Betriebssysteme

10. Tutorium - Synchronization und Deadlocks

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Synchronization Primitives

Synchronization Primitives

There are different kinds of synchronization primitives

Which ones do you know?

Spinlock

- `lock` / `unlock`
- Busy-waiting and atomic instructions (e.g. compare-and-set)

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- Recommended for *short* critical sections as it wastes CPU time
- Preemption wastes more resources (threads can't make progress)
- $\Rightarrow$ Mostly used in the kernel without interrupts

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Mutex (Binary Semaphore)

- `lock(m)`, `unlock(m)`
- Or a Semaphore with values 0 and 1

Synchronization Primitives

Condition Variables

```
void consume() {
  lock(l);
  while(queue.size == 0) {
    unlock(l);
    sleep(); lock(l);
  }
  queue.poll(); unlock(l); signal();
}
void produce() {
  lock(l);
  while(queue.size == MAX_SIZE) {
    unlock(l);
    sleep(); lock(l);
  }
  queue.add(X); unlock(l); signal();
}
```

This code can incorrectly sleep a consumer/producer. How?

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}
```

This code can incorrectly sleep a consumer/producer. How? *Lost wakeup problem*

Condition Variables

```
void consume() {
  lock(l);
  while(queue.size == 0) {
    // unlocks and sleeps atomically. Relocks when waking up
    wait(cond_filled, l);
  }
  queue.poll(); signal(cond_empty); unlock(l);
}
void produce() {
  lock(l);
  while(queue.size == MAX_SIZE) {
    // unlocks and sleeps atomically. Relocks when waking up
    wait(cond_empty, l);
  }
  queue.add(X); signal(cond_filled); unlock(l);
}
```

Now no wakeup is lost :)

Deadlocks

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What is that? Do you know an example?

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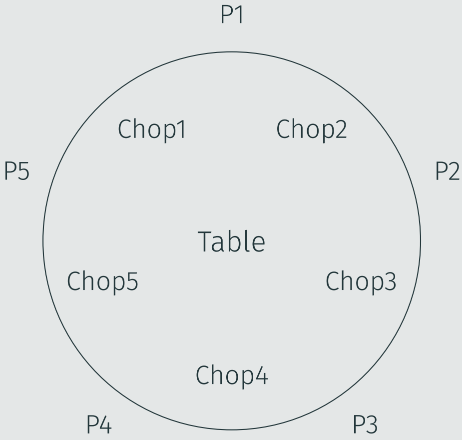
- Several processes or activities can not make progress, as they are waiting for resources held by each other
- Examples: 4-way intersection, *Dining Philosophers*

Dining Philosophers

The Problem



Philosophers (P) want to eat, but to do that they need *two* Chopsticks (Chop)!

How can this deadlock?

Dining Philosophers

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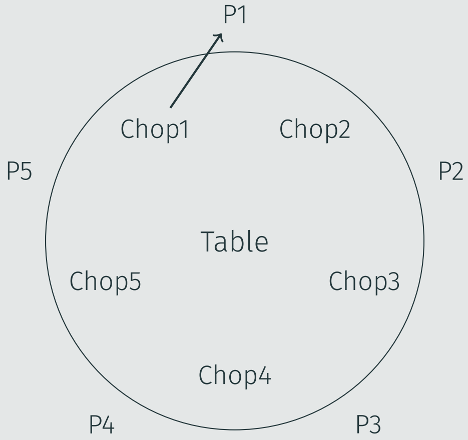

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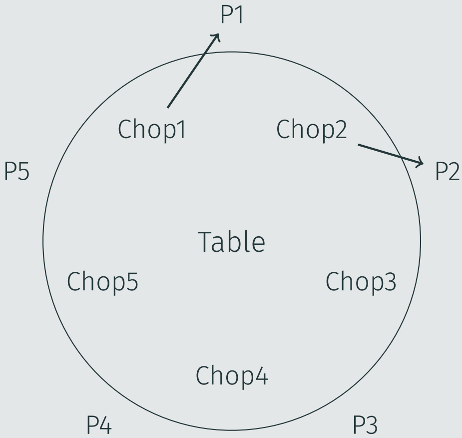

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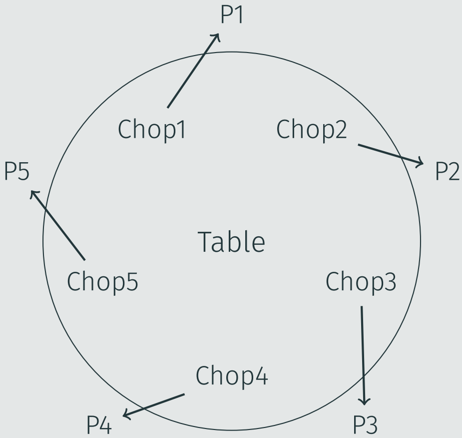

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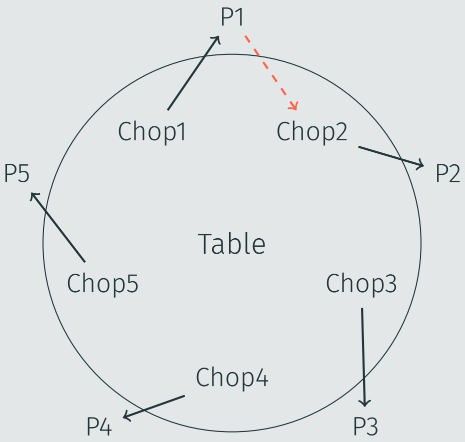

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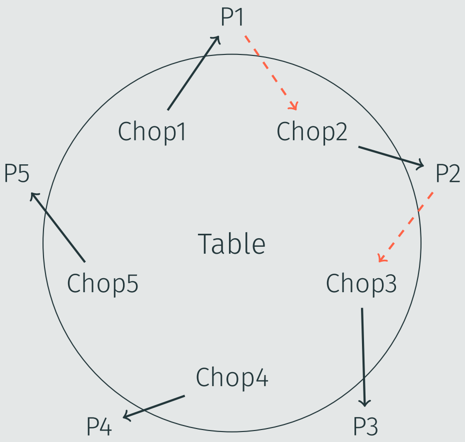

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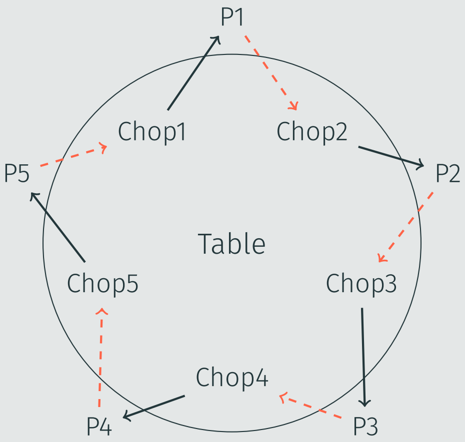

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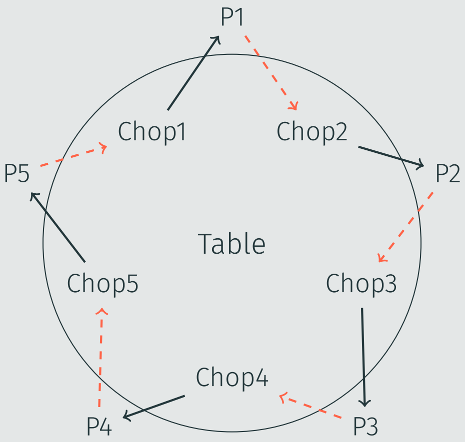

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How can this deadlock?

Why did that happen? What fateful circumstances lead to this starvation?

The Four ~~Horsemen of the Apocalypse~~ *Coffman Conditions*

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Circular Wait

There exists a set of Processes $P_0, P_1, \ldots P_n$ where P_0 is waiting for a resource held by P_1. P_1 is waiting for a resource held by P_2, ...and P_n is waiting for a resource held by P_1

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Note

These conditions *are not independent*! (e.g. Circular Wait $\Rightarrow$ Hold And Wait)

Finding a deadlock

Code

```
Spinlock s1,s2, s3 = FREE;
int counter = 0;
void Thread1() {
  if(counter == 0) {
    lock(s1);
    counter++;
    unlock(s1);
  }
  lock(s2);
  lock(s3);
  // update some more data
  unlock(s3);
  unlock(s2);
}
void Thread2() {
  lock(s3);
  counter++;
  // update some data
  if(counter == 2) {
    lock(s2);
    // update some more data
    unlock(s2);
  }
  lock(s1);
  // update even more data
  unlock(s3);
  unlock(s1);
}
```

Deadlock Prevention and Avoidance

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Make a deadlock *impossible*!

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Make a deadlock *impossible*! How?

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Make a deadlock *impossible*! How? Break ≥ 1 of the four necessary conditions

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Deadlock Avoidance

- Deadlocks are still possible
- The resource allocator knows what resources are used by the processes
- The resource allocator denies requests that *might* lead to a deadlock

Deadlock Prevention - Slay The Horses

How can you negate *Mutual Exclusion*?

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Sometimes: Spooling

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Like a Printer

- You send a job
- It is executed

$\Rightarrow$ Only the executor has access to the resource

Negate *Hold And Wait*

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Negate *Hold And Wait*

Allocate resources atomically: All you will need or nothing
$\Rightarrow$ Once you have resources, you can no longer request new ones

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Allow Preemption! Normally done by *multiplexing* resources (how RAM or CPU time is handled).

Not always possible

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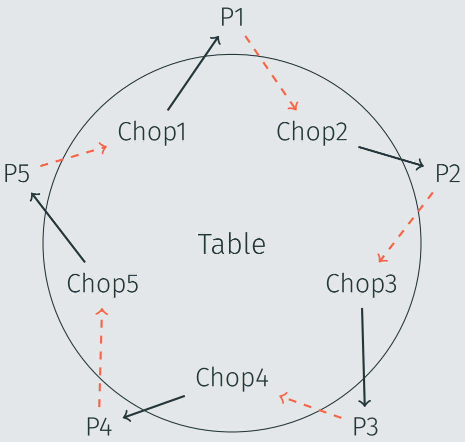
Negate *Circular Wait*

Order resources and only allocate in the *same* order, everywhere.

Commonly used (and also in the current exercise (not anymore :() :)

The Problem



What kind of vertices and edges are in this graph?

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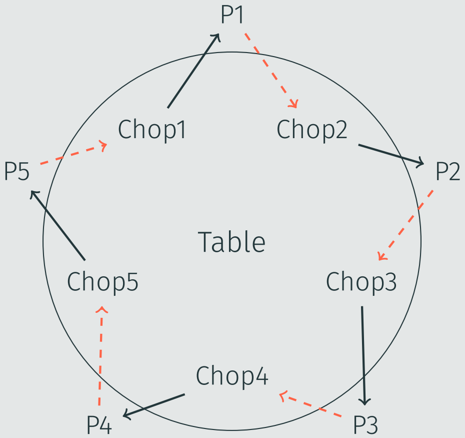
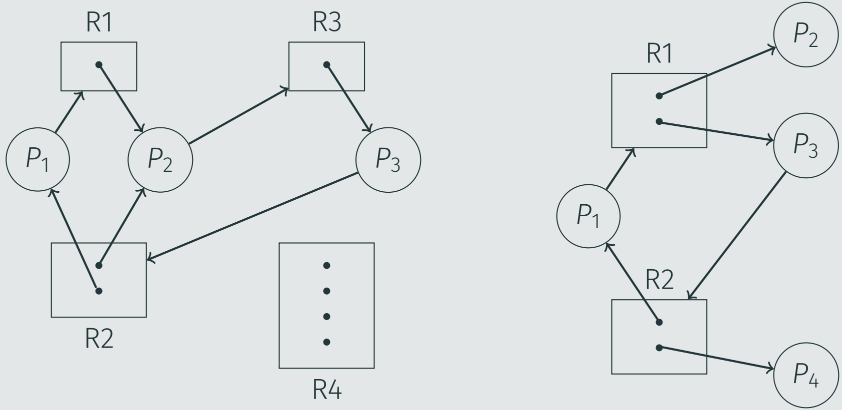


What kind of vertices and edges are in this graph?

How can you detect a deadlock in there?

Resource Allocation Graphs

Some examples



Is there a deadlock in one of the graphs?

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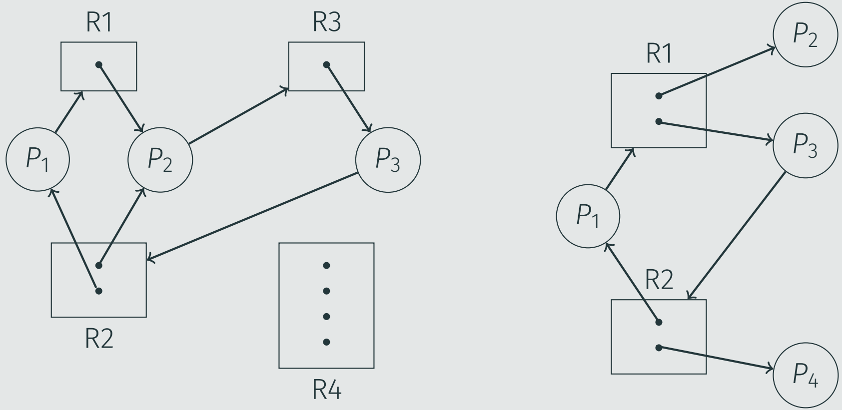

Is there a deadlock in one of the graphs?

Yes, in the left. Right has a cycle *but no deadlock*.

Cycle $\equiv$ Deadlock only holds if you have *one* instance of each resource

Also nice

Deadlock Empire

`https://deadlockempire.github.io/`

Kernel Synchronization

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Additionally, another core could be in the same routine and access the same data

Mutual Exclusion In The Kernel

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> *This removes the implementation of the big kernel lock, at last. A lot of people have worked on this in the past, I so the credit for this patch should be with everyone who participated in the hunt.* (Commit message)

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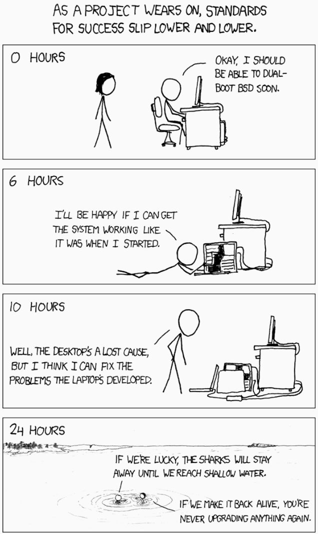
Remember Spinlocks and Interrupt handlers?

Without disabling interrupts there is a problem: *Lockholder Preemption*

1. Thread enters spinlock
2. Thread gets pre-empted by an interrupt handler
3. Interrupt handler needs the same lock $\Rightarrow$ Can never acquire it!

$\Rightarrow$ You might still need to disable interrupts for those



XKCD 349 - Success

F R A G E N?

Bis nächste Woche :)