ⁱ Forside IDATG2202 Aug 2023

Institutt for informasjonssikkerhet og kommunikasjonsteknologi
Eksamensoppgave i IDATG2202 Operativsystemer
Eksamensdato: 18.08.2023
Eksamenstid (fra-til): 09:00 - 12:00
Hjelpemiddelkode/Tillatte hjelpemidler: D: Ingen trykte eller håndskrevne hjelpemidler tillatt.
Bestemt, enkel kalkulator tillatt.

Faglig kontakt under eksamen: Erik Hjelmås
Tlf.: 93034446
Faglig kontakt møter i eksamenslokalet: Nei.

ANNEN INFORMASJON:
Skaff deg overblikk over oppgavesettet før du begynner på besvarelsen din.
Les oppgavene nøye, gjør dine egne antagelser og presiser i besvarelsen hvilke forutsetninger du har lagt til grunn i tolkning/avgrensing av oppgaven. Faglig kontaktperson skal kun kontaktes dersom det er direkte feil eller mangler i oppgavesettet. Henvend deg til en eksamensvakt hvis du ønsker å kontakte faglærer. Noter gjerne spørsmålet ditt på forhånd.

- **Språk:** Alle oppgavetekster er på engelsk, men du står fritt til å svare på norsk eller engelsk eller "blanding".
- **Negative poeng/minuspoeng**: Ingen oppgaver kan føre til minuspoeng totalt på den respektive oppgaven, men noen av flervalgsoppgavene kan ha minuspoeng internt i oppgaven for å unngå at man "helgarderer". *Dette står da tydelig presistert i oppgaveteksten for de respektive oppgavene.*
- **Tolkning av spørsmål:** Hvis du er uenig i en oppgavetekst eller svaralternativene i en av de automatisk rettede oppgavene, så kommenter gjerne det i tekstfeltet i en av de vanlige tekst-svar-oppgavene.
- **Varslinger**: Hvis det oppstår behov for å gi beskjeder til kandidatene underveis i eksamen (f.eks. ved feil i oppgavesettet), vil dette bli gjort via varslinger i Inspera. Et varsel vil dukke opp som en dialogboks på skjermen i Inspera. Du kan finne igjen varselet ved å klikke på bjella øverst i høyre hjørne på skjermen.
- **Trekk fra/avbrutt eksamen:** Blir du syk under eksamen, eller av andre grunner ønsker å levere blankt/avbryte eksamen, gå til "hamburgermenyen" i øvre høyre hjørne og velg «Lever blankt». Dette kan ikke angres selv om prøven fremdeles er åpen.
- **Tilgang til besvarelse:** Etter eksamen finner du besvarelsen din i arkivet i Inspera. Merk at det kan ta én virkedag før eventuelle håndtegninger vil være tilgjengelige i arkivet.

Lykke til!

NYNORSK VERSJON:

Institutt for informasjonssikkerhet og kommunikasjonsteknologi
Eksamensoppgåve i IDATG2202 Operativsystemer
Eksamensdato: 18.08.2023
Eksamenstid (frå-til): 09:00 - 12:00
Hjelpemiddelkode/Tillatne hjelpemiddel: D: Ingen trykte eller handskrevne hjelpemiddel tillate.
Bestemt, enkel kalkulator tillate.

Fagleg kontakt under eksamen: Erik Hjelmås
Tlf.: 93034446
Fagleg kontakt kjem til eksamenslokalet: Nei.

ANNAN INFORMASJON:

Skaff deg eit overblikk over oppgåvesettet før du byrjar å svare på oppgåvene.

Les oppgåvene nøye, gjer deg opp dine eigne meiningar og presiser i svara dine kva for føresetnadar du har lagt til grunn i tolking/avgrensing av oppgåva. Fagleg kontaktperson skal berre kontaktast dersom du meiner det er direkte feil eller manglar i oppgåvesettet. Vend deg til ei eksamensvakt om du ynskjer å kontakte faglærar. Noter gjerne spørsmålet ditt på førehand.

- **Språk:** Alle oppgåvetekstar er på engelsk, men du står fritt til å svare på norsk eller engelsk eller "blanda".
- **Negative poeng/minuspoeng**: Ingen oppgåver kan føre til minuspoeng totalt på dei respektive oppgåva, men nokon av flervalgsoppgavene kan ha minuspoeng internt i oppgåva for å unngå at ein "heilgarderer". *Dette står då tydeleg presistert i oppgåveteksten for dei respektive oppgåvene.*
- **Tolking av spørsmål:** Viss du er usamd i ein oppgåvetekst eller svaralternativa i ein av dei automatisk retta oppgåvene, så kommenter gjerne det i tekstfeltet i ein av dei vanlege tekst-svar-oppgåvene.
- **Varslingar**: Dersom det oppstår behov for å gje beskjedar til kandidatane medan eksamen er i gang (f.eks. ved feil i oppgåvesettet), vil dette bli gjort via varslingar i Inspera. Eit varsel vil dukke opp som en dialogboks på skjermen i Inspera. Du kan finne att varselet ved å klikke på bjølla i øvre høgre hjørne på skjermen.
- **Trekk frå/avbroten eksamen:** Blir du sjuk under eksamen, eller av andre grunnar ynskjer å levere blankt/avbryte eksamen, gå til "hamburgermenyen" i øvre høgre hjørne og vel «Lever blankt». Dette kan <u>ikkje</u> angrast sjølv om prøven framleis er open.
- **Tilgang til svara dine:** Etter eksamen finn du svara dine i arkivet i Inspera. Merk at det kan ta ein virkedag før eventuelle handteikningar vert tilgjengelege i arkivet.

1   introproc.os (2%)

What best describes the main function of an operating system?
Velg ett alternativ:

- 🖉 Manage system resources and provide a set of services to user programs

- ○ Allow user programs to directly control the CPU

- ○ Allow user programs to manage system resources directly

- ○ Boot the system and hand over control of the keyboard and mouse to user programs

---

Maks poeng: 2

2 hwreview.interrupt (2%)

The CPU is interrupted in all of the following situations *except:*
Velg ett alternativ:

○ A periodic hardware timer resumes the kernel.

○ A direct memory access (DMA) transfer has completed.

🖉 A read from memory has finished.

○ An I/O-device has finished processing a request.

Maks poeng: 2

3 hwreview.stack (2%)

The stack is used for:
Velg ett alternativ:

✓ Local variables

○ Global variables

○ Program code

○ Static variables

Maks poeng: 2

4 syscalls.def (2%)

A system call is defined as:
Velg ett alternativ:

- ✓ A transition into the operating system kernel at the request of the user program

- ○ A transfer of control from user- to kernel-mode

- ○ A periodic timer interrupt that transfers control of the CPU to the operating system kernel

- ○ A branch or jump instruction in a user program

Maks poeng: 2

5 syscalls.kernel (2%)

Which of the following statements is *true* about the operating system **kernel**?
Velg ett alternativ:

- ○ The kernel must compete for resources with application software.

- ○ The kernel has full and direct access to the machine hardware.

- ○ The kernel can, in certain circumstances, allow application software direct access to its internal data structures.

- ○ The kernel must check that a process has permission to execute each individual instruction in it's program code.

Maks poeng: 2

6 syscalls.shell (2%)

Consider a simple shell program (a shell program is the command line interface you use on Linux). The correct ordering of system calls in a shell program is:

Velg ett alternativ:

- ✓ First fork() a new process, then exec() to replace the executable code, and then wait() for the child process to terminate.

- ○ First exec() to replace the executable code, then fork() a new process, and then wait() for the child process to terminate.

- ○ First wait() for the return of exec() to replace the executable code, and then fork() to spawn a new process.

- ○ First wait() for the return of fork() to spawn a new process, and then exec() to replace the executable code.

Maks poeng: 2

7 addrspace.TLB (2%)

Which statement is correct about TLB?

Velg ett alternativ

- ○ TLB misses are the cause of Major Page Faults.

- ✓ TLB contains copies of Page Table Entries.

- ○ TLB performs address translation.

- ○ TLB points to the current page table.

Maks poeng: 2

8 threads.pthreads (2%)

What is the pthreads (threading library) equivalent of the wait() system call?
Velg ett alternativ:

✓ pthread_join()

○ pthread_clone()

○ pthread_exec()

○ pthread_exit()

Maks poeng: 2

9 threads.mutex (2%)

A mutex is a variable that:
Velg ett alternativ

✓ Can be used to lock critical section.

○ Can count up and down atomically.

○ Can increment a register uninterrupted.

○ Can ensure that deadlock does not occur.

Maks poeng: 2

10 semaph.spinwait (2%)

What is *spin waiting* (also know as *busy waiting*)?
Velg ett alternativ

- That a process waits in a while loop until an event (typically a spinlock that changes value) occurs.

- ○ A method to prevent deadlock from occurring.

- ○ That a process is waiting for an interrupt generated by the data bus.

- ○ That a process executes CPU-intensive code while sitting in an I/O queue.

Maks poeng: 2

11 io.dma (2%)

Direct memory access (DMA) is:
Velg ett alternativ:

- ○ where the CPU can request pages from the cache with certainty that cache misses will not occur

- ○ where the CPU can request pages from main memory bypassing the cache hierarchy

- ○ where hardware I/O devices transfer data to and from main memory with continuous involvement of the CPU

- where hardware I/O devices transfer data to and from main memory without continuous involvement of the CPU

Maks poeng: 2

12 fscore.journalling (2%)

Which statement is correct about journalling file systems?
Velg ett alternativ

- ○ The file system is protected if a power outage happens.

- ○ File metadata uses less space.

- ○ Directory lookups are less efficient.

- ○ Maximum file size is doubled.

Maks poeng: 2

13 fscore.links (2%)

The following commands was just executed in sequence in an empty directory:
echo A>a
ln a b
ln -s a c
rm a
Now the directory contains one or more files. How many of the files contain the letter **A** ?
Velg ett alternativ

- ○ 0

- ○ 1

- ○ 2

- ○ 3

Maks poeng: 2

14 **fscore.inode (2%)**

Which one of the following fields is not contained in an inode?
Velg ett alternativ:

- Parent directory

- User (owner)

- SetUID

- Group

Maks poeng: 2

15 **ossec.perms (2%)**

What is the SetUID-bit?
Velg ett alternativ:

- It allows you the change the owner of a file.

- It is used for changing permissions on the id command.

- It can be used to read hidden permission bits.
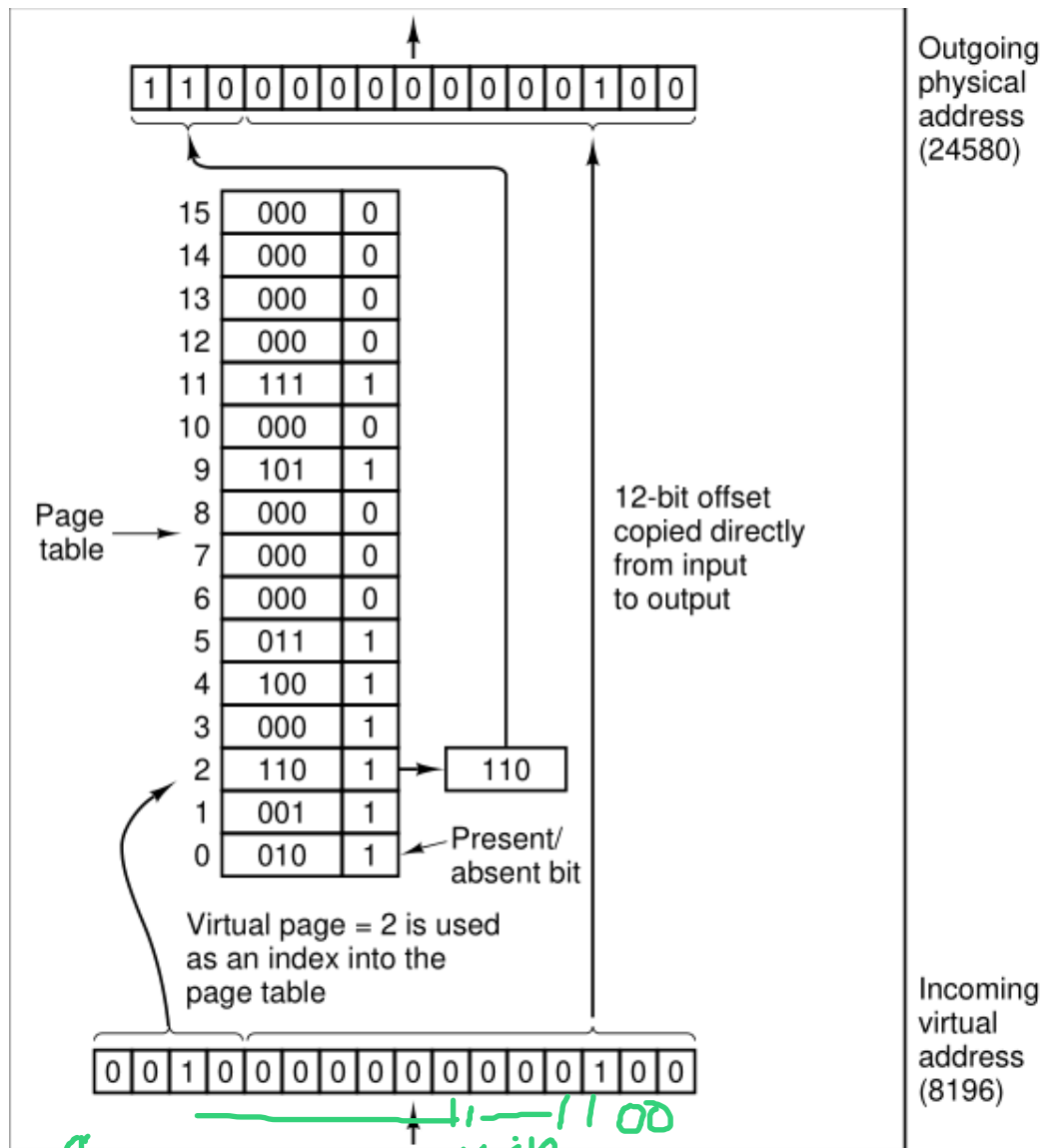
- It lets you run a program as someone else.

Maks poeng: 2

16 addrspace.pagetable (5%)

Consider the following diagram where the incoming virtual address 8196 (decimal) is translated to the outgoing physical address 24580 (decimal).

If the incoming virtual address is 12 (decimal), what will be the outgoing physical address (decimal)?

Outgoing physical address (24580)

15	000	0
14	000	0
13	000	0
12	000	0
11	111	1
10	000	0
9	101	1
8	000	0
7	000	0
6	000	0
5	011	1
4	100	1
3	000	1
2	110	1
1	001	1
0	010	1

Page table

12-bit offset copied directly from input to output

110

Present/absent bit

Virtual page = 2 is used as an index into the page table

Incoming virtual address (8196)

Velg ett alternativ:

○ 24592

○ 24588

◉ 8204

○ 8196

○ 4096

○ 12

○ Gir page fault

○ 24580

○ 4108

○ 8200

Maks poeng: 5

17 hwreview.assembly (3%)

The following three lines of assembly code are in the wrong order (when reading from the top like we do when we read code). Move the lines to the right in such a way that they end up in the correct order.

Drag and drop

movl $0, -4(%rbp)

pushq %rbp

movq %rsp, %rbp

Maks poeng: 3

18 **hwreview.time (3%)**

You (the CPU) want to read data as fast as possible (meaning as little waiting time/delay as possible). From which of the following components would you prefer to read?

Velg ett alternativ

○ L1 cache

○ HDD disk

○ SSD disk

○ RAM

○ L3 cache

○ L2 cache

Maks poeng: 3

¹⁹ introproc.time (4%)

A single-threaded CPU-bound process uses six minutes when running on a single-core CPU without hyperthreading. How much time will it take for three such processes to complete (when they start at the same time) on a modern preemptive multitasking operating system (such as Windows or Linux) on a quad-core CPU (quad-core is four cpu cores) ?

Velg ett alternativ:

○ 18 minutes

           All three processes can run on their own core, each taking 6 minutes.

○ 12 minutes

○ 9 minutes

○ 7.5 minutes

✓ 6 minutes

○ 4.5 minutes

○ 3 minutes

○ 2.5 minutes

○ 2 minutes

Maks poeng: 4

20 **introproc.intro (9%)**

1. (3%) How does the operating system "virtualize" the CPU (making it appear as multiple processes are running at the same time even if we have just one CPU core) ?
Skriv ditt svar her

> Uses scheduling polices such as MLFQ. Each process gets a short time-slice to itself. All of this happens extremely fast.

2. (3%) How does the operating system "virtualize" Memory (so multiple processes can access the same memory addresses without sharing those memory locations)?
Skriv ditt svar her

> Each process is required to have its own virtual address space, thus isolating it from other processes. The system then divides them into pages and maps to physical page frames on the memory.

3. (3%) How does the operating system "virtualize" storage of data on storage media like HDD, SSD, flash cards, etc.?
Skriv ditt svar her

> By introducing software-based file system. We can thus introduce concepts such as directories and files.

Maks poeng: 9

21 syscalls.fork (10%)

Write a C program that creates a new process (use the system call fork). The new process that is created should print "My PID is **XYZ**" and then make a system call to run /bin/date.

XYZ should be the new process ID and it should be retrieved with a system call.

(you do not need to include header files, just focus on the contents of main())

Skriv ditt svar her

```
int main(int argc, char** argv) {
  pid_t rc = fork();
  if (rc < 0) {
    fprintf(stderr, "Fork failed!\n);
    exit(-1);
  } else if (rc == 0) {
    printf("My PID is %i", getpid());
    execl("/bin/date", "date", NULL);
  } else {
   wait(NULL);
  }
  return 0;
}
```

Maks poeng: 10

²² scheduling.mlfq (9%)

1. (5%) Explain how Multi-Level Feedback Queue (MLFQ) works by writing down the scheduling rules the algorithm is composed of (hint: there are ca five such rules dependent on the variant of MLFQ presented in the text book, any variant you answer is fine).
2. (4%) Why is MLFQ such a good scheduling algorithm? (in other words: which problems does MLFQ solve? what is the goal of MLFQ?)

Skriv ditt svar her

Format ▾ | **B** *I* <u>U</u> x₂ x² | Iₓ | ⎀ ⎀ | ↩ ↪ ⟳ | ≔ ⋮≡ | Ω ⊞ | ✎ |

Σ | ⤧

1. If P(A) > P(B), A runs, B doesnt
2. If P(A) = P(B), A & B runs in RR
3. If a process uses time slice while it's running (regardless how many times it has given up the CPU, reduce priority
4. When a process enters the system, it's places in the topmost queue
5. After some time S, move all processes to the topmost queue.

MLFQ is good because it solves two of the most problematic problems when it comes to a good schelduing algorithm; balance between average turnaround- and responsetime.

Is good for short interavtive jobs and is also fair for longer workheavy processes.

Words: 0

Maks poeng: 9

23 semaph.sync (16%)

Consider the C-program balance.c :

```
1  #include <pthread.h>
2  #include <stdint.h>
3  #include <stdio.h>
4  #include <stdlib.h>
5  #define MAX 10000000 // 10.000.000
6
7  int g_balance = MAX;
8
9  void *updateBalance(void *arg) {
10   long id = (long) arg;
11   if (id == 1) {
12    for (int i=0; i<MAX; i++) {
13      g_balance--;
14    }
15   } else if (id == 2) {
16    for (int i=0; i<MAX; i++) {
17      g_balance = g_balance + 2;
18    }
19   } else {
20    printf("%ld is not a valid ID.\n", id);
21   }
22   pthread_exit(NULL);
23  }
24
25  int main(void) {
26   pthread_t t1,t2;
27   int status;
28   status = pthread_create(&t1, NULL, updateBalance, (void *) 1);
29   if (status != 0) { exit(EXIT_FAILURE); }
30   status = pthread_create(&t2, NULL, updateBalance, (void *) 2);
31   if (status != 0) { exit(EXIT_FAILURE); }
32   pthread_join(t1, NULL);
33   printf("Balance is %d after thread 1.\n",g_balance);
34   pthread_join(t2, NULL);
35   printf("Balance is %d after thread 2.\n",g_balance);
36   return 0;
37  }
```

When executed, it outputs something like this:

```
$ ./balance
Balance is 11453068 after thread 1.
Balance is 23012458 after thread 2.
```

1. (4%) What should be the output value of g_balance after thread 2 if nothing goes wrong?
2. (4%) What exactly is the problem with this code?
3. (4%) How can you fix the problem in such a way that the output is guaranteed to be correct with maximum parallelism (but it might be slow)?
4. (4%) How can you fix the program in such a way that the output is guaranteed to be correct and runs fast (where maybe you ignore parallelism)?

Skriv ditt svar her

```
1  1. 20'
   2. Race condition, i.e., both threads enter the same critical section without having locks
   3. Add locks between 12 and 14. Add locks between 16 and 18
   4. Make use of semaphore such that only thread 1 runs first, i'd thus set the starting value to 1.
```

Maks poeng: 16

24 addrspace.bitmap (5%)

Calculate the size of the bitmap in a page-based memory system with page size 4KB and physical memory of 32GB? Give the answer in bytes, not bits.

Skriv ditt svar her

32GB/4KB = 2^35 / 2^12 b = 2^23 b = 2^20 B = 1MB

Maks poeng: 5

25 virt.container (6%)

What is a container? How is a container different from a virtual machine?

Skriv ditt svar her

A container is a collection of grouped, isolated (w/ Namespaces), resourece limited through cgroups, limited in the file-system with some "copy-on-write" filesystem processes.
 It's is different
because it runs directly on the host CPU. There isn't any (as much) overhead compared to running a virtual machine.

Words: 0

Maks poeng: 6