
xv6...
cpu0: starting 0
sb: size 1000 nblocks 941 ninodes 200 nlog 30 logstart 2 inodestart 32 bmap start 58
init: starting sh
$ demandpaging
global addr from user space: B00
page fault occurred, doing demand paging for address: 0x1000
Pgdir number 0 Entry number: 0, Virtual address: 8dee1000, Physical address: dee1000
Pgdir number 0 Entry number: 1, Virtual address: 8dee1004, Physical address: dee1004
Pgdir number 0 Entry number: 2, Virtual address: 8dee1014, Physical address: dee1014
page fault occurred, doing demand paging for address: 0x2000
Pgdir number 0 Entry number: 0, Virtual address: 8dee1000, Physical address: dee1000
Pgdir number 0 Entry number: 1, Virtual address: 8dee1004, Physical address: dee1004
Pgdir number 0 Entry number: 2, Virtual address: 8dee1008, Physical address: dee1008
Pgdir number 0 Entry number: 3, Virtual address: 8dee1014, Physical address: dee1014
page fault occurred, doing demand paging for address: 0x3000
Printing final page table:
Pgdir number 0 Entry number: 0, Virtual address: 8dee1000, Physical address: dee1000
Pgdir number 0 Entry number: 1, Virtual address: 8dee1004, Physical address: dee1004
Pgdir number 0 Entry number: 2, Virtual address: 8dee1008, Physical address: dee1008
Pgdir number 0 Entry number: 3, Virtual address: 8dee100c, Physical address: dee100c
Pgdir number 0 Entry number: 4, Virtual address: 8dee1014, Physical address: dee1014
Value: 2
$ 
```

The above assignment has been done in collaboration with Dr. Rajesh Kedia and students for page fault creation in `exec.c` Their roll numbers and names are:

- Aayush Patel CS20BTECH11001
- Vikhyath CS20BTECH11056

The following are some of the references used to solve the assignment

- https://pdos.csail.mit.edu/6.828/2017/homework/xv6-zero-fill.html

- https://oslab.kaist.ac.kr/wp-content/uploads/esos_files/courseware/undergraduate/UKD/homework/homework04.pdf
- https://pdos.csail.mit.edu/6.828/2008/lec/l5.html
- https://www.cs.virginia.edu/~cr4bd/4414/F2018/paging-and-protection.html#tocAnchor-1-3
- https://www.cs.columbia.edu/~junfeng/11sp-w4118/lectures/exec.pdf
- https://www.cse.iitd.ac.in/~sbansal/os/previous_years/2011/xv6-book/mem.pdf

Note

- The above results may differ based on the oeprating system xv6 is run on
- It may also depend on the version of xv6 using and the architecture on which it is running
- The address printed where page fault occured is the address got from `rcr2()`