Documentation

❖ Problem Statement:

- Task 1: Implement system calls: Read, Write, Exit, Fork, Exec.
- Task 2: Provide functionality to run multiple user programs for given quantum time.
- Task 3: Implement virtual memory (implement demand paging).

❖ Design/solution for each requirement

- Task 1:
  - For task 1 I have defined the system calls in the syscall.h file and their respective implementation in the ksyscall.h file.
  - I have implemented the read, write, exit, exec and fork system call.
  - For each system call I have created a file in the code/test/ directory to test each system call that I have implemented.

- Task 2:
  - For task 2 we have to provide functionality to run multiple user programs and to provide a quantum from the user.
  - For executing multiple user programs I have added a list of userProg files in the main.cc file where in each file provided is stored and then a thread is created for executing each of the user program.
  - For providing the quantum I have provide the –q flag which user can provide as an input.
  - This user provided quantum is then set in the stats.h and stats.cc file.

- Task 3:
  - For implementing task 3 I have created a swap file in the kernel.h and kernel.cc file which is used as an unlimited virtual memory.
  - For each thread I have created a page table in the addresspace.cc file.
  - Whenever a user program is given for execution it is first loaded into the swap file.
  - In this way the swap file is populated completely and then as and when a page fault occurs we load the page from the swap file to main memory.
  - Once the main memory is full we swap pages out of the main memory to the swap file using the random page replacement algorithm.
  - All this logic is implemented in the exception.cc file in the PageFaultException case.

❖ Files with directory name you modified:

- nachos/code/build.linux/Makefile
- nachos/code/test/Makefile
- nachos/code/machine/stats.h
- nachos/code/machine/stats.cc
- nachos/code/threads/kernel.h
- nachos/code/threads/kernel.cc
- nachos/code/threads/main.cc
- nachos/code/threads/thread.h
- nachos/code/threads/thread.cc
- nachos/code/userprog/addrspace.h
- nachos/code/ userprog /addrspace.cc
- nachos/code/ userprog /exception.cc
- nachos/code/ userprog /ksyscall.h
- nachos/code/ userprog /syscall.h
- nachos/code/test/readSC.c
- nachos/code/test/writeSC.c
- nachos/code/test/forkSC.c
- nachos/code/test/execSC.c
- nachos/code/test/exitSC.c

❖ Test cases:

To execute the test cases run the following commands:

1. Testing single user program: ./nachos -x ../test/matmult
2. Testing all system calls: ./nachos -x ../test/readSC -x ../test/writeSC -x ../test/forkSC -x ../test/execSC -x ../test/exitSC

```
opbuchad@lcs-vc-cis486:~/nachos/code/build.linux$ ./nachos -x ../test/readSC
 -x ../test/writeSC -x ../test/forkSC
size is: 3
FileName: ../test/readSC
FileName: ../test/writeSC
FileName: ../test/forkSC
number of pages: 4
Page fault exception no: 1
page 1 copied to main memory
Page fault exception no: 2
page 2 copied to main memory
Page fault exception no: 3
page 3 copied to main memory
Page fault exception no: 4
page 4 copied to main memory
********** Read system call invoked **********
This is read buffer: omkar
number of pages: 4
Page fault exception no: 5
page 5 copied to main memory
Page fault exception no: 6
page 6 copied to main memory
Page fault exception no: 7
page 7 copied to main memory
Page fault exception no: 8
page 8 copied to main memory
********** Write system call invoked **********
Value of the buffer to write is: This is write
------------------------------------------------------------------
Total memory references: 97
Total page faults: 8
Total page hit: 89
register 4: 0
********** Exit system call invoked **********
Thread id: 3 completed
------------------------------------------------------------------
```

```
Thread id: 3 completed
------------------------------------------------------------------------
number of pages: 4
Page fault exception no: 9
page 9 copied to main memory
Page fault exception no: 10
page 10 copied to main memory
Page fault exception no: 11
page 11 copied to main memory
********** Fork system call invoked **********

------------------------------------------------------------------------
Total memory references: 129
Total page faults: 11
Total page hit: 118
register 4: 0
********** Exit system call invoked **********
Thread id: 4 completed
------------------------------------------------------------------------


------------------------------------------------------------------------
Total memory references: 134
Total page faults: 11
Total page hit: 123
register 4: 0
********** Exit system call invoked **********
Thread id: 2 completed
------------------------------------------------------------------------
```

```
opbuchad@lcs-vc-cis486:~/nachos/code/build.linux$ ./nachos -x ../test/exitSC
 -x ../test/execSC
size is: 2
FileName: ../test/exitSC
FileName: ../test/execSC
number of pages: 3
Page fault exception no: 1
page 1 copied to main memory
Page fault exception no: 2
page 2 copied to main memory

------------------------------------------------------------------
Total memory references: 17
Total page faults: 2
Total page hit: 15
register 4: 0
********** Exit system call invoked **********
Thread id: 2 completed
------------------------------------------------------------------
number of pages: 4
Page fault exception no: 3
page 3 copied to main memory
Page fault exception no: 4
page 4 copied to main memory
Page fault exception no: 5
page 5 copied to main memory
********** Exec system call invoked **********

------------------------------------------------------------------
```

```
------------------------------------------------------------------
Total memory references: 72
Total page faults: 5
Total page hit: 67
register 4: 0
********** Exit system call invoked **********
Thread id: 3 completed
------------------------------------------------------------------
number of pages: 4
Page fault exception no: 6
page 6 copied to main memory
Page fault exception no: 7
page 7 copied to main memory
Page fault exception no: 8
page 8 copied to main memory
Page fault exception no: 9
page 9 copied to main memory
********** Read system call invoked **********
This is read buffer: omkar

------------------------------------------------------------------
Total memory references: 119
Total page faults: 9
Total page hit: 110
register 4: 0
********** Exit system call invoked **********
Thread id: 4 completed
------------------------------------------------------------------
```

3. Testing multiple user programs: ./nachos -x ../test/matmult -x ../test/matmult -x ../test/sort

```
opbuchad@lcs-vc-cis486:~/nachos/code/build.linux$ ./nachos -x ../test/matmult -x ../test/matmult -x ../test/sort
size is: 3
FileName: ../test/matmult
FileName: ../test/matmult
FileName: ../test/sort
number of pages: 55
Page fault exception no: 1
page 1 copied to main memory
Page fault exception no: 2
page 2 copied to main memory
Page fault exception no: 3
page 3 copied to main memory
Page fault exception no: 4
page 4 copied to main memory
number of pages: 55
Page fault exception no: 5
page 5 copied to main memory
Page fault exception no: 6
page 6 copied to main memory
Page fault exception no: 7
```

```
Page fault exception no: 162
********** Main memory full. Swapping a page from main memory to swap file **********
page replaced
Page fault exception no: 163
********** Main memory full. Swapping a page from main memory to swap file **********
page replaced

------------------------------------------------------------------
Total memory references: 2305914
Total page faults: 163
Total page hit: 2305751
register 4: 7220
********** Exit system call invoked **********
Thread id: 3 completed
------------------------------------------------------------------


------------------------------------------------------------------
Total memory references: 2305983
Total page faults: 163
Total page hit: 2305820
register 4: 7220
********** Exit system call invoked **********
Thread id: 2 completed
------------------------------------------------------------------


------------------------------------------------------------------
Total memory references: 67072844
Total page faults: 163
Total page hit: 67072681
register 4: 0
********** Exit system call invoked **********
Thread id: 4 completed
------------------------------------------------------------------
```

One more test case: ./nachos -q 1000 -x ../test/matmult -x ../test/matmult -x ../test/matmult -x ../test/matmult -x ../test/matmult -x ../test/matmult -x ../test/sort

❖ Output Screenshots:

The important screenshots for the entire simulation is appended here:
Executing 5 user programs:

```
opbuchad@lcs-vc-cis486:~/nachos/code/build.linux$ ./nachos -x ../test/matmult -x ../test/sort -x ../test/readSC -x ../test/writeSC -x ../test/matmult
size is: 5
FileName: ../test/matmult
FileName: ../test/sort
FileName: ../test/readSC
FileName: ../test/writeSC
FileName: ../test/matmult
```

Output of readSC:

```
********** Read system call invoked **********
This is read buffer: omkar

------------------------------------------------------------------
Total memory references: 175
Total page faults: 12
Total page hit: 163
register 4: 0
********** Exit system call invoked **********
Thread id: 4 completed
------------------------------------------------------------------
```

Output of writeSC:

```
********** Write system call invoked **********
Value of the buffer to write is: This is write
------------------------------------------------------------------
Total memory references: 230
Total page faults: 16
Total page hit: 214
register 4: 0
********** Exit system call invoked **********
Thread id: 5 completed
------------------------------------------------------------------
```

Output of 1st matmult:

```
--------------------------------------------------------------------
Total memory references: 2306134
Total page faults: 195
Total page hit: 2305939
register 4: 7220
********** Exit system call invoked **********
Thread id: 2 completed
--------------------------------------------------------------------
```

Output of 2nd matmult:

```
--------------------------------------------------------------------
Total memory references: 2306232
Total page faults: 195
Total page hit: 2306037
register 4: 7220
********** Exit system call invoked **********
Thread id: 6 completed
--------------------------------------------------------------------
```

Output of sort:

```
--------------------------------------------------------------------
Total memory references: 67073004
Total page faults: 199
Total page hit: 67072805
register 4: 0
********** Exit system call invoked **********
Thread id: 3 completed
--------------------------------------------------------------------
```

Demand paging / memory overflow demonstration: Main memory has only 128 pages so for pages beyond 128 there will be demand paging or memory overflow.

```
Page fault exception no: 129
********** Main memory full. Swapping a page from main memory to swap file **********
page replaced
Page fault exception no: 130
********** Main memory full. Swapping a page from main memory to swap file **********
page replaced
```

Specifying quantum using the '-q flag':

```
opbuchad@lcs-vc-cis486:~/nachos/code/build.linux$ ./nachos -q 1000 -x ../test/matmult -x ../test/matmult -x ../test/matmult -x ../test/sort
```

The previously set interrupts are reset to the new user provided quantum in the interrupt.cc file using the following method:

```
358   void Interrupt::resetPending(int newTime)
359   {
360       ListIterator<PendingInterrupt *> *itr = new ListIterator <PendingInterrupt *>(pending);
361       while (!itr->IsDone())
362       {
363          PendingInterrupt *obj=itr->Item();
364          //std::cout<<"Interrupt val: "<<obj->when<<"\n";
365          obj->setWhen(newTime);
366          //std::cout<<"Changed interrupt val: "<<obj->when<<"\n";
367          itr->Next();
368       }
369   }
```