

**EECS 338 Assignment #3 solutions: Concurrent Programming Algorithms #1  
2007**

Turn in your typed hard-copy in the class, and deposit your solution document (word, pdf, text) to Digital Dropbox on Feb. 20<sup>th</sup>. (To help you prepare your assignment document, you can download a word document of this assignment from the blackboard).

(15 pts) (1) Consider the Bakery algorithm given below.

```
Pi: repeat
    choosing[i] := true;
A ---- number[i] := max (number[0], number[1], ..., number[n-1])+1;
    choosing[i] := false;
    for j:=0 to n-1 do begin
        while choosing[j] do skip;-----(*)
        while (number[j], j) < (number[i], i)
            and number[j] ≠ 0 do skip;
    endfor
    Critical Section
    number[i] := 0;
    Remainder Section
until false;
```

Initially, all choosing values are false, and all number values are zeroes.

- (a) Assume that the line (\*) is removed. Describe a scenario in which the algorithm does not work (i.e., it does not solve the critical section problem). Briefly, explain what goes wrong and why.

*Violation of ME can occur.*

*Example:*

*P1: Wants to enter CS. Number[1]=0. Leaves CPU at A, after computing the max() function, but before executing the assignment statement.*

*P2: Wants to enter CS. Picks number[2] as, say, 250. Goes into CS.*

*P1: Picks number[1] as 250 also. Goes into CS. Violation of ME!*

- (b) Is the Bakery algorithm FIFO (First-In-First-Come) with respect to CS entry? Explain why/why not.

*No. Consider the scenario:*

*P1: Wants to enter CS. Number[1]=0. Leaves CPU at A, after computing the max() function, but before executing the assignment statement.*

*P2: Wants to enter CS. Goes into CS. Leaves CS.*

*P1: Picks number[1] and goes into its CS.*

*P2 arrives after P1, but goes into its CS first.*

- (c) Does the Bakery algorithm satisfy the bounded waiting property? If no, why not? If yes, what is the bounded waiting value?

*BW is satisfied, and the BW bound is (n-1) where n is the number of processes. This happens when all processes pick the same number, and, by luck, the process that comes in first is Pn.*

- (10 pts) (2) Assume that you have a sequential programming language of your choice, the concurrent statement (i.e., the `parbegin/parend` statement), semaphores and `wait/signal` semaphore primitives. Assume that integer variables  $A, B, C, D, E$  and  $F$  are already initialized. Write a concurrent program fragment that computes the formula below (without algebraic transformations on the formula) with maximum concurrency.

$$((A * B) + (C * D)) / (E * F)$$

You can use temporary variables to hold intermediate results.

(Binary or nonbinary) semaphores  $a, b, c, d$  are all set to 0 initially.

```
parbegin
  begin  $X := A * B$ ; signal( $a$ ); end;
  begin  $Y := C * D$ ; signal( $b$ ); end;
  begin wait( $a$ ); wait( $b$ );  $Z := X + Y$ ; signal( $c$ ); end;
  begin  $V := E * D$ ; signal( $d$ ); end;
  begin wait( $c$ ); wait( $d$ );  $Out := Z / V$ ; end;
parend;
```

- (75 pts) (3) **Railroad Crossing Problem.** Consider a single-track railroad with multiple trains using the track and a two-way car crossing where cars can cross the railroad in both directions at the same time.

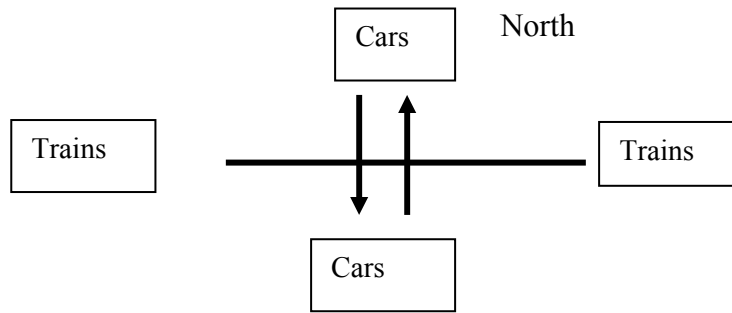
The crossing is controlled by a “crossing light”. The light always rotates from green to yellow to red, and then to green. When the light is green, at most four cars—in any direction—can be crossing the railroad at the same time. That is, the number of (north-to-south, south-to-north) car combinations crossing the railroad can be (4, 0), (3, 1), (2, 2), (1, 3), or (0, 4).

When the light is yellow, no new cars are allowed to cross the railroad, and the cars that are in the process of crossing the railroad track complete their crossing. When the light is red, no cars are allowed to cross the railroad.

We assume that there is enough time between the event that the light changes from green to yellow and the event that the light changes from yellow to red so that all cars that are in the process of crossing the railroad complete the crossing process safely and, when the light turns red, there are no more cars that are crossing the railroad.

Multiple trains can use the railroad at the same time, and arrive at the crossing one after another—but, always in the same direction; we assume that the sequence of trains using the railroad is controlled by an independent authority that makes sure that there are no trains colliding with each other.

At most four cars can cross the railroad crossing at the same time and in any direction. Cars can starve while crossing the railroad tracks; trains never do.



Your task is to give a concurrent process management algorithm to the Railroad Crossing Problem where trains and cars are processes. The train approaching the crossing activates the light that changes from green to yellow. The change of the light from yellow to red is activated either by the last car crossing the railroad (at most four at a time) or, if no car is passing the crossing at the time, by the train approaching the crossing. The change of the light from the red to green is activated by the train that is finishing its crossing. Your algorithm does not know the total number of trains and cars in the system.

Give a semaphore-based algorithm (solution) to the Railroad Crossing Problem. Explain your algorithm, and explicitly specify any assumptions you make about the model.

**Hints:** It is a good idea to

- (1) Use a shared enumerated variable *light* (with values green, yellow, and red) that maintains the state of the light.
- (2) Maintain shared variables to keep counts of
  - (i) cars “waiting to cross the track”,
  - (ii) cars that are “in the process of crossing the track”, and
  - (iii) trains that are “approaching” the crossing.
- (3) Define and employ “a number of” semaphores that will block cars and trains when needed, and provide mutual exclusion.

## Railroad Crossing Problem: Semaphore-Based Solution

### Variables:

*Nonbinary Semaphores:* mutex, car-wait, train-wait, initialized to 1, 0, and 0 respectively.

*Integers:* WaitCarCnt, PassCarCnt, TrainCnt, all initialized to zeroes.

*Enumerated variable* light with values {green, yellow, red}

### CAR:

```
wait(mutex);
if (PassCarCnt < 4 and light=green)
  then PassCarCnt++;           //Fix the count and start crossing the intersection.
  else { WaitCarCnt++;         //Can't pass. Fix the count and block self.
        signal(mutex);       // By releasing mutex, we allow other cars or trains come in.
        wait(car-wait);       // Wait for your turn
        wait(mutex);          // Cleared to cross.
        WaitCarCnt--;         // But, first, adjust the counts mutually exclusively.
        PassCarCnt++;
      }
signal(mutex);
```

### CAR-PASS-CROSSING;

```
wait(mutex);           //Done crossing.
PassCarCnt--;          // Fix the counts.
if (light = green and WaitCarCnt > 0) then signal(car-wait); // if light is green, release another waiting car.
signal(mutex);
```

### TRAIN:

```
wait(mutex);
TrainCnt++;
if(TrainCnt = 1)
  then {light := yellow; signal(mutex) } //if first train then change light to yellow.
  else { signal(mutex); wait(train-wait) } //Otherwise, wait for your turn to approach the crossing.
```

### TRAIN-APPROACH-CROSSING;

```
wait(mutex);           //About to enter the crossing; no cars are crossing (assumed);
light:=red;            //so, change light to red.
signal(mutex);
```

### TRAIN-PASS-CROSSING;

```
wait(mutex);           //Done crossing; do housekeeping work mutually exclusively and exit.
TrainCnt--;           // Fix the count.
if (TrainCnt ≥ 1) then {light := yellow; signal(train-wait)}; //Release waiting trains first (cars starve).
else {light := green; //No waiting trains. Release waiting cars.
      if (WaitCarCnt=1) then {signal(car-wait)}
      else if (WaitCarCnt=2) then {signal(car-wait); signal(car-wait)}
      else if (WaitCarCnt=3) then {signal(car-wait); signal(car-wait); signal(car-wait)}
      else if (WaitCarCnt ≥ 4) then {signal(car-wait); signal(car-wait); signal(car-wait); signal(car-wait)}
    }
signal(mutex);
```