Betriebssysteme

9. Tutorium - IPC

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9. Januar 2024

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Begrüßung

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- Neujahresvorsatz: OS-Übungsblätter bearbeiten
- `<rant>` Wenn man vorher explizit sagt das man kommt, hat man das auch zu tun, oder sich abzumelden! `</rant>`

Inter-Process-Communication

IPC

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- OS facilities (e.g. messages, pipes, Signals, sockets)
- High level abstractions (files, database entries)

IPC - Getting Stuck

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Timeouts! You don't want to wait for buggy programs or poor dead ones :(

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$\Rightarrow$ Does not scale well. You either allow every sender to allocate memory for you (*ouch*) or you might run out with many clients

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\+ We only need to store it once: The sender has it in a buffer somewhere anyways

\+ Scales better, as each sender keeps their messages

± We need to tell the client when it can reclaim the buffer

The Joys of Synchronous IPC

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- You spent your whole life *waiting for timeouts to expire*
- How could you solve that with a new syscall? How does `send-and-receive`, which sends and instantly receives help?
- The server can assume you are using it and set a zero timeout. After all, if you are using that syscall you *will* be waiting

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\+ Allows async I/O

\- How many messages can you send? Yea, one per thread...

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⇒ Send `ACK` message on receiver side, wait for `ACK` to be received.

And receive?

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⇒ Implement a very simple protocol involving multiple messages

⇒ Send `ACK` message on receiver side, wait for `ACK` to be received.

And receive?

Just loop until `async_receive` receives a message (that is not an `ACK`)

Critical Sections

Synchronizing Properly - Core Properties

Does this work?

```
1 void foo() { // called in parallel
2   if(random() < 0.5) {
3     sleep(10);
4   }
5   a += 10;
6 }
```

Synchronizing Properly - Core Properties

Does this work?

```
1 void foo() { // called in parallel
2   if(random() < 0.5) {
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4   }
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6 }
```

Nope. Multiple threads can call `a += 10` at the same time.

Property 1: Mutual Exclusion

Synchronizing Properly - Notes on Terminology

Some boring definitions

```
1  void foo() { // called in parallel
2
3    // This is the code before the critical section
4    // ==> Entry section
5
6    // Here common data is accessed (e.g. shared variable).
7    // Only one thread might be in here at a time.
8    // ==> Critical Section
9    a += 10;
10
11   // This is the code after the critical section
12   // ==> Exit section
13 }
```

Everything else is the Remainder section

Synchronizing Properly - Core Properties

Does this work?

```
1 void foo() { // called in parallel
2   // The late bird catches the worm
3   while(me != selectLastWaiting()) {
4     sleep(10);
5   }
6   a += 10;
7 }
```

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How long could a thread wait?

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How long could a thread wait?

Forever :(

Property 2: Bounded Waiting

Synchronizing Properly - Core Properties

Does this work?

```
1 void foo() { // called in parallel
2   while(waitingThreadCount > 1) {
3     sleep(10);
4   }
5   a += 10;
6 }
```

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Does this work?

```
1 void foo() { // called in parallel
2   while(waitingThreadCount > 1) {
3     sleep(10);
4   }
5   a += 10;
6 }
```

Threads *outside* the critical section prevent threads from *entering* it

$\Rightarrow$ There's no progress!

Property 3: Progress

Synchronizing Properly - Core Properties

And the last one isn't really a property of a correct solution

Property 4: Performance

Synchronizing Properly - Core Properties

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Only *one thread* can enter the critical section at once.

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Bounded Waiting

There is an upper bound on *how many* different threads can enter the CS while a thread is waiting.

Important: This is not a *time* bound!

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Important: This is not a *time* bound!

Performance

The time overhead of the synchronization primitive is low (for low / medium / high contention).

Synchronizing Properly - Core Properties

Does this code fulfill all properties?

```
1  /* aligned to cache lines */
2  volatile int next = 0;
3  volatile int executing = 0;
4
5  lock_acquire() {
6    /* atomic version of "ticket = next; next += 1;" */
7    int ticket = fetch_and_add(next, 1);
8    /* busy wait until the counter matches */
9    while (ticket != executing ) {}
10  }
11
12 lock_release() {
13   executing++;
14 }
```

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Synchronizing Properly - Core Properties

Does this code fulfill all properties?

- Mutual Exclusion: Yes (though if you have 2^{32} threads waiting it doesn't)
- Bounded Waiting: Yes. Eventually my number is the next one!
- Progress: Yes, threads in the remainder section do not hinder any thread from entering the critical section. Only threads in the *entry section* can do that temporarily.

Fixing The Bank

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```
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2 current += delta; // delta ∈ {−50, 100}
3 set_balance(current);
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1 current = get_balance();
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```

How could you fix that?

Synchronize it!

```
1 lock(L);
2 current = get_balance();
3 current += delta; // delta ∈ {−50, 100}
4 set_balance(current);
5 unlock(L);
```

Race Conditions

The Parallel Wizard Strikes Again

```
1 current = get_balance();
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```

What happens if this code is executed in *parallel* for the two values of `delta`?

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```

What happens if this code is executed in *parallel* for the two values of `delta`?

Unrolled

```
1 current = get_balance();
2 int tmp = current;
3 current = tmp + delta; // delta ∈ {−50, 100}
4 set_balance(current);
```

Race Conditions

Thread execution

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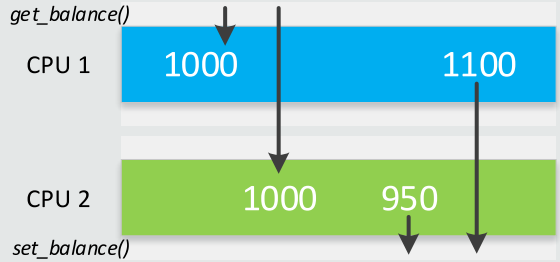

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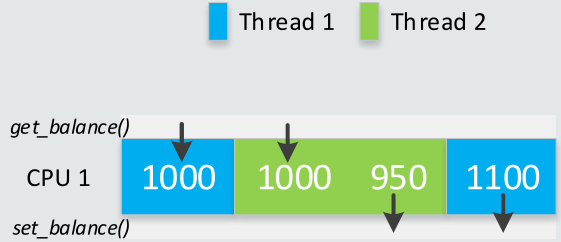
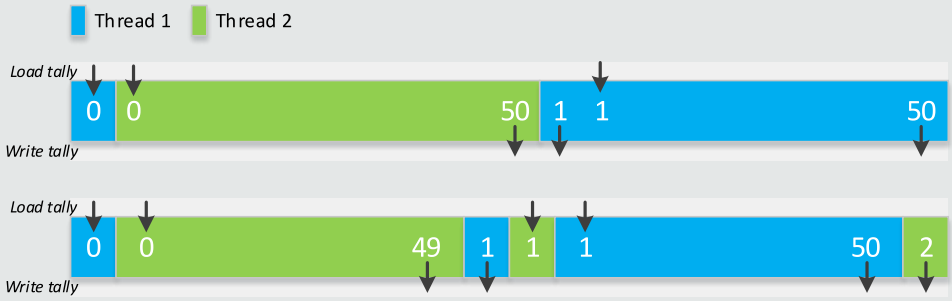


Having Fun With It...

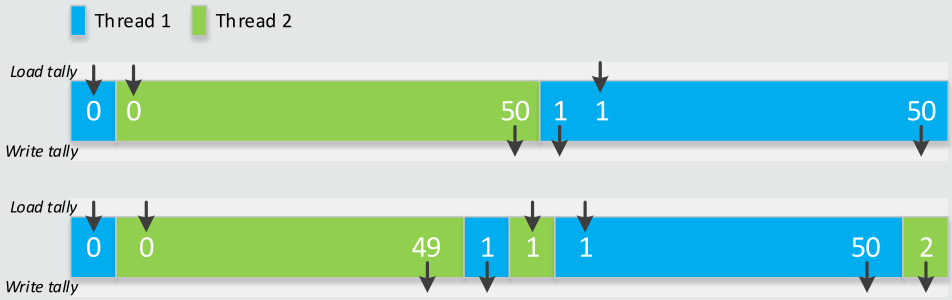
What is the value of `tally` at the end?

```
1  #include <stdio.h>
2
3  int tally;
4  void total(int N) {
5      for(int i = 0; i < N; i++)
6          tally += 1;
7  }
8
9  int main() {
10     tally = 0;
11
12     #pragma omp parallel for
13     for(int i = 0; i < 2; i++)
14         total(50);
15
16     printf("%d\n" , tally);
17     return 0;
18 }
```

This!


Thread 1
Thread 2
Load tally
0
0
50
1
1
50
Write tally
Load tally
0
0
49
1
1
1
50
2
Write tally

This!



And what happens when we use $N, N > 0$ threads instead of 2?

The range is now

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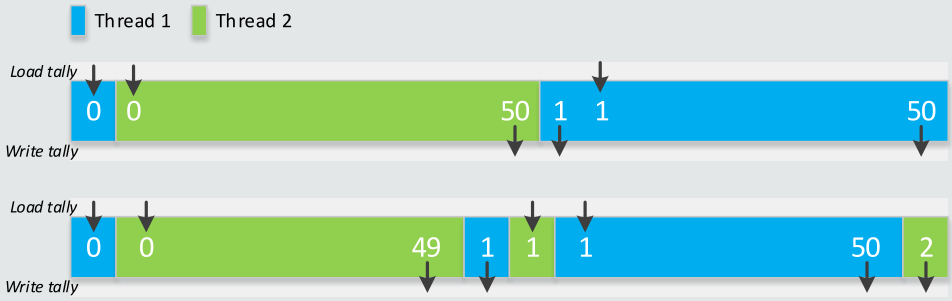

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The range is now $[2, 50 \cdot N]$. We can still have the same problem.

...And Adding ULTs!

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In that spirit: Does this work (with 1:1 threads)?

```
1 void total(int N) {
2   for(int i = 0; i < N; ++ i) {
3     tally += 1;
4     sched_yield();
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Deadlock Empire

https://deadlockempire.github.io

Ende

XKCD 281 - Package Tracking

F R A G E N?

https://forms.gle/9CwJSKidKibubran9

Bis nächste Woche