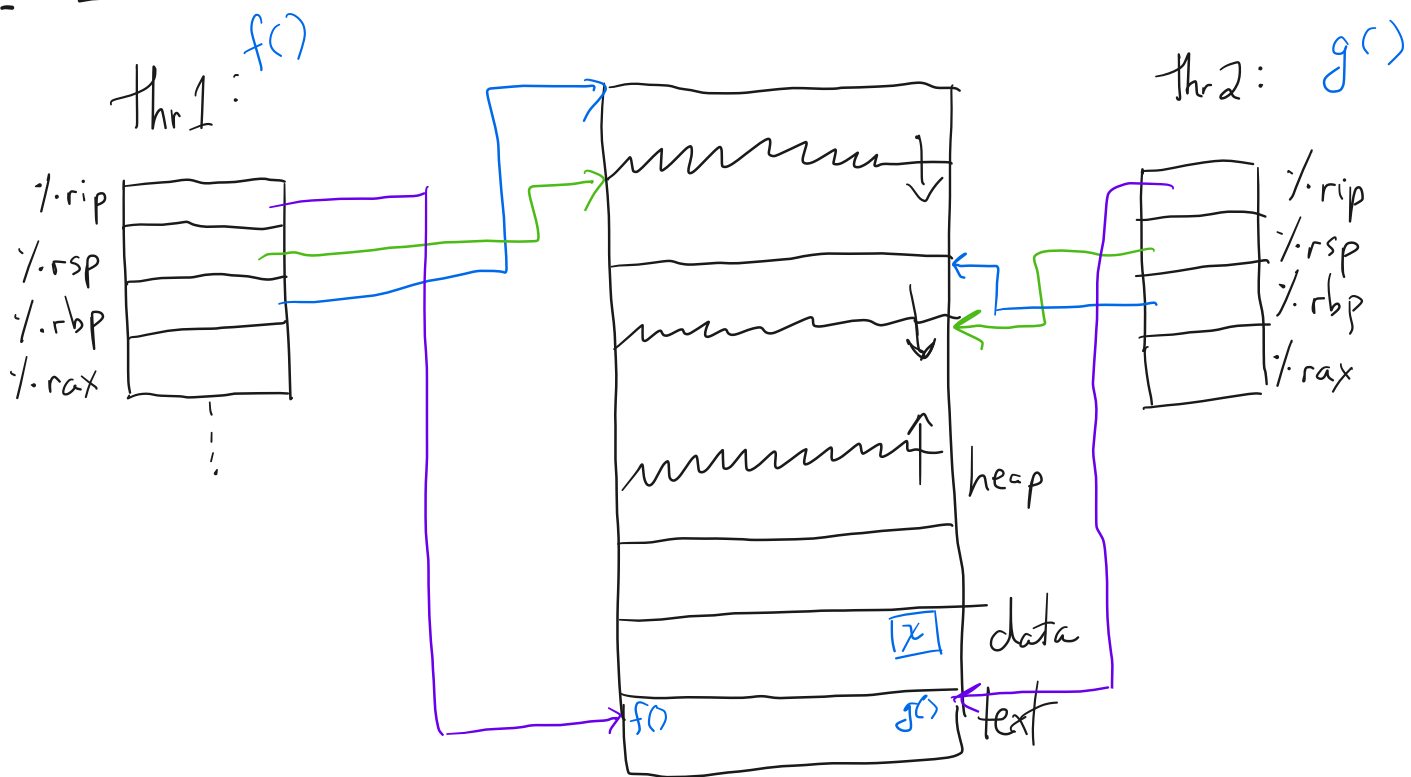


- 1. Last time
- 2. Intro to concurrency, continued
- 3. Managing concurrency
- 4. Mutexes
- 5. Condition Variables
- 6. Semaphores

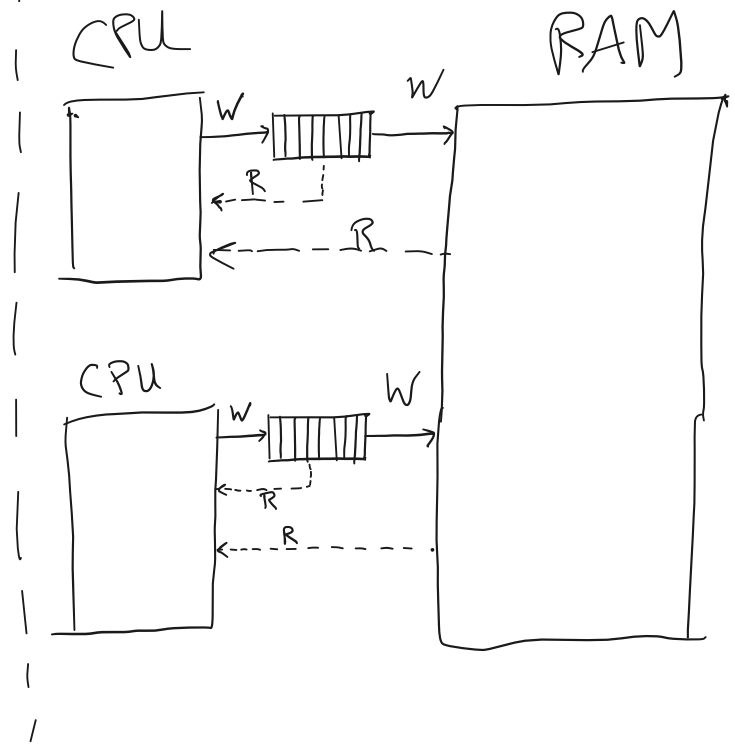
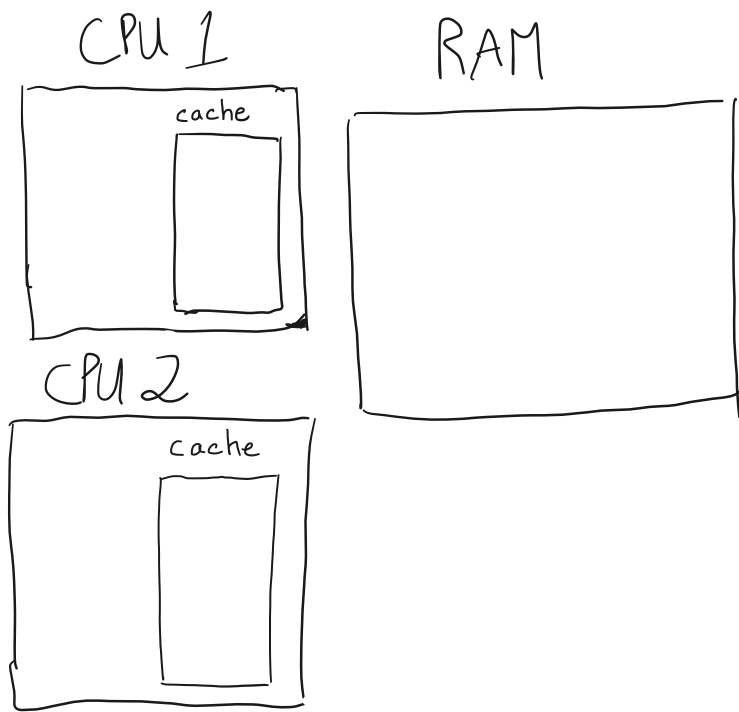
- ## 2. Intro to concurrency
- panels 1-3 on handout 03: all examples of "race conditions"
(uncontrolled access to shared memory)
 - hardware makes the problem harder (see panel 4)



Threads share memory, but they have their own "execution context" (registers and stack).

To the programmer, it "feels like" multiple things are happening at once in the program.

memory consistency



3. Managing concurrency

a. Critical sections: the concept: "protect from concurrent execution".

- i. mutual exclusion
- ii. progress
- iii. bounded waiting

b. Protecting critical sections

lock() / unlock()

enter() / leave()

acquire() / release()

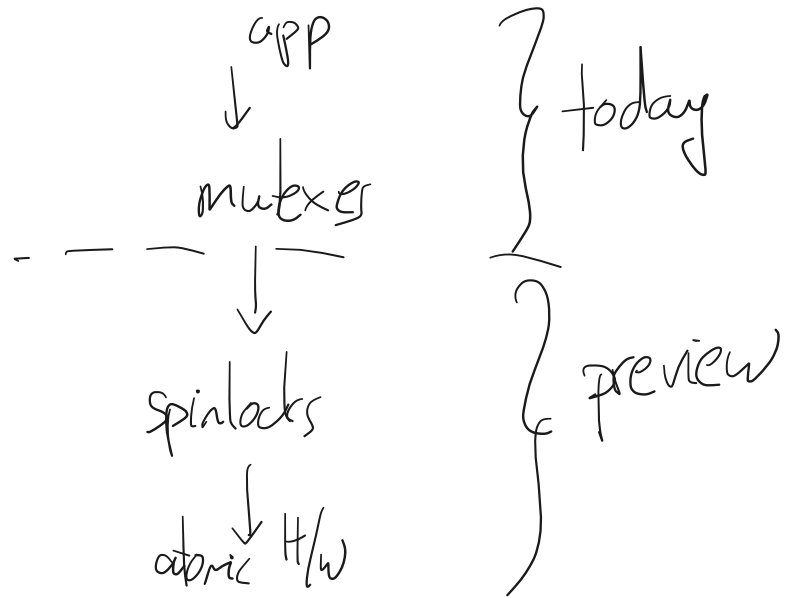
Implementing critical sections

c. Implementing critical sections

(i) single-CPU machine: $\text{enter}() \rightarrow$ disable interrupts

$\text{leave}() \rightarrow$ enable interrupts

4. Mutexes



5. Condition variables

$\text{cond_int}(\text{Cond}^*, --);$

$\text{cond_wait}(\text{Mutex}^* m, \text{Cond}^*);$

$\text{cond_signal}(\text{Mutex}^* m, \text{Cond}^*);$

$\text{cond_broadcast}(\text{Mutex}^* m, \text{Cond}^*);$

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handout04.txt

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```

1 CS 202
2 Handout 4 (Class 5)
3
4 The handout from the last class gave examples of race conditions. The following
5 panels demonstrate the use of concurrency primitives (mutexes, etc.). We are
6 using concurrency primitives to eliminate race conditions (see items 1
7 and 2a) and improve scheduling (see item 2b).
8
9 1. Protecting the linked list.....
10
11     Mutex list_mutex;
12
13     insert(int data) {
14         List_elem* l = new List_elem;
15         l->data = data;
16
17         acquire(&list_mutex);
18
19         l->next = head;
20         head = l;
21
22         release(&list_mutex);
23     }
24

```

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```

25 2. Producer/consumer revisited [also known as bounded buffer]
26
27 2a. Producer/consumer [bounded buffer] with mutexes
28
29     Mutex mutex;
30
31     void producer (void *ignored) {
32         for (;;) {
33             /* next line produces an item and puts it in nextProduced */
34             nextProduced = means_of_production();
35
36             acquire(&mutex);
37             while (count == BUFFER_SIZE) {
38                 release(&mutex);
39                 yield(); /* or schedule() */
40                 acquire(&mutex);
41             }
42
43             buffer [in] = nextProduced;
44             in = (in + 1) % BUFFER_SIZE;
45             count++;
46             release(&mutex);
47         }
48     }
49
50     void consumer (void *ignored) {
51         for (;;) {
52
53             acquire(&mutex);
54             while (count == 0) {
55                 release(&mutex);
56                 yield(); /* or schedule() */
57                 acquire(&mutex);
58             }
59
60             nextConsumed = buffer[out];
61             out = (out + 1) % BUFFER_SIZE;
62             count--;
63             release(&mutex);
64
65             /* next line abstractly consumes the item */
66             consume_item(nextConsumed);
67         }
68     }
69

```

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```

70
71      2b. Producer/consumer [bounded buffer] with mutexes and condition variables
72
73      Mutex mutex;
74      Cond nonempty;
75      Cond nonfull;
76
77      void producer (void *ignored) {
78          for (;;) {
79              /* next line produces an item and puts it in nextProduced */
80              nextProduced = means_of_production();
81
82              acquire(&mutex);
83              while (count == BUFFER_SIZE)
84                  cond_wait(&nonfull, &mutex);
85
86              buffer[in] = nextProduced;
87              in = (in + 1) % BUFFER_SIZE;
88              count++;
89              cond_signal(&nonempty, &mutex);
90              release(&mutex);
91          }
92      }
93
94      void consumer (void *ignored) {
95          for (;;) {
96
97              acquire(&mutex);
98              while (count == 0)
99                  cond_wait(&nonempty, &mutex);
100
101              nextConsumed = buffer[out];
102              out = (out + 1) % BUFFER_SIZE;
103              count--;
104              cond_signal(&nonfull, &mutex);
105              release(&mutex);
106
107              /* next line abstractly consumes the item */
108              consume_item(nextConsumed);
109          }
110      }
111
112      Question: why does cond_wait need to both release the mutex and
113      sleep? Why not:
114
115      while (count == BUFFER_SIZE) {
116          release(&mutex);
117          cond_wait(&nonfull);
118          acquire(&mutex);
119      }
120
121

```

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```

122      2c. Producer/consumer [bounded buffer] with semaphores
123
124      Semaphore mutex(1);          /* mutex initialized to 1 */
125      Semaphore empty(BUFFER_SIZE); /* start with BUFFER_SIZE empty slots */
126      Semaphore full(0);           /* 0 full slots */
127
128      void producer (void *ignored) {
129          for (;;) {
130              /* next line produces an item and puts it in nextProduced */
131              nextProduced = means_of_production();
132
133              /*
134               * next line diminishes the count of empty slots and
135               * waits if there are no empty slots
136               */
137              sem_down(&empty);
138              sem_down(&mutex); /* get exclusive access */
139
140              buffer[in] = nextProduced;
141              in = (in + 1) % BUFFER_SIZE;
142
143              sem_up(&mutex);
144              sem_up(&full); /* we just increased the # of full slots */
145          }
146      }
147
148      void consumer (void *ignored) {
149          for (;;) {
150
151              /*
152               * next line diminishes the count of full slots and
153               * waits if there are no full slots
154               */
155              sem_down(&full);
156              sem_down(&mutex);
157
158              nextConsumed = buffer[out];
159              out = (out + 1) % BUFFER_SIZE;
160
161              sem_up(&mutex);
162              sem_up(&empty); /* one further empty slot */
163
164              /* next line abstractly consumes the item */
165              consume_item(nextConsumed);
166          }
167      }
168
169      Semaphores *can* (not always) lead to elegant solutions (notice
170      that the code above is fewer lines than 2b) but they are much
171      harder to use.
172
173      The fundamental issue is that semaphores make implicit (counts,
174      conditions, etc.) what is probably best left explicit. Moreover,
175      they *also* implement mutual exclusion.
176
177      For this reason, you should not use semaphores. This example is
178      here mainly for completeness and so you know what a semaphore
179      is. But do not code with them. Solutions that use semaphores in
180      this course will receive no credit.

```