Fall 2015 **EECS 338 Assignment 2** **Due:** Oct. 1st, 2015

G. Ozsoyoglu *Concurrent Programming with Semaphores; 140 points*

(100 pts) **1. Priority-based Searchers/Inserters/Deleters Problem without starvation.** Three types of processes, namely, *searchers*, *inserters*, and *deleters* share access to a singly linked list L, and perform search, insert, or delete operations, respectively. The list L does not have duplicate values.

a) *Searchers* merely search the list L, and report success (i.e., item searched is in L) or no-success (i.e., item searched is not in L) to a log file. Hence they can execute concurrently with each other.

b) *Inserters* add new items to the end of the list L, and report success (i.e., item is not in L, and successfully inserted into L) or no-success (i.e., item is already in L, and no insertion takes place) to a log file. Insertions must be mutually exclusive to preclude two *inserters* from inserting new items at about the same time. However, one insert can proceed in parallel with any number of searches.

c) *Deleters* remove items from anywhere in the list, and report success (i.e., the item is found in L and deleted) or no-success (i.e., item is not in L, and could not be deleted) to a log file. At most one *deleter* can access the list L at a time, and the deletion must be mutually exclusive with searches and insertions.

d) ***Initial start.*** *Searcher*, *inserter*, and *deleter* processes are initially launched as follows. A user process that needs a search/insertion/deletion operation to the list L first *forks* a process, and then, in the forked process, performs an *execv* into a *searcher/ inserter/deleter* process.

e) ***Log maintenance.*** Upon start, each *searcher/inserter/deleter* writes to a log file, recording the time of insertion, process id, process type (i.e., *searcher, inserter*, or *deleter*), and the item that is being searched/inserted/deleted.

f) ***Termination.*** Upon successful or unsuccessful completion, each *searcher/inserter/deleter* writes to the same log file, recording the time and the result of its execution.

g) ***Priority-based service between three types.*** *Searchers, inserters*, and *deleters* perform their search, insert, delete operations, respectively, ***on a priority basis*** (not on a first-come-first-serve (FCFS) basis) between separate process types (i.e., *searchers, inserters, deleters)* as follows. *Searchers* search with the highest priority; *inserters* insert with the second highest priority, and *deleters* delete with the lowest priority.

h) ***FCFS service within a single type.*** Processes of the same type are serviced FCFS. As an example, among multiple *inserters*, the order of insertions into L is FCFS. Similarly, among multiple *deleters*, the order of deletions into L is FCFS. Note that, among *searchers*, while the start of search among searchers is FCFS, due to concurrent *searcher* execution, the completions of multiple searchers may not be FCFS.

i) ***Starvation avoidance.*** In addition to the above priority-based search/insert/delete operations, the following ***starvation-avoidance rule*** is enforced.

   - ***After 10 consecutive searchers search the list L***, if there is at least one waiting *inserter* or *deleter* then newly arriving *searchers* are blocked until (a) all waiting *inserters* are first serviced FCFS, and, then (b) all waiting *deleters* are serviced FCFS. Then, both the standard priority-based service between process types and the FCFS service within a process type resume.

You are to specify a semaphore-based algorithm to synchronize *searcher, inserter* and *deleter* processes.

Note:

- Explain your algorithm.
- Make sure to state any assumptions you make in your solution.
- Specify the initial states of your variables and semaphores.
- Specify whether your semaphores are binary or nonbinary.
- Do not bother specifying algorithms for sequential tasks: simply specify a well-defined function/procedure (i.e., one with well-defined input/output/functional specification).

```
binary semaphore mutex:=1;
nonbinary semaphore s-mutex:=1;i-mutex:=1; d-mutex:=0;
                    sWait:=0;          //This semaphore blocks the first searcher when either
                                       // a deleter is deleting or the starvation service starts.
                    iWait:=0; dWait:=0;  // These semaphores block the first newly arriving inserter (deleter)
                                       // arriving after starvation service starts.
int sPassingCnt:=0; sPassedCnt:=0; sWaitCnt:=0; iWaitCnt:=0; dWaitCnt:=0;
  iStarvationServiceCnt:=0; dStarvationServiceCnt:=0;
boolean StarvationService:=False; iPassing:=False; dPassing:=False; sBlocked:=False; siEmptying:=False;


process searcher (item, L)
{wait(mutex); sWaitCnt++; signal(mutex);
 wait(s-mutex);
 wait(mutex);
 sWaitCnt−−;
 if (dPassing) {signal(mutex); wait(sWait); sPassingCnt++; signal(s-mutex)}
 else if ((sPassingCnt+sPassedCnt) <10) {sPassingCnt++; signal(mutex); signal(s-mutex)}
    else if ((sPassingCnt+sPassedCnt) = 10) and iWaitCnt=0 and dWaitCnt=0)
                         {sPassedCnt:=0; sPassingCnt++;  signal(mutex); signal(s-mutex)}
       else { StarvationService:=True;  sPassedCnt:=0;      // Starvation service is initiated here.
           iStarvationServiceCnt:=iWaitCnt;  iWaitCnt:=0;
           dStarvationServiceCnt:=dWaitCnt; dWaitCnt:=0
           if  (iPassing or sPassingCnt>0) {siEmptying:=True; signal(mutex)}
           while (siEmptying) do no-op;          // Wait for passing searchers and inserter to finish passing.
           if iStarvationServiceCnt≠0 { signal(mutex); signal(i-mutex)} else {signal(mutex); signal(d-mutex)}
           wait(sWait);
           sPassingCnt++;
           signal(s-mutex)}
 SEARCH-AND-LOG-RESULTS (L, item);
wait(mutex);
if  siEmptying                         // Once passing searchers/inserter emptied, starvation service will start!
    {sPassingCnt−−; if (sPassingCnt=0 and ¬iPassing) siEmptying:=False else signal(mutex)}
else {sPassingCnt−−;  sPassedCnt++;   //Regular service mode
    if (sPassingCnt=0 and sWaitCnt=0 and ¬iPassing and dWaitCnt≠0) signal(d-mutex);
    signal(mutex)}
```

```
}

process inserter (item, L)
{wait(mutex);
 iWaitCnt++;
 if StarvationService {signal(mutex); wait(iWait)} else signal(mutex);
 wait(i-mutex);
 wait(mutex);
  if (not StarvationService) iPassing:=True;
  signal(mutex)}
        SEARCH-INSERT-AND-LOG-RESULTS (L, item);
  wait(mutex)
  if siEmptying {iPassing:=False;       // Once passing searchers/inserter are emptied, starvation service will start!
                 if sPassingCnt=0 siEmptying:=False else signal(mutex)}
  else {if StarvationService                                        //In starvation service mode!
           {iStarvationServiceCnt−−; if (iStarvationServiceCnt≠0) signal(i-mutex)
                                     else if (dStarvationServiceCnt≠0) signal(d-mutex)
                                        else {StarvationService:=False;     //End of Starvation service!
                                              signal(sWait);
                                              while (iWaitCnt≠0) {signal(iWait); iWaitCnt−−}} }
     else {iPassing:=False;                         // Normal service mode
          iWaitCnt− −;
          if (sPassingCnt=0 and sWaitCnt=0 and iWaitCnt=0 and dWaitCnt≠0) signal(d-mutex)
          else signal(i-mutex) }
     signal(mutex)}
  signal(mutex)}
```

```
process deleter (item, L)
{wait(mutex);
 dWaitCnt++;
 if StarvationService {signal(mutex; wait(dWait)}
else if (sWaitCnt=0 and sPassingCnt=0 and iWaitCnt=0 and dWaitCnt=0)
            {signal(mutex); dPassing:=True; wait(i-mutex)exit}
      else {signal(mutex); wait(d-mutex)}
 SEARCH-DELETE-AND-LOG-RESULTS (L, item);
   wait(mutex);
   if StarvationService {dStarvationServiceCnt− −;        // In Starvation service mode!
                          if dStarvationServiceCnt≠0  {signal(d-mutex); signal(mutex)}
                          else {StarvationService:=False; signal(sWait);       //End of starvation service.
                                while (dWaitCnt≠0) {signal(dWait); dWaitCnt− −} }
   else {dPassing:=False;                              // Normal service mode.
          if sWaitCnt≠0 signal(sWait);
          if iWaitCnt≠0 signal(i-mutex);
          if (sWaitCnt=0 and iWaitCnt=0 and dWaitCnt≠0) signal(d-mutex) }
   signal(mutex)
}
```

(40 pts) **2. Four-of-a-Kind Problem** is defined as follows.

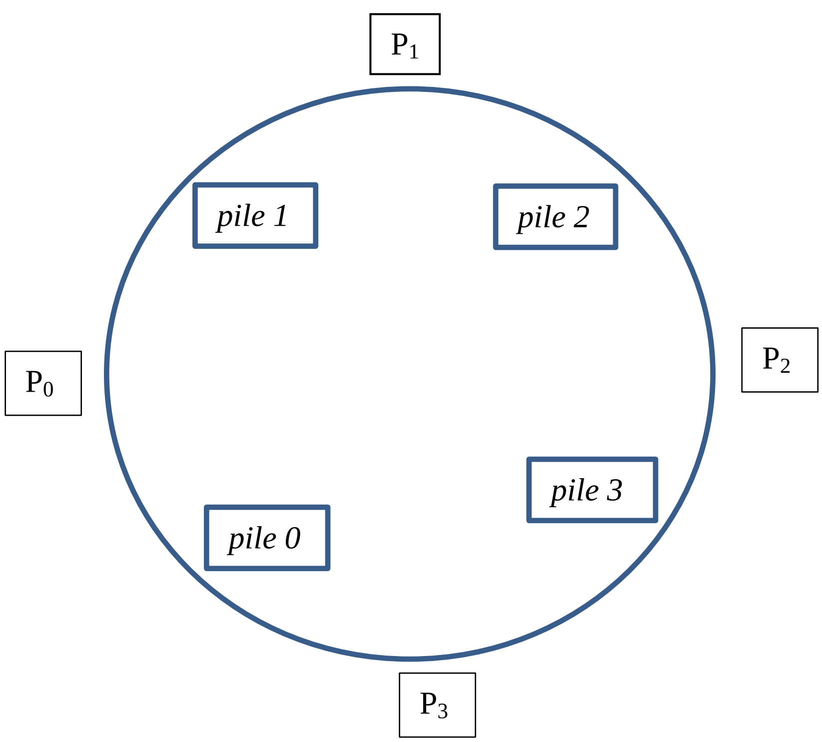
- There is a deck of 24 cards, split into 6 different kinds, 4 cards of each kind.
- There are 4 players (i.e., processes) $P_i, 0 \leq i \leq 3$; each player can hold 4 cards.
- Between each pair of adjacent (i.e., seated next to each other) players, there is a pile of cards.
- The game begins by
  - someone dealing four cards to each player, and putting two cards on the pile between each pair of adjacent players, and
  - P_0 starting the game. If P_0 has four-of-a-kind, P_0 wins. Whoever gets four-of-a-kind first wins.
- Players take turns to play clockwise. That is, P_0 plays, P_1 plays, P_2 plays, P_3 plays, P_0 plays, etc.
- Each player behaves as follows.
  - So long as no one has won, keep playing.
  - If it is my turn and no one has won:
    - Check for Four-of-a-Kind. If yes, claim victory. Otherwise discard a card into the pile on the right; pick up a card from the pile on the left; and, check again: If Four-of-a-Kind, claim victory; otherwise revise turn so that the next player plays and wait for your turn.

- There are no ties; when a player has claimed victory, all other players stop (when their turns to play come up).

You are to specify a semaphore-based algorithm to the Four-of-a-Kind problem.

Note:

- Explain your algorithm.
- Make sure to state any assumptions you make in your solution.
- Specify the initial states of your variables and semaphores.
- Specify whether your semaphores are binary or nonbinary.
- Do not bother specifying algorithms for sequential tasks: simply specify a well-defined function/procedure (i.e., one with well-defined input/output/functional specification).



Initialization:

binary semaphore *mutex:=1;*

int *turn:=0;*

boolean *GameWon:=False;*

enumerated *card: {kind1a, kind1b, kind1c, kind1d, kind2a, kind2b, kind2c, kind2d, …, kind6a, kind6b, kind6c, kind6d}*

array *hand [0..3, 0..3]* ***of*** *(**int**, card);* *//hand[i,*] denotes the hand of player i.*

array *pile [0..3, 0..1]* ***of*** *(**int**, card);* *// pile[i, *] denotes the 2-card pile to the right of player i;*

*//pile[(i+1) mod 4, *] denotes the 2-card pile to the left of player i.*

.....

InitializeHandsAndPilesRandomly (pile[,], hand[,]);

....

Soln:

PLAYER i:

```
while ¬GameWon do
{wait(mutex);
 if turn=i
        if FourOfAKind(i)  {Print ("I, player", i, "win!"); GameWon:=True}
        else {DiscardCardToRightPile (pile[(i,], hand[i, ]);
              PickUpCardFromLeftPile (pile[(i+1)mod 4,], hand[i, ])
              if FourOfAKind(i) {Print ("I, player", i, "win!"); GameWon:=True}
              else  turn:=i+1 (mod 4)}
  signal(mutex) }
```