Concurrent programming in operating systems

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Professor of Computer Programming
(scouting for talent)

4th February 2004

Slogans

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- Call me Richard.

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- Call me Richard.
- Say “Slow down!”.

Slogans

- Call me Richard.
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- Try “Shut up and listen to me!”

Programming versus Operating Systems

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- Safety and security are resource management problems.
- So are fairness, liveness, sharing, race-conditions.
- RM problems are also programming problems, even in everyday programming with pointers.
- My research (and one day, perhaps yours too) is in resource logics applied to programming problems.

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- What could go wrong?
- Whoops! processes/threads can have *races* (and sometimes your horse loses).

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```
ptr = cache_lookup(k);
if (ptr==NULL) {
  ptr = getbuffer(); cache_forget(ptr.key);
  ptr.key = k; ptr.value = Y(k);
  cache_remember(k, ptr);
}
return ptr.value;
```

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- Luckily, we had the Unix source ...

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while (true) {
  ptr = find_buffer(dev, b);
  if (ptr==NULL) {
    ptr = getbuffer();
    ptr.device = dev; ptr.block = b;
    start_read(dev, ptr, b);
  } else if (ptr.lock==0)
    return ptr;
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- If there are no free (lock==0) buffers, getbuffer waits.

A block cache with pre-fetch

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```
while (true) {
  ptr = find_buffer(dev, b);
  if (ptr==NULL) {
    ptr = getbuffer(); ...
    start_read(dev, ptr, b);
    if (find_buffer(dev,b+1)==NULL) {
      ptr2 = getbuffer(); ...
      start_read(dev, ptr2, b+1);
    }
  } else if (ptr.lock==0)
    return ptr;
  wait(ptr);
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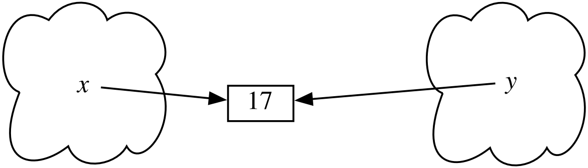
- and then for a second fork;
- ... deadlock! Starvation!
- But if just one person hangs back ...

The standard "race condition"



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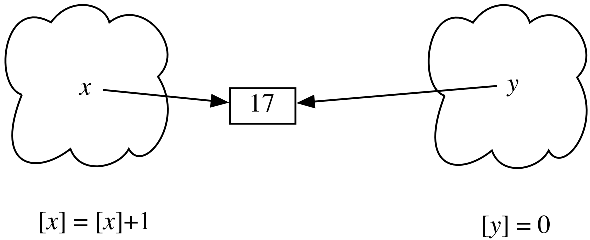

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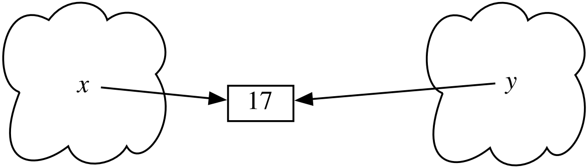

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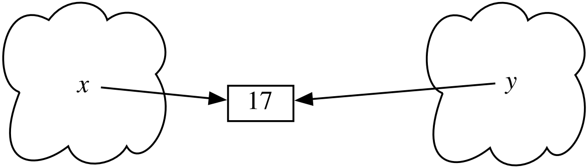

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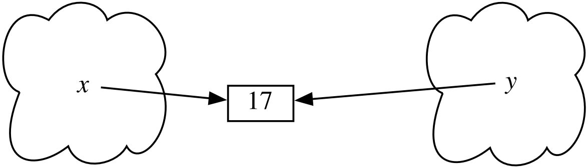

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- If read and write can be subdivided – chaos.

Dijkstra's solution: block signalling

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- But semaphores caused waiting, queuing, *stopping*.
- New problems: deadlock, livelock, unfairness, starvation, ...

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Reader:

$\mathrm{P}(read);$
$count += 1;$
$\text{if } (count == 1)\ \mathrm{P}(write);$
$\mathrm{V}(read);$

... reading happens here ...;

$\mathrm{P}(read);$
$count -= 1;$
$\text{if } (count == 0)\ \mathrm{V}(write);$
$\mathrm{V}(read)$

Writer:

$\mathrm{P}(write);$

... writing happens here ...

$\mathrm{V}(write)$

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- There are rules for every program structure.

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- ... now we can prove lots of pointer programs.

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$$x \overset{n}{\longmapsto} E \iff x \overset{n+1}{\longmapsto} E \star x \mapsto E$$

A proof

$write : z \stackrel{0}{\longmapsto} \_$

$read : \text{if } count = 0 \text{ then } \mathbf{emp} \text{ else } z \xmapsto{count} \_$

$\{\mathbf{emp}\}$

$\mathrm{P}(read);$

$\{\text{if } count = 0 \text{ then } \mathbf{emp} \text{ else } z \xmapsto{count} \_\}$

$count{+} := 1;$

$\{\text{if } count - 1 = 0 \text{ then } \mathbf{emp} \text{ else } z \xmapsto{count-1} \_\}$

$\text{if } count = 1 \text{ then } \{\mathbf{emp}\}\ \mathrm{P}(write)\ \{z \stackrel{0}{\longmapsto} \_\}$

$\qquad\qquad \text{else} \qquad\qquad \{z \xmapsto{count-1} \_\};$

$\{z \xmapsto{count-1} \_\}$

$\{z \xmapsto{count} \_ \star z \mapsto \_\}$

$\mathrm{V}(read);$

$\{z \mapsto \_\}$

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- $\{\mathbf{emp}\}\ \mathrm{P}(m)\ \{I_m\}$ is “partial correctness” - *if* you get through then you collect a prize, but you may never get through.
- We can reason about resource ownership, resource leaks, resource safety ... all at the local level.

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