보고서(HOMEWORK3)

✓ 작성한 프로그램의 동작 과정과 구현 방법
- 각 알고리즘에 대하여 **순서도나 블록 다이어그램 등 도식화 자료**를 반드시 이용할 것

전체적인 코드의 개요는 'Input 파일을 읽기 -> Input 파일을 분석하고 프로세스를 생성 -> 해당 프로세스에 대한 명령어 수행'의 과정으로 이루어진다.

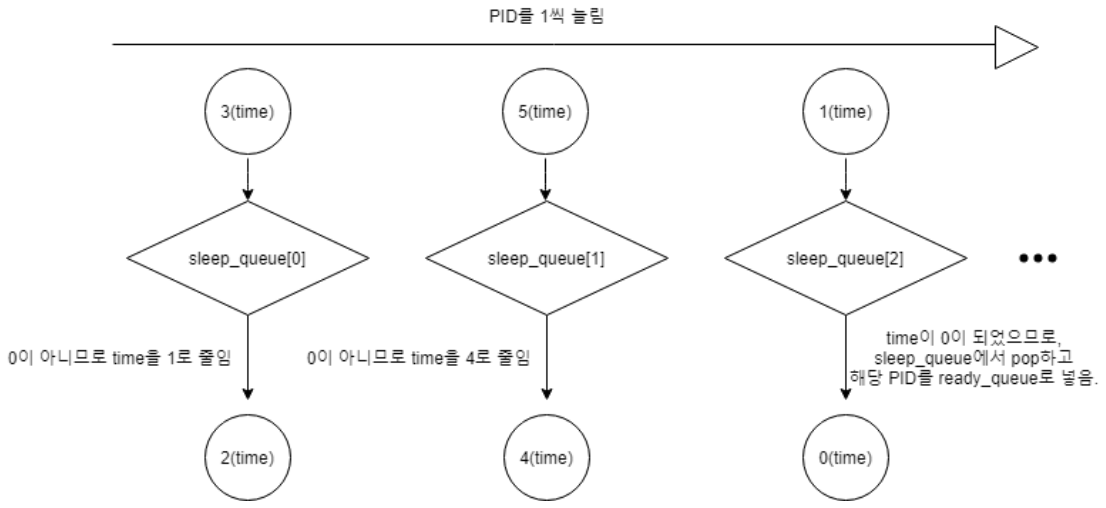
이를 위해서, 먼저 project3 프로그램을 실행 시킬 때에 붙는 옵션들을 분석해 -dir, -page 옵션이 붙는다면 char* 형식의 dir와 page에 입력을 하였다. 없다면, 과제 세부사항에서 제시된 것처럼 dir = 현재 디렉토리, page = lru로 지정된다. 이후에, directory에 존재하는 input 파일을 불러들여, 코드를 읽고 작업의 수, VM, PM, Page의 size를 저장하고 작업의 수만큼 pid라는 struct를 만들어 초기화 시키고 input의 명령어를 게속 실행시킨다.

이후의 명령어에서 해당 코드가 들어오는 Cycle(=time에 저장), Priority(=priority에 저장)를 pid라는 struct의 변수에 저장하고 code를 불러들여, opcode와 argument를 i번째 pid[i]의 queue에 넣는다. (i는 0부터 작업의 수에 따라 1씩 늘어난다.) 2번째 값에 INPUT이 존재한다면, 어느 PID가 어느 Cycle에서 IO가 발생하는지를 input_time이라는 배열에 *input_time[pid] = cycle;* 의 형태로 저장한다.

명령어를 다 읽어들이면, 현재 directory를 *chdir(dir);* 명령어를 사용하여 옵션으로 제시된 dir로 바꾸고 fopen을 통해서, *"./scheduler.txt"*, *"./memory.txt"* 처럼 현재 directory를 이용해 출력할 텍스트 파일의 위치를 지정한다.

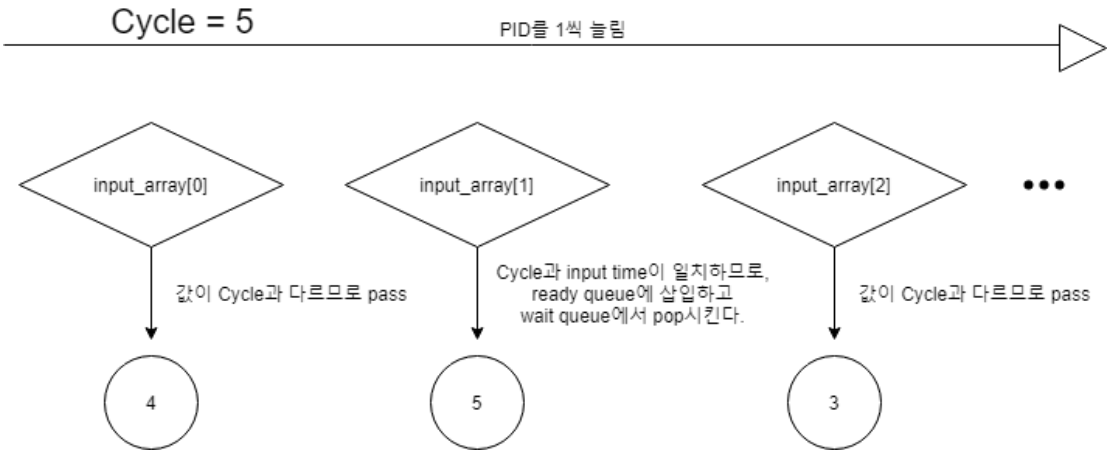
그리고 Cycle이 시작되는데, 과제 세부 사항에서 제시된 것과 같이,

1. Sleep된 프로세스의 종료 여부 검사
   - sleep_queue[i]에서 i는 sleep된 process의 pid를 의미하고, sleep_queue[i]의 값은 남아 있는 시간을 의미하는데, 이 시간이 0이 된다면 sleep queue에서 pop하고 해당 priority에 해당하는 ready ueue의 맨 뒤로 넣는다.



2. Input으로 주어진 IO 작업의 시행

- 위의 Input 파일에서 INPUT이 들어간 명령어의 값(=pid가 I/O되는 시간)을 넣은 input_time array가 존재하는데, 현재 Cycle이 해당 input_array[pid]의 값과 일치하다면 IO wait queue에서 pop하고 ready queue의 맨 뒤로 넣는다.



3. Input으로 주어진 Process 생성 작업의 시행

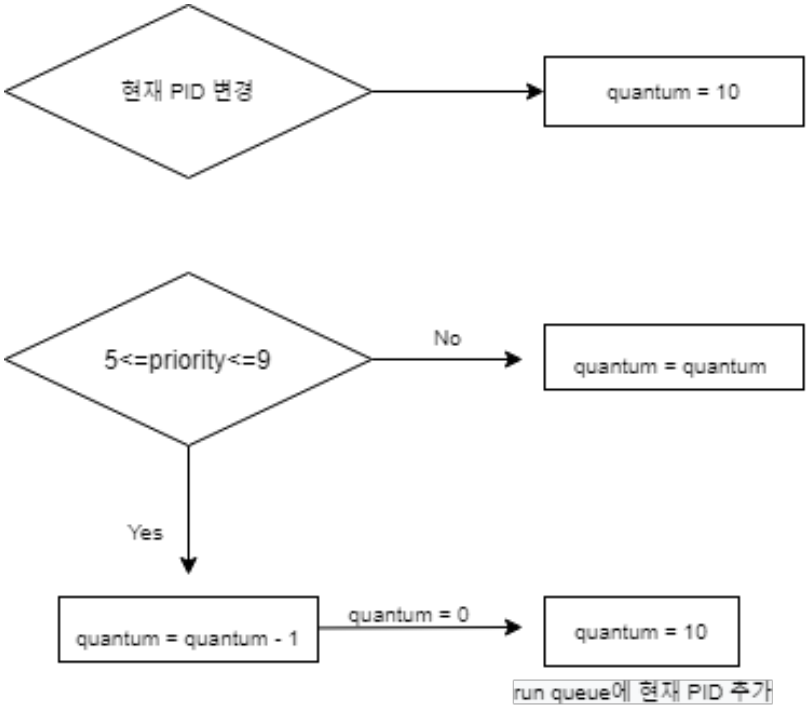
- 이 작업 이전에, 현재 PID의 남아있는 instruction이 0이라면, 해당 PID는 presentMem[pid]의 값이 0으로 지정되어, 종료된 process로 인식하고 해당 memory를 다 초기화 시키고 현재 PID를 -1(=현재 PID가 지정되지 않음)로 바꾼다.
- 그리고 pid[i].time에 보관된, 해당 Process가 들어오는 시간이 cycle과 똑같다면, 해당 PID를 ready queue의 가장 뒤쪽에 넣고 presentMem[i]를 1로 표시한다.

4. 이번 Cycle에 실행 될 Process 결정

- 현재 실행중인 Process가 없다면, Priority 수치가 낮은 ready queue부터 시작해서 맨 앞에 있는 process를 현재 PID로 지정한다. 또한, 현재 Process가 존재하더라도 자신보다 priority가 높은 Proecss가 ready queue에 존재하면 해당 Process가 현재 PID가 된다.
- 여기서 page replacement algorithm이 "sampled"라면, 8번째 Cycle마다 reference Byte를 갱신한다.

5. 해당 Cycle에 수행할 Process의 명령을 확인하여 수행 및 출력

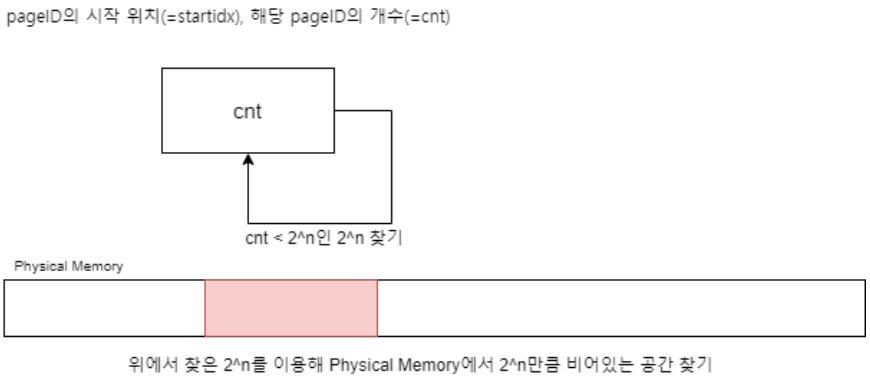
- opcode와 argument에 따라 memory를 관리하고 "scheduled.txt", "memory.txt"에 해당하는 내용들을 출력한다.
  - Priority가 5이상, 9이하의 경우에 quantum을 1씩 감소시킨다.
  - Quantum이 0이 된다면, 현재 PID를 ready_queue에 넣는다. (현재 PID가 바뀌면 quantum이 10으로 초기화)

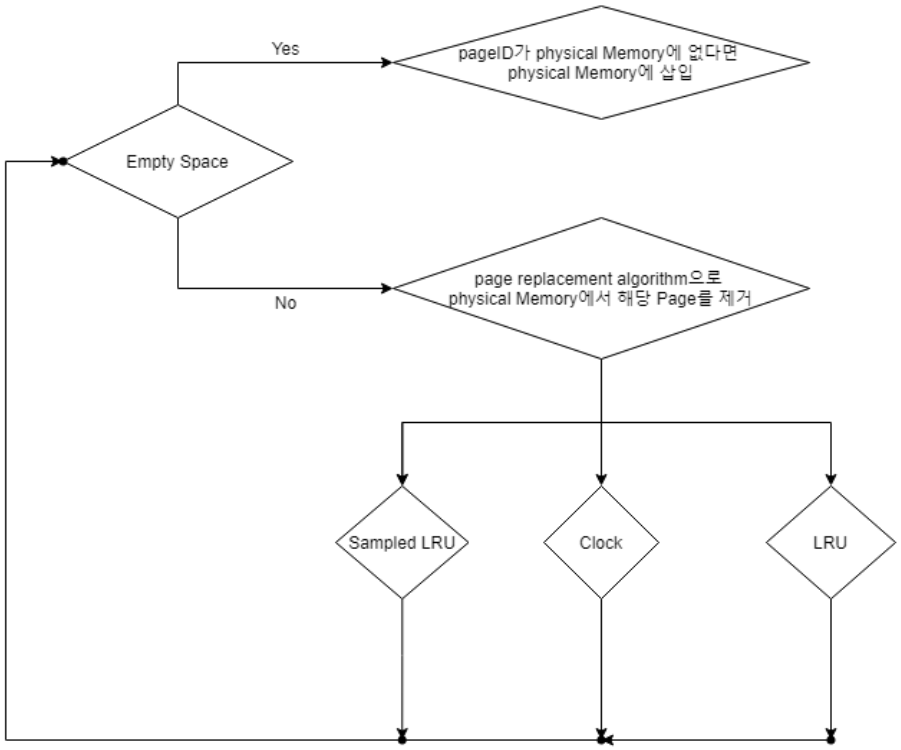


- Opcode 0 (ALLOCATION): argument의 수만큼 page allocation을 진행하고, allocation이 성공적으로 이루어졌다면, allocation ID를 증가시킨다.
- Opcode 1 (ACCESS): 기본적으로 page replacement algorithm에 관계없이, replace가 일어나지 않는 상황에 대한 code는 동일하다. 우선 접근하고자 하는 pageID의 allocation ID가 지정되지 않았다면, allocation ID를 바꾸고 allocation ID의 count를 1 증가시킨다. 동시에, pageID의 시작 위치(=startidx), 해당 pageID의 개수(=cnt)를 파악한다.

  pageID의 개수를 파악했다면, physical Memory에 개수에 맞는 공간이 존재하고 해당 pageID가 access하고 있지 않는 상태라면, physical Memory의 해당 공간에 넣는다.

  빈 공간이 존재하지 않는다면, 알고리즘에 따라 page replacement를 진행한다
  - LRU : LRU라는 queue에 physical memory에 들어간 순서대로 pageID를 저장한다. 페이지 교체가 필요할 경우에는 queue의 맨 앞의 것에 해당하는 pageID를 빼낸다. 그래도 공간이 마련되지 않는다면, bool 형식의 inserted가 true로 그대로 유지되어 while문이 반복되어 공간이 날 때까지 replace를 한다.
  - Sampled LRU : 각각의 pageID가 가지는 reference Byte 중에서 가장 작은 reference Byte를 가지는 page가 physical Memory에서 나온다.
  - Clock : 초기에는 0으로 지정된 clock이 replacement할 page를 찾을 때까지 pageID를 둘러보면서 reference bit가 1이면 0으로 바꾸고 0이면 replacement할 page로 지정한다. Clock은 pid struct안에 존재하는 pageCount(=마지막으로 지정된 pageID의 +1)을 이용해서 Clock%pageCount로 활용이 된다.





- ■ Opcode 2 (RELEASE): 제시된 pageID에 해당되는 memory를 physical memory에서 할당 해제하고 해당 pageID를 가진 memory는 모두 초기화된다.
- ■ Opcode 3 (NO-OP): 아무런 명령을 수행하지 않는다.
- ■ Opcode 4 (SLEEP): 해당되는 PID를 argument만큼 sleep queue에 넣는다.
- ■ Opcode 5 (IOWAIT): 해당되는 PID를 IO 신호가 올 때까지 wait queue에 넣는다.

- 이후 각각의 txt에 맞게 내용들이 저장된다.

✓ 개발 환경 명시

- uname -a 실행 결과

```
kjon1018@ubuntu:~/Pictures$ uname -a
Linux ubuntu 5.10.20-2017147536 #1 SMP Thu Mar 4 20:25:39 PST 2021 x86_64 x86_64
 x86_64 GNU/Linux
```

- CPU, 메모리 정보 등

```
kjon1018@ubuntu:~/Desktop$ gcc --version
gcc (Ubuntu 7.5.0-6ubuntu2) 7.5.0
Copyright (C) 2017 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.

kjon1018@ubuntu:~/Desktop$ cat /proc/cpuinfo
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 158
model name      : Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz
stepping        : 9
microcode       : 0xb4
cpu MHz         : 2807.995
cache size      : 6144 KB
physical id     : 0
siblings        : 1
core id         : 0
cpu cores       : 1
apicid          : 0
initial apicid  : 0
fpu             : yes
fpu_exception   : yes
cpuid level     : 22
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cm
pat pse36 clflush mmx fxsr sse sse2 ss syscall nx pdpe1gb rdtscp lm constant_
 arch_perfmon nopl xtopology tsc_reliable nonstop_tsc cpuid pni pclmulqdq sss
fma cx16 pcid sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave
 f16c rdrand hypervisor lahf_lm abm 3dnowprefetch cpuid_fault invpcid_single
 ssbd ibrs ibpb stibp fsgsbase tsc_adjust bmi1 avx2 smep bmi2 invpcid rdseed
 smap clflushopt xsaveopt xsavec xgetbv1 xsaves arat md_clear flush_l1d arch_
abilities
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf m
swapgs itlb_multihit srbds
bogomips        : 5615.99
clflush size    : 64
cache_alignment : 64
address sizes   : 45 bits physical, 48 bits virtual
power management:

processor       : 1
vendor_id       : GenuineIntel
```

✓ **결과 화면 스크린샷과 그것에 대한 토의 내용**

- **Input.txt (페이지 교체 알고리즘의 성능을 확인하기 위해, 다른 파일은 예제와 동일하고 program2의 내용만 수정하여서 비교했습니다.)**
-
- **Program2 – 1**

```
38
3 0
3 0
5 0
0 7
0 10
0 4
0 3
0 14
1 0
1 1
1 0
3 0
3 0
3 0
3 0
3 0
3 0
1 1
1 3
4 2
1 4
1 0
1 3
1 0
1 1
1 1
1 2
1 3
1 4
1 1
1 0
1 3
1 2
1 1
1 4
1 3
1 2
1 3
1 0
```

- **Scheduler.txt - 1** (text가 긴 관계로, 첫 부분과 마지막 부분의 스크린샷을 첨부합니다.)

```
[0 Cycle] Scheduled Process: 0 program1 (priority 6)
Running Process: Process#0(6) running code program1 line 1(op 0, arg 16)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[1 Cycle] Scheduled Process: None
Running Process: Process#0(6) running code program1 line 2(op 0, arg 12)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[2 Cycle] Scheduled Process: None
Running Process: Process#0(6) running code program1 line 3(op 0, arg 22)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

```

```
[48 Cycle] Scheduled Process: None
Running Process: Process#1(3) running code program2 line 36(op 1, arg 2)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[49 Cycle] Scheduled Process: None
Running Process: Process#1(3) running code program2 line 37(op 1, arg 3)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[50 Cycle] Scheduled Process: None
Running Process: Process#1(3) running code program2 line 38(op 1, arg 0)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

```

- **memory.txt - 1**(text가 긴 관계로, 결과의 차이가 보이는 마지막 부분만 넣겠습니다.)
  - LRU

```
373 >> pid(1)  Page Table(Valid): |1111|1110|0000|0000|0111|1111|0000|0000|0000|00--|----|----|----|----|----|----|
374 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
375
376 [45 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[10]
377 >> Physical Memory:           |7777|7777|----|----|4444|4444|4444|4444|
378 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
379 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
380 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1111|1000|0000|0000|0000|00--|----|----|----|----|----|----|
381 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
382
383 [46 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[14]
384 >> Physical Memory:           |6666|6666|6666|6666|4444|4444|4444|4444|
385 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
386 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
387 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1000|0000|1111|1111|1111|11--|----|----|----|----|----|----|
388 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
389
390 [47 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[3]
391 >> Physical Memory:           |6666|6666|6666|6666|5555|----|----|----|
392 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
393 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
394 >> pid(1)  Page Table(Valid): |0000|0000|0000|0000|0000|0111|1111|1111|1111|11--|----|----|----|----|----|----|
395 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
396
397 [48 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
398 >> Physical Memory:           |6666|6666|6666|6666|5555|----|7777|7777|
399 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
400 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
401 >> pid(1)  Page Table(Valid): |0000|0000|0000|0000|0111|1111|1111|1111|1111|11--|----|----|----|----|----|----|
402 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
403
404 [49 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[3]
405 >> Physical Memory:           |6666|6666|6666|6666|5555|----|7777|7777|
406 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
407 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
408 >> pid(1)  Page Table(Valid): |0000|0000|0000|0000|0111|1111|1111|1111|1111|11--|----|----|----|----|----|----|
409 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
410
411 [50 Cycle] Input: Pid[1] Function[ACCESS] Page ID[0] Page Num[7]
412 >> Physical Memory:           |3333|3333|----|----|5555|----|7777|7777|
413 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
414 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
415 >> pid(1)  Page Table(Valid): |1111|1110|0000|0000|0111|1111|0000|0000|0000|00--|----|----|----|----|----|----|
416 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
417
418 page fault = 21
```

  - Sampled LRU

```
374 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
375
376 [45 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[10]
377 >> Physical Memory:           |7777|7777|5555|----|4444|4444|4444|4444|
378 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
379 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
380 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1111|0000|0000|0000|0000|00--|----|----|----|----|----|----|
381 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
382
383 [46 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[14]
384 >> Physical Memory:           |6666|6666|6666|6666|4444|4444|4444|4444|
385 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
386 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
387 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1000|0000|1111|1111|1111|11--|----|----|----|----|----|----|
388 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|1111|1111|1111|1100|0000|0000|0000|0000|0000|0000|
389
390 [47 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[3]
391 >> Physical Memory:           |5555|----|----|----|4444|4444|4444|4444|
392 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
393 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
394 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1000|0111|0000|0000|0000|00--|----|----|----|----|----|----|
395 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
396
397 [48 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
398 >> Physical Memory:           |5555|----|7777|7777|4444|4444|4444|4444|
399 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
400 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
401 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1111|0000|0000|0000|0000|00--|----|----|----|----|----|----|
402 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
403
404 [49 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[3]
405 >> Physical Memory:           |5555|----|7777|7777|4444|4444|4444|4444|
406 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
407 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
408 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1111|1111|0000|0000|0000|00--|----|----|----|----|----|----|
409 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
410
411 [50 Cycle] Input: Pid[1] Function[ACCESS] Page ID[0] Page Num[7]
412 >> Physical Memory:           |5555|----|3333|3333|4444|4444|4444|4444|
413 >> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
414 >> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
415 >> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1000|0111|0000|0000|0000|00--|----|----|----|----|----|----|
416 >> pid(1)  Page Table(Ref):   |1111|1110|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
417
418 page fault = 22
```

■ Clock

```
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[45 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[10]
>> Physical Memory:          |7777|7777|5555|----|4444|4444|4444|4444|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1111|1111|0000|0000|0000|00--|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[46 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[14]
>> Physical Memory:          |7777|7777|5555|----|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0000|0000|0000|0111|1111|1111|1111|1111|11--|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|1111|1111|1111|1100|0000|0000|0000|0000|0000|0000|

[47 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[3]
>> Physical Memory:          |7777|7777|5555|----|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0000|0000|0000|0111|1111|1111|1111|1111|11--|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|1111|1111|1111|1100|0000|0000|0000|0000|0000|0000|

[48 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
>> Physical Memory:          |7777|7777|5555|----|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0000|0000|0000|0111|1111|1111|1111|1111|11--|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|1111|1111|1111|1100|0000|0000|0000|0000|0000|0000|

[49 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[3]
>> Physical Memory:          |7777|7777|5555|----|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0000|0000|0000|0111|1111|1111|1111|1111|11--|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0111|1000|1111|1111|1111|1100|0000|0000|0000|0000|0000|0000|

[50 Cycle] Input: Pid[1] Function[ACCESS] Page ID[0] Page Num[7]
>> Physical Memory:          |7777|7777|3333|3333|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1111|1222|2333|4444|4444|4444|44--|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4444|4777|7555|6666|6666|6666|66--|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1110|0000|0000|0111|1000|1111|1111|1111|11--|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|1110|0000|0000|0000|0000|1111|1111|1111|1100|0000|0000|0000|0000|0000|0000|

page fault = 23
```

- **Program2 – 2**

```
44
3 0
3 0
5 0
0 7
0 7
0 4
0 5
0 13
1 0
1 1
1 0
3 0
3 0
3 0
3 0
3 0
1 1
1 3
4 2
1 4
1 0
1 3
1 0
1 1
1 1
1 2
1 3
1 4
1 1
1 0
1 3
1 2
1 1
1 4
1 3
1 2
1 3
1 0
1 3
1 2
1 1
1 4
1 2
1 3
```

- **Scheduler.txt – 2**

```
[0 Cycle] Scheduled Process: 0 program1 (priority 6)
Running Process: Process#0(6) running code program1 line 1(op 0, arg 16)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[1 Cycle] Scheduled Process: None
Running Process: Process#0(6) running code program1 line 2(op 0, arg 12)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[2 Cycle] Scheduled Process: None
Running Process: Process#0(6) running code program1 line 3(op 0, arg 22)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty
```

```
[54 Cycle] Scheduled Process: None
Running Process: Process#1(3) running code program2 line 42(op 1, arg 4)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[55 Cycle] Scheduled Process: None
Running Process: Process#1(3) running code program2 line 43(op 1, arg 2)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[56 Cycle] Scheduled Process: None
Running Process: Process#1(3) running code program2 line 44(op 1, arg 3)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty
```

- **Memory.txt - 2**
  - LRU

```
415 >> pid(1)  Page Table(Valid): |1111|1110|0000|0011|1100|0001|1111|1111|1111|----|----|----|----|----|----|----|
416 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
417
418 [51 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[5]
419 >> Physical Memory:           |6666|6666|6666|6666|3333|3333|5555|5555|
420 >> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
421 >> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
422 >> pid(1)  Page Table(Valid): |1111|1110|0000|0000|0011|1111|1111|1111|1111|----|----|----|----|----|----|----|
423 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
424
425 [52 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
426 >> Physical Memory:           |7777|7777|----|----|3333|3333|5555|5555|
427 >> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
428 >> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
429 >> pid(1)  Page Table(Valid): |1111|1110|0000|0011|1111|1110|0000|0000|0000|----|----|----|----|----|----|----|
430 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
431
432 [53 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[7]
433 >> Physical Memory:           |7777|7777|4444|4444|3333|3333|5555|5555|
434 >> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
435 >> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
436 >> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1111|1110|0000|0000|0000|----|----|----|----|----|----|----|
437 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
438
439 [54 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[13]
440 >> Physical Memory:           |7777|7777|4444|4444|6666|6666|6666|6666|
441 >> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
442 >> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
443 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1100|0001|1111|1111|1111|----|----|----|----|----|----|----|
444 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
445
446 [55 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
447 >> Physical Memory:           |7777|7777|4444|4444|6666|6666|6666|6666|
448 >> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
449 >> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
450 >> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1100|0001|1111|1111|1111|----|----|----|----|----|----|----|
451 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
452
453 [56 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[5]
454 >> Physical Memory:           |5555|5555|4444|4444|6666|6666|6666|6666|
455 >> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
456 >> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
457 >> pid(1)  Page Table(Valid): |0000|0001|1111|1100|0011|1111|1111|1111|1111|----|----|----|----|----|----|----|
458 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
459
460 page fault = 27
```

■ Sampled LRU

```
>> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1111|1110|0000|0000|0000|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0011|1100|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[51 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[5]
>> Physical Memory:           |4444|4444|3333|3333|5555|5555|7777|7777|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1111|1110|0000|0000|0000|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0011|1100|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[52 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
>> Physical Memory:           |4444|4444|3333|3333|5555|5555|7777|7777|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1111|1110|0000|0000|0000|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0011|1100|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[53 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[7]
>> Physical Memory:           |4444|4444|3333|3333|5555|5555|7777|7777|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1111|1110|0000|0000|0000|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0011|1100|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[54 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[13]
>> Physical Memory:           |----|----|3333|3333|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1110|0000|0000|0000|0001|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0001|1111|1111|1111|0000|0000|0000|0000|0000|0000|0000|

[55 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
>> Physical Memory:           |7777|7777|3333|3333|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1110|0000|0011|1100|0001|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0011|1100|0001|1111|1111|1111|0000|0000|0000|0000|0000|0000|0000|

[56 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[5]
>> Physical Memory:           |7777|7777|5555|5555|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0000|0000|0011|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0011|1110|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

page fault = 25
```

■ Clock

```
>> pid(1)  Page Table(Valid): |1111|1110|0000|0000|0011|1111|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|1110|0000|0000|0000|0001|1111|1111|1111|0000|0000|0000|0000|0000|0000|0000|

[51 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[5]
>> Physical Memory:           |5555|5555|3333|3333|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1110|0000|0000|0011|1111|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|1110|0000|0000|0000|0001|1111|1111|1111|0000|0000|0000|0000|0000|0000|0000|

[52 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
>> Physical Memory:           |7777|7777|3333|3333|6666|6666|6666|6666|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1110|0000|0011|1100|0001|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|1110|0000|0011|1100|0001|1111|1111|1111|0000|0000|0000|0000|0000|0000|0000|

[53 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[7]
>> Physical Memory:           |7777|7777|3333|3333|4444|4444|----|----|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1100|0000|0000|0000|0000|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0001|1111|1100|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[54 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[13]
>> Physical Memory:           |6666|6666|6666|6666|4444|4444|----|----|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1100|0000|0001|1111|1111|1111|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0001|1111|1111|1111|0000|0000|0000|0000|0000|0000|0000|

[55 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[4]
>> Physical Memory:           |6666|6666|6666|6666|4444|4444|7777|7777|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0001|1111|1111|1100|0001|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0011|1100|0001|1111|1111|1111|0000|0000|0000|0000|0000|0000|0000|

[56 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[5]
>> Physical Memory:           |6666|6666|6666|6666|5555|5555|7777|7777|
>> pid(1)  Page Table(PID):   |0000|0001|1111|1122|2233|3334|4444|4444|4444|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|3334|4444|4477|7755|5556|6666|6666|6666|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|0000|0000|0011|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0011|1111|1110|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

page fault = 27
```

- **Program2 – 3**

```
44
3 0
3 0
5 0
0 4
0 5
0 6
0 2
0 7
1 0
1 1
1 0
3 0
3 0
3 0
3 0
3 0
1 1
1 3
4 2
1 4
1 0
1 3
1 0
1 1
1 1
1 3
1 4
1 1
1 4
1 0
1 3
1 0
1 2
1 3
1 1
1 4
1 0
1 2
1 4
1 3
1 4
1 1
1 2
1 1
```

- **Scheduler.txt – 3**

```
[0 Cycle] Scheduled Process: 0 program1 (priority 6)
Running Process: Process#0(6) running code program1 line 1(op 0, arg 16)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[1 Cycle] Scheduled Process: None
Running Process: Process#0(6) running code program1 line 2(op 0, arg 12)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[2 Cycle] Scheduled Process: None
Running Process: Process#0(6) running code program1 line 3(op 0, arg 22)
RunQueue 0: Empty
RunQueue 1: Empty
RunQueue 2: Empty
RunQueue 3: Empty
RunQueue 4: Empty
RunQueue 5: Empty
RunQueue 6: Empty
RunQueue 7: Empty
RunQueue 8: Empty
RunQueue 9: Empty
SleepList: Empty
IOWait List: Empty

[3 Cycle] Scheduled Process: None
```

```
810
811 [54 Cycle] Scheduled Process: None
812 Running Process: Process#1(3) running code program2 line 42(op 1, arg 1)
813 RunQueue 0: Empty
814 RunQueue 1: Empty
815 RunQueue 2: Empty
816 RunQueue 3: Empty
817 RunQueue 4: Empty
818 RunQueue 5: Empty
819 RunQueue 6: Empty
820 RunQueue 7: Empty
821 RunQueue 8: Empty
822 RunQueue 9: Empty
823 SleepList: Empty
824 IOWait List: Empty
825
826 [55 Cycle] Scheduled Process: None
827 Running Process: Process#1(3) running code program2 line 43(op 1, arg 2)
828 RunQueue 0: Empty
829 RunQueue 1: Empty
830 RunQueue 2: Empty
831 RunQueue 3: Empty
832 RunQueue 4: Empty
833 RunQueue 5: Empty
834 RunQueue 6: Empty
835 RunQueue 7: Empty
836 RunQueue 8: Empty
837 RunQueue 9: Empty
838 SleepList: Empty
839 IOWait List: Empty
840
841 [56 Cycle] Scheduled Process: None
842 Running Process: Process#1(3) running code program2 line 44(op 1, arg 1)
843 RunQueue 0: Empty
844 RunQueue 1: Empty
845 RunQueue 2: Empty
846 RunQueue 3: Empty
847 RunQueue 4: Empty
848 RunQueue 5: Empty
849 RunQueue 6: Empty
850 RunQueue 7: Empty
851 RunQueue 8: Empty
852 RunQueue 9: Empty
853 SleepList: Empty
854 IOWait List: Empty
```

- **Memory.txt - 3**
  - LRU

```
415 >> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
416 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
417
418 [51 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[7]
419 >> Physical Memory:          |7777|7777|3333|3333|5555|----|6666|6666|
420 >> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
421 >> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
422 >> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
423 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
424
425 [52 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[2]
426 >> Physical Memory:          |7777|7777|3333|3333|5555|----|6666|6666|
427 >> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
428 >> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
429 >> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
430 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
431
432 [53 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[7]
433 >> Physical Memory:          |7777|7777|3333|3333|5555|----|6666|6666|
434 >> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
435 >> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
436 >> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
437 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
438
439 [54 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[5]
440 >> Physical Memory:          |7777|7777|3333|3333|4444|4444|6666|6666|
441 >> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
442 >> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
443 >> pid(1)  Page Table(Valid): |1111|1111|1111|1110|0111|1111|----|----|----|----|----|----|----|----|----|----|
444 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
445
446 [55 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[6]
447 >> Physical Memory:          |7777|7777|3333|3333|4444|4444|6666|6666|
448 >> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
449 >> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
450 >> pid(1)  Page Table(Valid): |1111|1111|1111|1110|0111|1111|----|----|----|----|----|----|----|----|----|----|
451 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
452
453 [56 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[5]
454 >> Physical Memory:          |7777|7777|3333|3333|4444|4444|6666|6666|
455 >> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
456 >> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
457 >> pid(1)  Page Table(Valid): |1111|1111|1111|1110|0111|1111|----|----|----|----|----|----|----|----|----|----|
458 >> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|
459
460 page fault = 30
```

- Sampled LRU

```
>> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[51 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[7]
>> Physical Memory:           |7777|7777|3333|3333|5555|----|6666|6666|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[52 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[2]
>> Physical Memory:           |7777|7777|3333|3333|5555|----|6666|6666|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[53 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[7]
>> Physical Memory:           |7777|7777|3333|3333|5555|----|6666|6666|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|0000|0111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[54 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[5]
>> Physical Memory:           |7777|7777|4444|4444|5555|----|6666|6666|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[55 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[6]
>> Physical Memory:           |7777|7777|4444|4444|5555|----|6666|6666|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[56 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[5]
>> Physical Memory:           |7777|7777|4444|4444|5555|----|6666|6666|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

page fault = 30
```

- Clock

```
>> pid(1)  Page Table(Valid): |1111|1111|1111|1110|0111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[51 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[7]
>> Physical Memory:           |3333|3333|7777|7777|4444|4444|6666|6666|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1111|1111|1110|0111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[52 Cycle] Input: Pid[1] Function[ACCESS] Page ID[3] Page Num[2]
>> Physical Memory:           |3333|3333|7777|7777|4444|4444|5555|----|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |1111|1111|1111|1111|1000|0000|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0001|1000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[53 Cycle] Input: Pid[1] Function[ACCESS] Page ID[4] Page Num[7]
>> Physical Memory:           |6666|6666|7777|7777|4444|4444|5555|----|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0001|1111|1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[54 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[5]
>> Physical Memory:           |6666|6666|7777|7777|4444|4444|5555|----|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0001|1111|1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[55 Cycle] Input: Pid[1] Function[ACCESS] Page ID[2] Page Num[6]
>> Physical Memory:           |6666|6666|7777|7777|4444|4444|5555|----|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0001|1111|1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

[56 Cycle] Input: Pid[1] Function[ACCESS] Page ID[1] Page Num[5]
>> Physical Memory:           |6666|6666|7777|7777|4444|4444|5555|----|
>> pid(1)  Page Table(PID):   |0000|1111|1222|2223|3444|4444|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(AID):   |3333|4444|4777|7775|5666|6666|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Valid): |0000|1111|1111|1111|1111|1111|----|----|----|----|----|----|----|----|----|----|
>> pid(1)  Page Table(Ref):   |0000|1111|1000|0001|1111|1111|0000|0000|0000|0000|0000|0000|0000|0000|0000|0000|

page fault = 30
```

- 3가지의 경우를 놓고 test해 본 결과,

	Page Fault		
Test Case	**LRU**	**Sampled LRU**	**Clock**
Program2 - 1	21	22	23
Program2 – 2	27	25	27
Program2 - 3	30	30	30

각각에 대한 Page Fault는 위와 같이 나왔는데, Page Fault는 모두 같은 경우도 존재하고 어떤 경우에는 LRU > Sampled LRU > Clock, Sampled LRU > LRU = Clock와 같은 경우들이 존재한다. 즉, test case에 따라 page fault가 적게 발생하는 최적화된 알고리즘은 상황에 따라 변한다고 볼 수 있다. 물론, 각각의 알고리즘마다 page fault가 적게 나오는 algorithm의 조건이 있을지도 모르지만, test case만으로는 해당 조건에 대한 유추가 어려웠다. 따라서 어떤 input이 주어졌을 때, 해당 input에 가장 최적화된 알고리즘을 고르는 것이 어렵기 때문에, 이 스케줄러는 세 알고리즘 모두 실행시켜서 최적화된 알고리즘을 찾아야 한다는 한계점이 존재한다.

- 각 페이지 교체 알고리즘의 성능을 비교 분석
위의 표에서 각 test case마다, page fault가 가장 적은 알고리즘부터 순서대로 가중치를 1,2,3으로 둔다면 LRU = 1+2+1 = 4, Sampled LRU = 2+1+1 = 4, Clock = 3+2+1 = 6으로 나오는데, 이는 알고리즘의 성능이 LRU = Sampled LRU > Clock 이라는 것을 의미한다. 위의 test case로 추론하면, 'LRU, Sampled LRU Algorithm이 Clock보다 좋은 성능을 낼 확률이 높다'는 가정을 얻을 수 있다. 따라서, 새로운 input이 주어졌을 때에 Clock 보다는 LRU, Sampled LRU의 성능이 더 뛰어날 수 있다고 예측할 수 있다.

✓ 과제 수행 시 겪었던 어려움과 해결 방법

- 과제에 대한 이해가 처음에는 어려웠었다. 메모리를 어디에 관리를 하며, Priority에 따른 Scheduling은 또 어떻게 수행하는지 모든 것이 어렵게 느껴졌다. 그렇지만, test case에 제시된 input 내용들을 하나씩 분석해가면서 과제를 조금씩 이해하고 test case를 따라가보려고 하니, 저번 과제보다는 빨리 해낸 것 같다. 또한 코드를 짜면서, 여러 가지 Memory들과 변수들을 많이 다루다 보니 각각을 어느 부분에 저장해야 될 지 혼란이 조금 있었는데, Code를 계속 디버깅하면서 struct 안에 둬야 될 것은 struct 안에 넣는 등 적재적소에 변수와 배열 등을 배치하였다.