From last time

Explain briefly how starvation may occur in process scheduling. (2 marks)

In round-robin scheduling, new processes are typically placed at the end of the ready-state queue rather than at the beginning. Suggest a good reason for this. (2 marks)

A scheduler uses a time-slice of 4.5msec, and a context switch takes 0.5msec. What percentage of CPU time is spent on executing process instructions: (a) if processes use the whole time-slice? (b) if processes only need 0.5msec CPU-bursts?

In general, how would you improve the percentage of CPU time spent on executing process instructions? (3 marks)

COMP25111: Operating Systems

Lecture 8: Process/Thread Synchronisation

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Overview & Learning Outcomes

Process Synchronisation

Semaphores

Deadlocks

Dining Philosophers

Message-passing

Everything in this handout about process synchronisation also applies to thread synchronisation

Problem: Too much milk

Time	Person 1	Person 2	Person 3
8:00	sleeping	sleeping	check fridge - no milk
8:15	wakes up	sleeping	leave for lecture
8:30	check - no milk	sleeping	travelling
8:45	leave for store	wakes up	arrive at University
9:00	arrive at store	check - no milk	go to lecture
9:15	bought milk	leave for store	(lecture)
9:30	return home	arrive at store	(lecture)
9:45		bought milk	go to store
10:00		return home	arrive at store
10:15			bought milk
10:45			return home

Data inconsistency

Concurrent access to **shared data**

```
          static int i; // shared by A & B
// process or thread A    // process or thread B
i = 0;                    i = 0;
while (i < 100) {         while (i > -100) {
   i++;                      i--;
}                         }
System.out.println("A");  System.out.println("B");
```

(assume both access & assignment are **atomic** i.e. indivisible)

Questions:

– which will finish first?
– will they ever finish?
– if one finishes, will the other also finish?
– does it help if one gets a head start?

Race Condition

Several processes manipulate shared data concurrently
& outcome depends on precise order of what happens when

Q: what are a CPU's atomic operations?

e.g.: shared variable `i` in memory, initial value 4

process A: `i++;`
i.e. load Reg from i; Reg = Reg + 1; store Reg to i

process B: `i--;`
i.e. load Reg from i; Reg = Reg – 1; store Reg to i

Question: what can the final value of `i` be?

Definitions

Data inconsistency: disagreement about data values

Synchronisation: using appropriate policies and mechanisms to ensure the correct operation of cooperating processes

Critical section (Critical region): section of code in which shared data is used

Mutual exclusion (mutex): at most 1 process can be in its critical section at once

i.e. if more than one process tries to enter a critical section simultaneously, only one can succeed – others must wait

Semaphores

Dijkstra, 1965: An integer variable (e.g. `S`)
accessed via two atomic operations (with Dutch names!):

P(S) (“try-to-reduce”, down, wait, aquire, probe, procure)

```
while (S<=0)
 ; /*no action*/
S--;
```

V(S) (“increase”, up, signal, release, vacate)

```
S++;
```

Initialise `S` appropriately
= number of processes allowed in critical section at once
(usually 1)

Don’t loop – yield

In practice, it is silly to busy-wait in `P()`

`P()` adds process to a queue & gives up CPU

`V()` takes process from queue & makes it “ready”

Example – 1 semaphore

Two processes sharing `A[100]`; initialise `S=1;`

```
...             ...
P(S);           P(S);
r1=A[100];      r2=A[100];     critical
r1++;           r2++;
A[100]=r1;      A[100]=r2;     section
V(S);           V(S);
...             ...
```

Example – 2 semaphores

Initialise: `S1=0; S2=0; I=0;`

```
... /* A */   ... /* B */   ... /* C */
P(S1);        P(S2);        for(j=0;j<10;j++)
I=I*2;        I=I+5;          I++;
V(S1);        V(S1);        V(S2);
...           ...           ...
```

Question: What is the the sequence of events?

Deadlock: everyone waiting for everyone else

Deadlock

A set of waiting processes,
where each process is waiting for something
that can only be provided by another of the processes

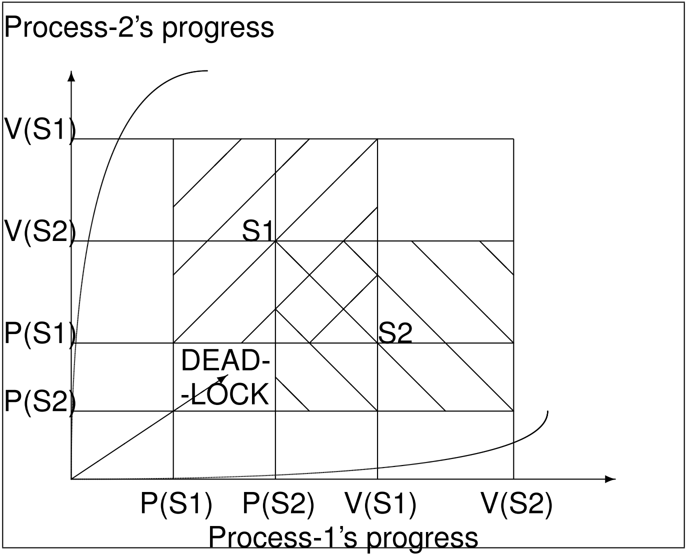
e.g. S1, S2 initialised to 1

```
// A       // B
P(S1);     P(S2);
P(S2);     P(S1);
...        ...
V(S1);     V(S2);
V(S2);     V(S1);
```

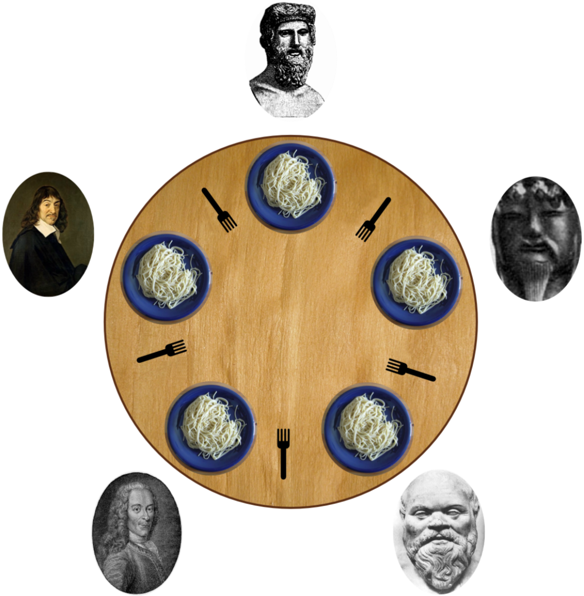
Detection complicated

Once occurred, almost impossible for OS to solve

Prevention e.g. Deadlock (trajectory) Diagram



Benjamin D. Esham / Wikimedia Commons



The Dining Philosophers

5 philosophers, 5 plates of spaghetti, 5 forks, 1 circular table
Alternately think (alone) or eat with 2 forks (from right and left)

```
Semaphore fork[5]; // initialise to 1

philosopher (int i) {
  while(true) {
    System.out.println (i + " hungry");
    P(fork[i]); P(fork[(i+1)mod 5]);
    System.out.println (i + " eating");
    V(fork[i]); V(fork[(i+1)mod 5]);
    System.out.println (i + " thinking"); // delay?
  }
}
```

This may deadlock

Message-passing

Shared data $\rightarrow$ Semaphore(s) control access

No shared data $\rightarrow$ send copy to other processes

Wait for message instead of semaphore
– from known source(s), or from any source

Con: slower(?)

Pro: more general/flexible
– RPC
– multi-CPU
– Distributed/Network

Summary of key points

Process Synchronisation

Semaphores

Deadlocks – may occur in a variety of situations, usually fatal

Dining Philosophers – many solutions

Message-passing

Everything in this handout about <u>process</u> synchronisation also applies to <u>thread</u> synchronisation

Next: Threads in Java.

Your Questions

For next time

Explain briefly how a deadlock may occur (2 marks)

shared variables x, y, s; initial values S1=S2=0 x=y=1 s=0

line	Thread A	Thread B	Explain the purpose
1.	do{	do{	of the semaphores in:
2.	V(S1)	P(S1)	– lines 2 & 3
3.	P(S2)	V(S2)	of both threads
4.	x=x+y	P(S1)	– line 4 of B
5.	V(S1)	y=x-y	& line 5 of A
6.	V(S1)	s=s+1	– lines 6 & 7 of A
7.	P(S2)	P(S1)	and 7 & 8 of B
8.	print s,y	V(S2)	
9.	}while(s<7)	}while(s<7)	(1 mark each)

Will A ever terminate? Justify your answer. (1 mark)

What is output by the print statement in line 8 of A? (3 marks)

Exam Questions

shared variables x1,x2,x3,x4,x5,x6; initially S1=S2=S3=0

	Thread A	Thread B	Thread C
2.	x1= 1	x2= 2	x3= 3
3.	V(S1)	V(S1)	P(S1); P(S1)
4.	P(S2)	P(S3)	V(S2); V(S3)
5.	x4= x2+x3	x5= x1+x3	x6= x1+x2
6.	V(S1)	V(S1)	P(S1); P(S1)
7.	P(S2)	P(S3)	V(S2); V(S3)
8.	x2= x5+x6	x3= x4+x6	x1= x4+x5

continued...

Exam Question ctd.

Is it possible that:

– line 5 of A executes before line 2 of B?

– line 5 of C executes before line 2 of A?

– line 5 of B executes before line 5 of C?

– line 5 of A executes before line 5 of B?

– line 5 of A executes after line 5 of C?

– line 8 of A executes before line 5 of B?

– line 8 of A executes before line 5 of C?

– line 8 of C executes before line 5 of B?

What are the final values of x1, x2, x3, x4, x5, x6?

If S3 is replaced by S2 throughout, can you find a pattern of execution which gives different answers to the questions above?

Glossary

Shared data
Concurrent access
Data (in)consistency
Atomic action/operation
Race condition
Synchronisation
Critical section/region
Mutual exclusion (mutex)
Semaphore
P()
V()
Busy-wait
Deadlock
Deadlock trajectory diagram
Dining Philosphers
Message-passing

Reading

OSC/J: 6.1, 6.2, 6.5 (skim 6.3, 6.4, 6.6)

older OSC/J: 7.1, 7.2, 7.5 (skim 7.3, 7.4, 7.6)

MOS: 2.3 (opening paragraphs), 2.3.1, 2.3.2, 2.3.5 (skim 2.3, 2.4, intro of MOS2 ch.3 or MOS3 ch.6)

Dining philosophers: AOS 7.6.3, MOS2 2.4.1)

Traffic deadlock: http://www.glommer.net/blogs/?p=189