CS 134:
Operating Systems
More Synchronization

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Overview

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More Synchronization
Monitors
Simpler Mechanisms

The Story So Far...

Mutual Exclusion

- Basic idea?

Semaphores

- Basic idea?

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Fairness

Just how fair do we need to be. . . ?

Our Take. . .

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- Too low-level
- Too much freedom (& too strange)
- Too hard to get right

Need an alternative. . .

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Monitors

Monitors were devised as an alternative to semaphores

- High-level synchronization construct, based on classes
- Only one task can be running “inside” the class at a time

Declare classes like this:

```
monitor class MyClass {
    public:
        /* method declarations only
    private:
        /* private data and private methods */
};
```


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└ More Synchronization
  └ Monitors
    └ Monitors

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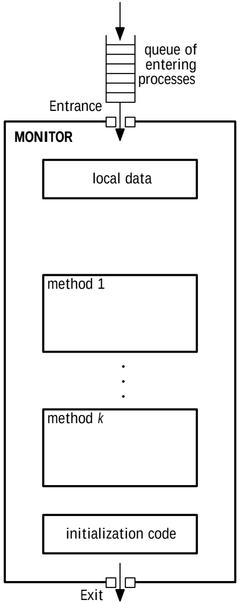
Monitors

Basic idea:

- Only one process can be in the monitor at a time

But what about waiting?



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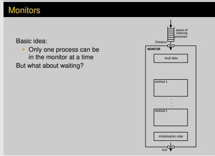

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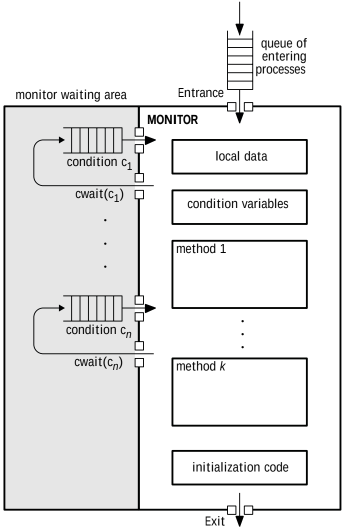

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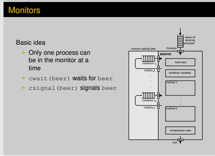

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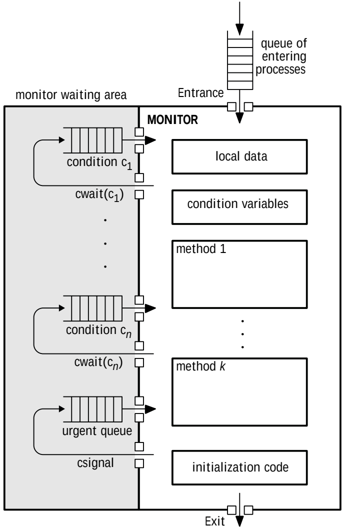

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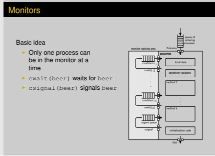

Equivalence Claims

How could we show that

- Semaphores aren't "more powerful" than monitors?
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Minimalism. . .

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Can we imagine something “less” than semaphores?

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Can we imagine something “less” than semaphores?

Binary Semaphores

Basic idea?

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Basic idea?

A binary semaphore is similar to test-and-set. If it's nonzero, one one process can set it to zero and continue past `bsem_dec`. If it's zero, `bsem_inc` sets it nonzero and wakes at least one process waiting on it. Multiple calls to `bsem_inc` with no intervening `bsem_dec` will have no effect. However, it is illegal to do that: you can't call `bsem_inc` unless the semaphore value is currently zero.

Semaphores from Binary Semaphores

Assume the following binary semaphore operations:

```
struct bsem* bsem_create (int count);
void bsem_dec (struct bsem* s);
void bsem_inc (struct bsem* s);
```

Data to implement semaphores...?

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Semaphores from Binary Semaphores (cont.)

Initialization:

```
struct sem* sem_init(int count)
{
  struct sem* s = malloc(sizeof(struct sem));
  assert(s != NULL && count >= 0);
  s->count = count;
  s->mutex = bsem_create(1); // Ordinary mutex
  s->wait = bsem_create(0);  // Mostly locked,
                             // briefly unlocked
  return s;
}
```


Semaphores from Binary Semaphores (cont.)
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Semaphores from Binary Semaphores (cont.)

Is this code okay?

```
void sem_dec(struct sem* s)
{
  bsem_dec(s->mutex);
  --(s->count);
  if (s->count < 0) {
    bsem_inc(s->mutex);
    bsem_dec(s->wait);
  }
  else {
    bsem_inc(s->mutex);
  }
}
```

```
void sem_inc(struct sem* s)
{
  bsem_dec(s->mutex);
  ++(s->count);
  if (s->count <= 0) {
    bsem_inc(s->wait);

  }

  bsem_inc(s->mutex);

}
```


There is a race after `sem_dec` calls `bsem_inc` on the mutex; we could sleep on `s->wait` even though `s->count` has become nonzero. We need to ensure that there is exactly one `bsem_inc` per wait. For example:

1. Process 1 decs and stops after mutex release
2. Process 2 decs and stops after mutex release
3. Process 3 incs and bumps wait
4. Process 4 incs and re-bumps wait (illegally)
5. Process 1 continues and passes through wait
6. Process 2 continues and waits forever

Semaphores from Binary Semaphores (cont.)

Does this version fix the problem?

```
void sem_dec(struct sem* s)
{
  bsem_dec(s->mutex);
  --(s->count);
  if (s->count < 0) {
    bsem_inc(s->mutex);
    bsem_dec(s->wait);
  }
  bsem_inc(s->mutex);
}
```

```
void sem_inc(struct sem* s)
{
  bsem_dec(s->mutex);
  ++(s->count);
  if (s->count <= 0) {
    bsem_inc(s->wait);
  }
  else {
     bsem_inc(s->mutex);
  }
}
```


Semaphores from Binary Semaphores (cont.)

Does this version fix the problem?

The assumption here is that if `sem_dec` waits, `sem_inc` would grab the mutex on its behalf and bump `wait`. So even if somebody else gets in between the release of the mutex and the wait, they will necessarily allow us to pass through. In our previous scenario:

1. Process 1 decs and stops after mutex release
2. Process 2 decs and stops after mutex release
3. Process 3 incs and bumps wait
4. Because the mutex is still held, process 4 can't proceed. Instead, one of process 1 & 2 will continue and pass through the wait.
5. Process 1 continues and releases mutex.
6. Process 4 incs and bumps wait
7. Process 2 can now continue and pass through wait.

Monitors Revisited

Basic idea

- Only one process can be in the monitor at a time
- `cwait(beer)` waits for `beer`
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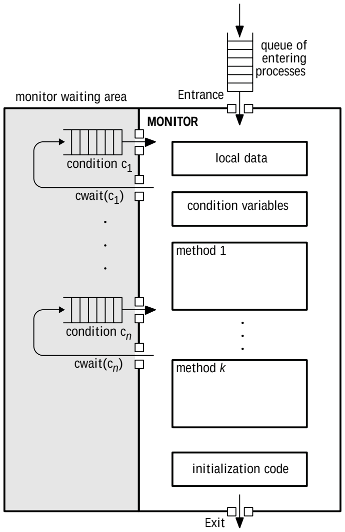
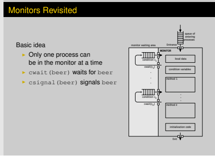


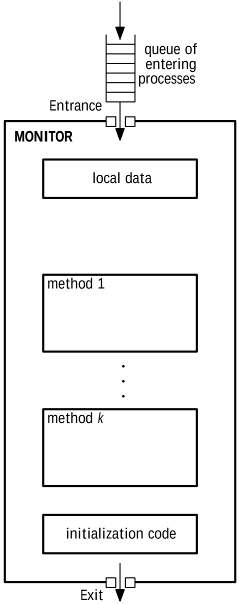


Monitors without Condition Variables

Basic idea

- Only one process can be in the monitor at a time

Remind you of anything?



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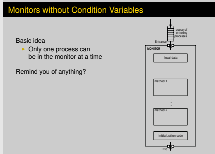
Monitors without Condition Variables



Mutexes / Locks

Like binary semaphores, but with *ownership* rules:

- You “acquire” the lock
- You “hold” the lock
- You “release” the lock

Someone else can’t release it for you.

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Mutexes / Locks

```
void task(const int i)
{
  for ( ; ; ) {
    lock_acquire(ourlock);
    critical_section_actions(i);
    lock_release(ourlock);
    other_actions(i);
  }
}
```

Class Exercise

Is `bool lock_tryacquire(lock)` useful?

2013-05-19

CS34
└More Synchronization
  └Simpler Mechanisms
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Mutexes / Locks

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Can you implement semaphores using mutexes?

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What do mutexes remind you of?

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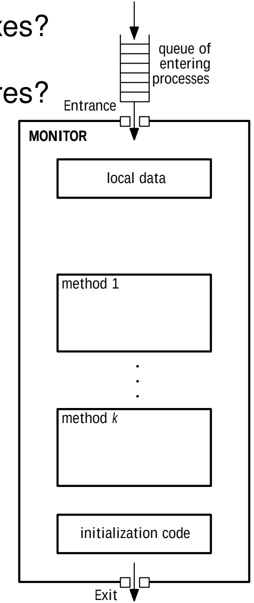
What do mutexes remind you of?

But what's missing?



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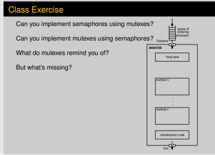
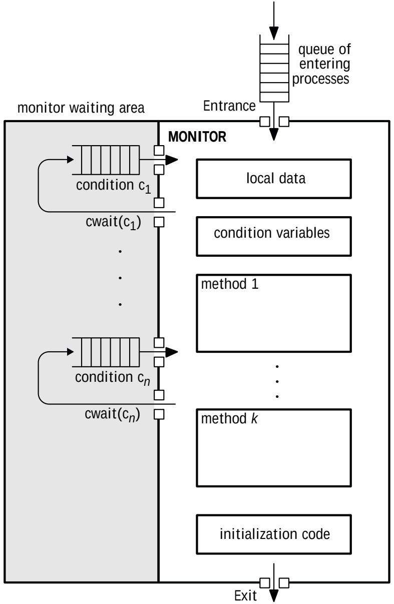


Condition Variables (for Mutexes)

What are the operations?

What are the arguments?



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More Synchronization
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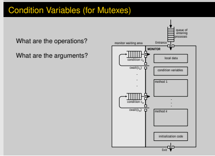

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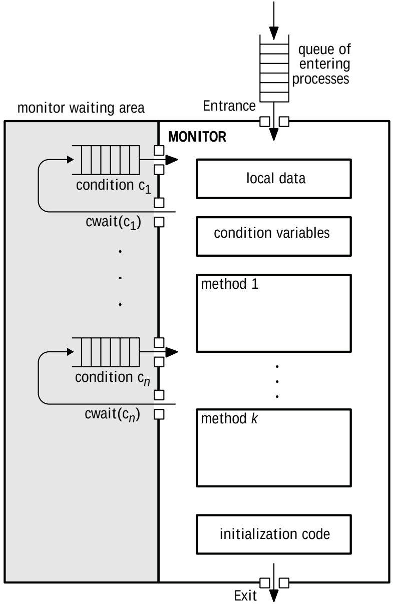
Do you need to hold the lock when you `cond_signal` or `cond_broadcast`?



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More Synchronization
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