Concurrency

COMPSCI210 Recitation

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Venues for systems research

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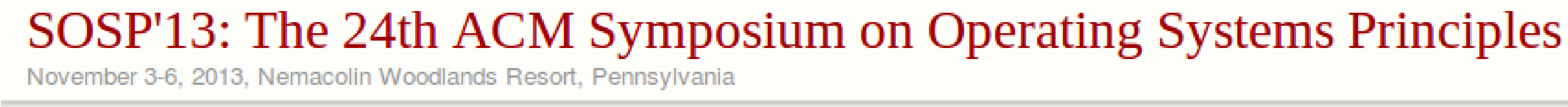


SOSP'13: The 24th ACM Symposium on Operating Systems Principles

November 3-6, 2013, Nemacolin Woodlands Resort, Pennsylvania

Comments on lab submissions so far..

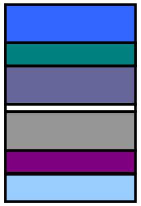
- Read handout, ask questions
- Think before you start coding
- Write readable code
- man/doc are your friends
- Please do not post your code on the web
- Please do not copy any code directly from the web or other sources
  - You can look, but write your own code
  - When in doubt, always ask first

We hear your feedback

- Next lab: Multi-threaded programming in Java
  - We provided only the interfaces
  - You can start from the scratch
  - Due on 26th Oct, 11:59pm
  - You can work in groups of 2 or at most 3.
- Exam FAQ
  - Check the course page

Processes: A Closer Look

virtual address space



The address space is represented by page table, a set of translations to physical memory allocated from a kernel memory manager.

The kernel must initialize the process memory with the program image to run.

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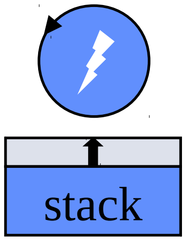
thread



Each process has a thread bound to the VAS.

The thread has a saved user context as well as a system context.

The kernel can manipulate the contexts to start the thread running wherever it wants.

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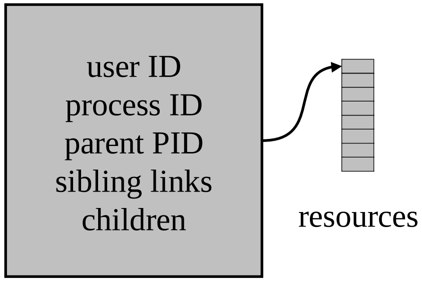
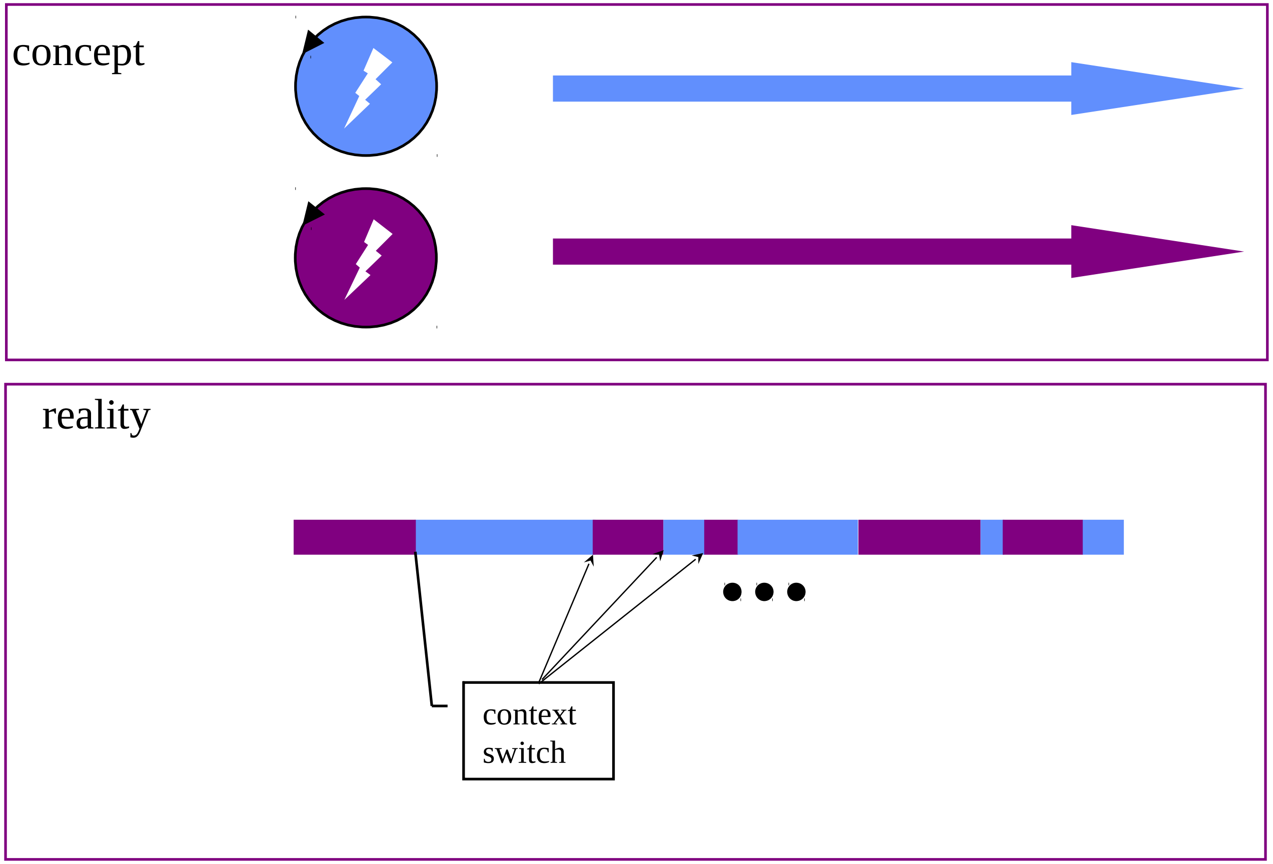
process descriptor (PCB)



Process state includes a file descriptor table, links to maintain the process tree, and a place to store the exit status.

Two threads sharing a CPU



Concurrency

- Having multiple threads active at one time
- Thread is the unit of concurrency
- Primary topics
  - How threads cooperate on a single task
  - How multiple threads can share the CPUs

An example

- Two threads (A and B)
  - A tries to increment i
  - B tries to decrement i

Thread A:

```
 i = 0;
 while (i < 10){
   i++;
 }
printf(“A done.”)
```

Thread B:

```
i = 0;
while (i > -10){
  i--;
}
printf(“B done.”)
```

Example continued ..

- Who wins?
- Does someone has to win?

Thread A:

```
i = 0;
while (i < 10){
 i++;
}
printf(“A done.”)
```

Thread B:

```
i = 0;
while (i > -10){
 i--;
}
printf(“B done.”)
```

Debugging non-determinism

- Requires **worst-case** reasoning
  - Eliminate **all** ways for program to break
- Debugging is hard
  - Can’t test all possible interleavings
  - Bugs may only happen sometimes
- **Heisenbug**
  - Re-running program may make the bug disappear
  - Doesn’t mean it isn’t still there!

Constraining concurrency

- **Synchronization**
  - Controlling thread interleavings
- Some events are independent
  - No shared state
  - Relative order of these events don’t matter
- Other events are dependent
  - Output of one can be input to another
  - Their order can affect program results

Goals of synchronization

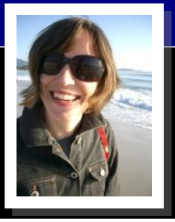
1. All interleavings must give correct result
   - Correct concurrent program
     - Works no matter how fast threads run
     - Important for your projects!
2. Constrain program as little as possible
   - Why?
     - Constraints slow program down
     - Constraints create complexity

“Too much milk” rules

- The fridge must be stocked with milk
  - Milk expires quickly, so never > 1 milk
- Landon and Melissa
  - Can come home at any time
  - If either sees an empty fridge, must buy milk
  - Code (no synchronization)

```
if (noMilk){
   buy milk;
}
```

“Too much milk” principals

Time		
3:00	Look in fridge (no milk)	
3:05	Go to grocery store	
3:10		Look in fridge (no milk)
3:15	Buy milk	
3:20		Go to grocery store
3:25	Arrive home, stock fridge	
3:30		Buy milk
3:35		Arrive home, stock fridge Too much milk!

What broke?

- Code worked sometimes, but not always
  - Code contained a **race condition**
  - Processor speed caused incorrect result
- First type of synchronization
  - **Mutual exclusion**
  - **Critical sections**

Synchronization concepts

- **Mutual exclusion**
  - Ensure 1 thread doing something at a time
  - E.g. 1 person shops at a time
  - Code blocks are atomic w/re to each other
  - Threads can’t run code blocks at same time

Synchronization concepts

- **Critical section**
  - Code block must run atomically
    - w.r.t some piece of the code
- If A and B are critical w/re to each other
  - Threads mustn’t interleave code from A and B
    A and B mutually exclude each other
- Conflicting code is often same block
  - But executed by different threads
  - Reads/writes shared data (e.g. screen, fridge)

Back to “Too much milk”

- What is the critical section?

```
if (noMilk){
  buy milk;
}
```

- Landon and Melissa’s critical sections
  - Must be atomic w/re to each other

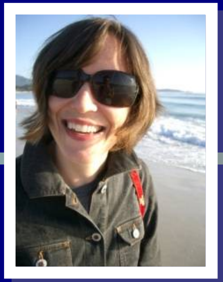
Solution 1 code

- Atomic operations
  - Load: check note
  - Store: leave note

```
if (noMilk) {
  if (noNote){
    leave note;
    buy milk;
    remove note;
  }
}
```

Does it work?

```
 if (noMilk) {
①  if (noNote){
      leave note;
  ③   buy milk;
      remove note;
    }
 }
```

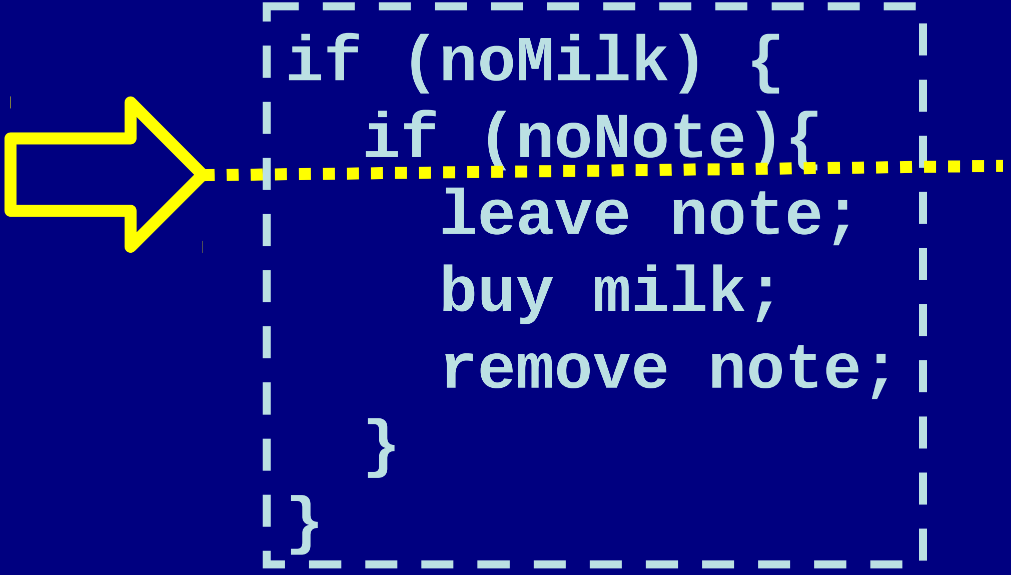


```
 if (noMilk) {
②  if (noNote){
      leave note;
  ④   buy milk;
      remove note;
    }
 }
```

Is this better than no synchronization at all?
What if "if" sections are switched?

What broke?

- Melissa’s events can happen
  - After Landon checks for a note
  - Before Landon leaves a note



```
if (noMilk) {
  if (noNote){
    leave note;
    buy milk;
    remove note;
  }
}
```

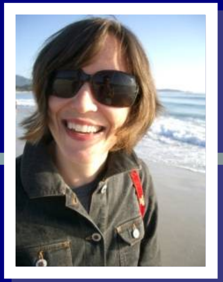
Next solution

Idea:

- Change the order of “leave note”, “check note”
- Requires labeled notes (else you’ll see your note)

Does it work?

```
leave noteLandon
if (no noteMelissa){
  if (noMilk){
    buy milk;
  }
}
remove noteLandon
```



```
leave noteMelissa
if (no noteLandon){
  if (noMilk){
    buy milk;
  }
}
remove noteMelissa
```

Nope. (Illustration of “starvation.”)

What about now?

```
while (noMilk){
   leave noteLandon
   if(no noteMelissa){
      if(noMilk){
         buy milk;
      }
   }
   remove noteLandon
}
```

```
while (noMilk){
   leave noteMelissa
   if(no noteLandon){
      if(noMilk){
         buy milk;
      }
   }
   remove noteMelissa
}
```

Nope.
(Same starvation problem as before)

Next solution

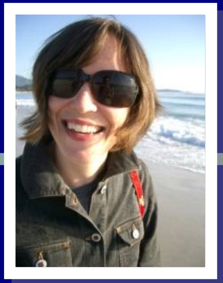
- We’re getting closer

- Problem
  - Who buys milk if both leave notes

- Solution
  - Let Landon hang around to make sure job is done

Does it work?

```
leave noteLandon
while (noteMelissa){
  do nothing
}
if (noMilk){
  buy milk;
}
remove noteLandon
```



```
leave noteMelissa
if (no noteLandon){
  if (noMilk){
    buy milk;
  }
}
remove noteMelissa
```

Yes! It does work! Can you show it?