VauLSMorg

07 SYNC - Synchronization
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1. **2016-1**

   Circle or cross: "**T**" if True – "**F**" if False.

   T / F A semaphore is a data structure.

   T / F Semaphores can not be used for avoiding dead locks

   T / F A monitor is a programming language construct

   T / F Monitors encapsulate shared data structures.

   T / F Both semaphores and monitors are distributed as function calls.

   T / F Monitors use condition variables, while semaphores do not.

2. **2016-2**

```
001 /*
002  * (c) 2015-2016 Rahmat M. Samik-Ibrahim
002  * -- This is free software
003  * Feel free to copy and/or modify and/
004  * or distribute it, provided this notice,
004  * and the copyright notice, are preserved.
005  * REV04 Tue Dec 13 15:19:04 WIB 2016
006  * START Wed Sep 30 00:00:00 UTC 2015
007  */
008
009 #include <stdio.h>
010 #include <stdlib.h>
011 #include <semaphore.h>
012 #include "99-myutils.h"
013 #define  nSem 7
014
015 sem_t sem[nSem];
016
017 void* thread1 (void* a) {
018    sem_wait   (&sem[1]);
019    printf("T1X\n");
020    sem_post   (&sem[4]);
021 }
022
023 void* thread2 (void* a) {
024    sem_wait   (&sem[2]);
025    printf("T2X\n");
026    sem_post   (&sem[5]);
027    sem_post   (&sem[1]);
028 }
030 void* thread3 (void* a) {
031    printf("T3X\n");
032    sem_post   (&sem[6]);
033    sem_post   (&sem[2]);
034 }
035
036 void* thread4 (void* a) {
037    sem_wait   (&sem[4]);
038    printf("T44\n");
039    sem_wait   (&sem[5]);
040    printf("T45\n");
041    sem_wait   (&sem[6]);
042    printf("T46\n");
043 }
044
045 void main(void) {
046    printf("MAIN\n");
047    for (int ii=1;ii<nSem;ii++)
048       sem_init(&sem[ii], 0, 0);
049    daftar_trit   (thread1);
050    daftar_trit   (thread2);
051    daftar_trit   (thread3);
052    daftar_trit   (thread4);
053    jalankan_trit ();
054    beberes_trit  ("TREXIT");
055 }
```

   Write down the program output:

3. **2017-1**

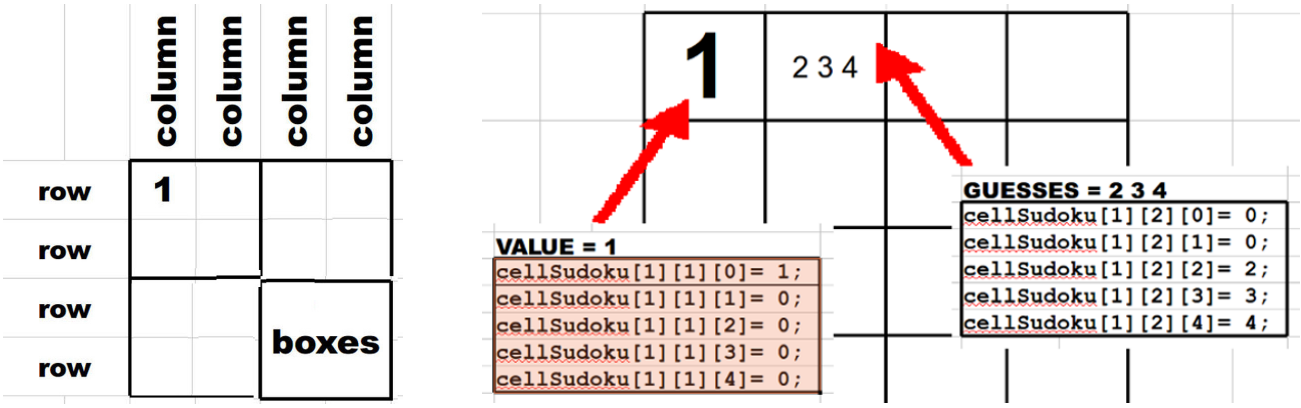
Program Code of Synchronization (using `99-myutils.h` and `99-myutils.c` from the lab assignment)

```
001 /* (c) 2011-2017 Rahmat M. Samik-Ibrahim
002  * This is free software. Feel free to copy and/or
003  * modify and/or distribute it, provided this
004  * notice, and the copyright notice, are preserved.
005  * REV01 Wed May 17 17:02:37 WIB 2017
006  * START Wed May  3 12:58:28 WIB 2017
007  *
008  * sem_init(), sem_wait(), sem_post(): semaphore
009  * sleep(X): sleep X seconds
010  * daftar_trit(T):  register thread T
011  * jalankan_trit(): start all registered threads.
012  * beberes_trit():  exit all threads above.  */
013 #define jmlKIRI     3
014 #define jmlKANAN    2
015 #define SLEEP       1
016 #include <stdio.h>
017 #include <stdlib.h>
018 #include <semaphore.h>
019 #include <unistd.h>
020 #include "99-myutils.h"
021 sem_t   mutexID, syncModKiri, syncModKanan;
022 sem_t   syncKiriMod, syncKananMod;
023 int     sequence = 0;
024
025 void cetak(char* posisi) {
026    sem_wait (&mutexID);
027    printf("%s (%d)\n", posisi, sequence++);
028    fflush(NULL);
029    sem_post (&mutexID);
030    sleep(SLEEP);
031 }
032 void* Kanan (void* a) {
033    while (TRUE) {
034       sem_wait (&syncModKanan);
035       cetak("-+-+-+Kanan");
036       sem_post (&syncKananMod);
037    }
038 }
039 void* Kiri (void* a) {
040    while (TRUE) {
041       cetak("Kiri-+-+-+-");
042       sem_post (&syncKiriMod);
043       sem_wait (&syncModKiri);
044    }
045 }
046 void* Moderator (void* a) {
047    int ii;
048    while (TRUE) {
049       for (ii=0; ii<jmlKIRI;  ii++)
050          sem_wait (&syncKiriMod);
051       for (ii=0; ii<jmlKANAN; ii++)
052          sem_post (&syncModKanan);
053       for (ii=0; ii<jmlKANAN; ii++)
054          sem_wait (&syncKananMod);
055       for (ii=0; ii<jmlKIRI;  ii++)
056          sem_post (&syncModKiri);
057    }
058 }
059 int main(int argc, char * argv[]) {
060    int ii;
061    sem_init (&syncModKiri,  0, 0);
062    sem_init (&syncModKanan, 0, 0);
063    sem_init (&syncKiriMod,  0, 0);
064    sem_init (&syncKananMod, 0, 0);
065    sem_init (&mutexID,      0, 1);
066
067    for (ii = 0 ; ii < jmlKANAN; ii++)
068       daftar_trit(Kanan);
069    for (ii = 0 ; ii < jmlKIRI; ii++)
070       daftar_trit(Kiri);
071    daftar_trit(Moderator);
072
073    jalankan_trit();
074    beberes_trit("Selese...");
075 }
```

Write down the next 5 lines of the program output:

K i r i - + - + - + - (0)

4. **2017-2**



In this mini-Sudoku 4x4 — each **column**, **row**, and 2x2 sub-grid **box** — should contain the digits of: **1, 2, 3, or 4**. This C program "`07-mini-sudoku-4x4.c`" is using a 3 dimensional array called "`cellSudoku[ ][ ][ ]`". If "`cellSudoku[row][column][0] == 0`" (or: no value), "`cellSudoku[row][column][1]`" to "`[4]`" will contain of all values that are possible (or guesses).

(a) How many Semaphores were created in that program?

(b) Specify what the names of those Semaphores are!

(c) How many threads were created in that program?

(d) Specify what the (unique) names of those threads are!

(e) How many critical zone(s) are there in that program?

(f) Specify the line numbers of those critical zone(s)!

(g) Name the function that receives the input file "`07-data.txt`" in that program above!

Program Code `07-mini-sudoku-4x4.c` **(using** `99-myutils.h` **and** `99-myutils.c` **from the DEMO set.)**

```
001 /*
002  * (c) 2017 Rahmat M. Samik-Ibrahim
003  * http://rahmatm.samik-ibrahim.vlsm.org/
004  * This is free software.
005  * REV04 Tue Dec 12 20:35:44 WIB 2017
006  * START Mon Dec  4 18:52:57 WIB 2017
007  */
008
009 #include <stdio.h>
010 #include <stdlib.h>
011 #include <unistd.h>
012 #include "99-myutils.h"
013 #define  WaitSudoku 3
014 #define  SSIZE      4
015 #define  TOTALSIZE  SSIZE * SSIZE
016
017 int    globalExit=FALSE;
018 sem_t  mutexing;
019 sem_t  syncing1;
020 sem_t  syncing2;
021
022 // cellSudoku[row][column][0]   = value
023 // cellSudoku[row][column][1-4] = guesses
024 // if (value != 0) all guesses  = 0
025 //                       (no more guesses)
026 int cellSudoku[][SSIZE+1][SSIZE+1]={
027    {},{{}, {0,1,2,3,4}, {0,1,2,3,4},
028             {0,1,2,3,4}, {0,1,2,3,4}},
029       {{}, {0,1,2,3,4}, {0,1,2,3,4},
030             {0,1,2,3,4}, {0,1,2,3,4}},
031       {{}, {0,1,2,3,4}, {0,1,2,3,4},
032             {0,1,2,3,4}, {0,1,2,3,4}},
033       {{}, {0,1,2,3,4}, {0,1,2,3,4},
034             {0,1,2,3,4}, {0,1,2,3,4}}
035 };
036
037 // Print Cells
038 void printCells(char* state) {
039    printf ("\nSudoku Cells: %s\n", state);
040    for (   int jj=1; jj<SSIZE+1; jj++) {
041       for (int kk=1; kk<SSIZE+1; kk++) {
042          int cell=cellSudoku[jj][kk][0];
043          if (cell == 0 || cell == 5)
044                          printf ("[ ]");
045          else     printf ("[%d]", cell);
046          if (kk == SSIZE) printf ("\n");
047       }
048    }
049    fflush(NULL);
050 }
052 // Filling the CELLs
053 void
054 fillCell(int rowCell,int colCell,int valCell)
055 {
056    sem_wait (&mutexing);
057    // Filling  "valCell" into
058    // cellSudoku[rowCell, colCell];
059    cellSudoku[rowCell][colCell][0] = valCell;
060    // This is Cell is "taken".
061    // Eliminate all guesses!
062    for (int ii=1; ii<SSIZE+1; ii++) {
063       cellSudoku[rowCell][colCell][ii] = 0;
064    }
065    // Deleting "valCell"
066    // from all "columns guess"
067    for (int ii=1; ii<SSIZE+1; ii++) {
068       cellSudoku[rowCell][ii][valCell] = 0;
069    }
070    // Delete "valCell" from all "rows guess".
071    for (int ii=1; ii<SSIZE+1; ii++) {
072       cellSudoku[ii][colCell][valCell] = 0;
073    }
074    // Delete "valCell" from all "boxes guess".
075    rowCell = 1 + 2*((rowCell - 1)/2);
076    colCell = 1 + 2*((colCell - 1)/2);
077    for (int ii=rowCell; ii<rowCell+2; ii++) {
078       for (int jj=colCell;jj<colCell+2;jj++){
079          cellSudoku[ii][jj][valCell] = 0;
080       }
081    }
082    sem_post (&mutexing);
083 }
084
085 // From Standard Input into Cell using
086 // fillCell  -- SCAN INPUT: scanf()
087 // is the oposite of printf()
088 void inputCell(void) {
089    for (int ii=0; ii < TOTALSIZE; ii++) {
090       int tmpCell=0;
091       scanf("%d", &tmpCell);
092       int rowCell = ii/4 + 1;
093       int colCell = ii%4 + 1;
094       if (tmpCell != 0) {
095             fillCell(rowCell,colCell,tmpCell);
096       }
097    }
098 }
```

Program Code `07-mini-sudoku-4x4.c` **(using** `99-myutils.h` **and** `99-myutils.c` **from the DEMO set.)**

```
100 // CellWatcher
101 int cwID = 0;
102 void* cellWatcher (void* a) {
103   sem_wait (&syncing1);
104   sem_wait (&mutexing);
105   int rowCell = cwID/4 + 1;
106   int colCell = cwID%4 + 1;
107   cwID++;
108   sem_post (&mutexing);
109   int localExit=FALSE;
110   while (!localExit && !globalExit) {
111     int tmpCell=0, nZero=0;
112     for (int ii=1; ii<SSIZE+1; ii++) {
113       if(cellSudoku[rowCell][colCell][ii]==0)
114         nZero++;
115       else
116         tmpCell=ii;
117     }
118     if (nZero==3)
119       fillCell(rowCell, colCell, tmpCell);
120     localExit =
121       cellSudoku[rowCell][colCell][0]!=0;
122   }
123   fflush(NULL);
124   sem_post (&syncing2);
125 }
126
127 // Timeout after "WaitSudoku"
128 void* managerSudoku (void* a) {
129   sleep(WaitSudoku);
130   for (int ii=0; ii<TOTALSIZE; ii++) {
131     int rowCell = ii/4 + 1;
132     int colCell = ii%4 + 1;
133     if(cellSudoku[rowCell][colCell][0]==0){
134        cellSudoku[rowCell][colCell][0]= 5;
135     }
136     sem_post (&syncing2);
137   }
138   globalExit = TRUE;
139 }
```

```
141 // Display Sudoku
142 void* displaySudoku (void* a) {
143    printCells("INITIAL");
144    for(int jj=0;jj<TOTALSIZE;jj++)
145       sem_post(&syncing1);
146    for(int jj=0;jj<TOTALSIZE;jj++)
147       sem_wait(&syncing2);
148    printCells("RESULT");
149 }
150
151 // This is MAIN
152 void main(void) {
153    printf   ("MAIN: START\n");
154    sem_init (&mutexing, 0, 1);
155    sem_init (&syncing1, 0, 0);
156    sem_init (&syncing2, 0, 0);
157    inputCell();
158    for (int ii=0; ii<TOTALSIZE; ii++) {
159       daftar_trit(cellWatcher);
160    }
161    daftar_trit   (displaySudoku);
162    daftar_trit   (managerSudoku);
163    jalankan_trit ();
164    beberes_trit  ("\nTRIT: EXIT");
165 }
```

This following is the output of executing:
`./07-mini-sudoku-4x4 < 07-data.txt`

```
MAIN: START

Sudoku Cells: INITIAL
[ ][ ][ ][3]
[ ][1][4][ ]
[ ][2][3][ ]
[1][ ][ ][ ]

Sudoku Cells: RESULT
[2][4][1][3]
[3][1][4][2]
[4][2][3][1]
[1][3][2][4]

TRIT: EXIT
```

Bonus Question:
What is inside file `07-data.txt` ?

5. **2018-1**

```
01  /*
02  Copyright 2018 Rahmat M. Samik-Ibrahim
03  You are free to SHARE (copy and
04  redistribute the material in any medium
05  or format) and to ADAPT (remix,
06  transform, and build upon the material
07  for any purpose, even commercially).
08  This program is distributed in the hope
09  that it will be useful, but WITHOUT ANY
10  WARRANTY; without even the implied
11  warranty of MERCHANTABILITY or FITNESS
12  FOR A PARTICULAR PURPOSE.
13
14  * REV02 Wed May  2 11:30:19 WIB 2018
15  * START Wed Apr 18 19:50:01 WIB 2018
16  */
17
18 // DO NOT USE THE SAME SEMAPHORE NAME!!!!
19 // Replace "demo" with your own SSO name.
20 #define SEM_COUNT1      "/count-1-demo"
21 #define SEM_COUNT2      "/count-2-demo"
22 #define SEM_MUTEX       "/mutex-demo"
23 #define SEM_SYNC        "/sync-demo"
24
25 #include <fcntl.h>
26 #include <stdio.h>
27 #include <stdlib.h>
28 #include <unistd.h>
29 #include <semaphore.h>
30 #include <sys/mman.h>
31 #include <sys/types.h>
32 #include <sys/wait.h>
33
34 // Shared Memory: R/W with no name.
35 #define PROT    (PROT_READ    |PROT_WRITE)
36 #define VISIBLE (MAP_ANONYMOUS|MAP_SHARED)
37
38 #define LOOP    2
39 #define BUFSIZE 1
40
41 sem_t*  ctr_prod;
42 sem_t*  ctr_cons;
43 sem_t*  mutex;
44 sem_t*  ssync;
45 int*    product;
46
47 // WARNING: NO ERROR CHECK! ////////////
48 void flushprintf(char* str, int ii) {
49    printf("%s [%d]\n", str, ii);
50    fflush(NULL);
51 }
```

```
053 void init(void) {
054    product  = mmap(NULL, sizeof(int),
055                    PROT, VISIBLE, 0, 0);
056    *product = 0;
057    ctr_prod = sem_open(SEM_COUNT1,
058               O_CREAT, 0600, BUFSIZE);
059    ctr_cons = sem_open(SEM_COUNT2,
060               O_CREAT, 0600, 0);
061    mutex    = sem_open(SEM_MUTEX,
062               O_CREAT, 0600, 1);
063    ssync    = sem_open(SEM_SYNC,
064               O_CREAT, 0600, 0);
065 }
066
067 void producer (void) {
068    sem_wait(ssync);
069    flushprintf("PRODUCER  PID",getpid());
070    for (int loop=0; loop<LOOP; loop++) {
071       sem_wait(ctr_prod);
072       sem_wait(mutex);
073       flushprintf("PRODUCT  ",
                              ++(*product));
074       sem_post(mutex);
075       sem_post(ctr_cons);
076    }
077    wait(NULL);
078 }
080 void consumer (void) {
081    flushprintf("CONSUMER  PID",getpid());
082    sem_post(ssync);
083    for (int loop=0; loop<LOOP; loop++) {
084       sem_wait(ctr_cons);
085       sem_wait(mutex);
086       flushprintf("CONSUME  ", *product);
087       sem_post(mutex);
088       sem_post(ctr_prod);
089    }
090 }
092 // WARNING: NO ERROR CHECK! ////////////
093 void main(void) {
094    flushprintf("STARTING  PID",getpid());
095    init();
096    if   (fork()) producer();  //  Parent
097    else          consumer();  //  Child
098    sem_unlink(SEM_COUNT1);
099    sem_unlink(SEM_COUNT2);
100    sem_unlink(SEM_SYNC);
101    sem_unlink(SEM_MUTEX);
102    flushprintf("STOP HERE PID", getpid());
103 }
```

6. **2018-1 (continued)...**

   (a) Assume the Parent PID is 1000 and the Child PID is 1001. What is the output of the program above?

   (b) Name all four (4) semaphore!

   (c) What is the purpose of line 68?

   (d) What is the purpose of line 71?

   (e) What is the purpose of line 77?

   (f) What is the purpose of line 84?

   (g) How many Critical Section(s) is/are there in the program above? Where/which lines are the Critical Section(s)?

   (h) Explain briefly the purpose of function `fflush(NULL)` in line 50!

   (i) What is the purpose of lines 98 - 101?

7. **2018-2** (See `https://rms46.vlsm.org/2/201.pdf` 2018-2)

   (a) Name all three (3) semaphores!

   (b) What is the purpose of lines 65 & 66?

   (c) What is the purpose of lines 74 & 75?

   (d) What is the purpose of lines 88, 89, 113 & 114?

   (e) What is the purpose of line 90 in regard of lines 91 & 115

   (f) Is there any Critical Section(s) in the program (Yes/No)? If "Yes", which line(s)?

8. **2019-1** (See `https://rms46.vlsm.org/2/201.pdf` 2019-1)

   (a) What is the purpose of semaphores "turns[ ]" (See lines 79-80, 94, 95)?

   (b) What is the purpose of semaphore "mutex" (See lines 82, 100, 106)?

   (c) Explain why the final "**rTime**" value of each rider will always be unique (See lines 101-104)!

   (d) Explain why the program output will always be printed in a proper "**rTime**" order (See lines 101-104)!

9. **2019-2** (See `https://rms46.vlsm.org/2/201.pdf` 2019-2)

   Modify lines 66 to 74, so that the child of `fork() (line 66)`, will be executed first at line 75.
