Exercise sheet 10 – Deadlock analysis

Goals:

- Deadlocks

Exercise 10.1: Deadlocks 1

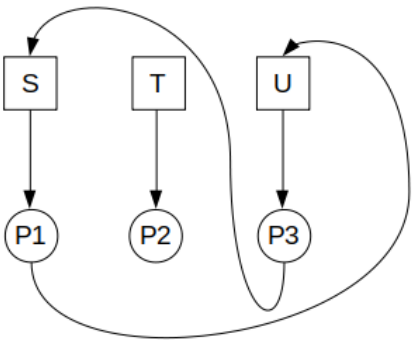
The three processes `P1`, `P2`, and `P3` are executing the following code:

P1	P2	P3
P(S)	P(T)	P(U)
P(U) <=	. <=	P(S) <=
work_with_s_and_u();	work_with_t();	work_with_s_and_u();
V(S)	V(T)	V(U)
V(U)		V(S)

All semaphores start with the value 1; the arrow shows the code which is executed at the moment.

(a) Draw a system resource acquisition graph for this situation!

Proposal for solution:



(b) Show that a deadlock exists.

Proposal for solution: There is a cycle in the system resource acquisition graph! => Deadlock!

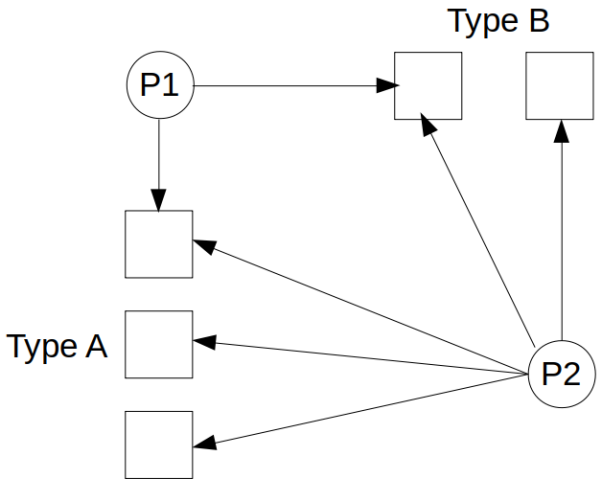
(c) Show two possibilities to avoid the deadlock!

Proposal for solution:

- Try to avoid the circular wait: Switch `P(U)` and `P(S)` in `P1` or `P3`. Please consider also the `V(S)` and `V(U)` operations. Release the semaphores from the inside to the outside. Preferred solution here.
- Try to avoid the non-preemption: If `P1` or `P3` can't acquire `P(U)` or `P(S)` it releases all resources and tries it after some time again. But this can mean that work already done is lost and must be repeated.

Exercise 10.2: Deadlocks 2

Look at this system resource acquisition graph:



(a) Is there a deadlock?

Proposal for solution: No, because there is no cycle in the graph.

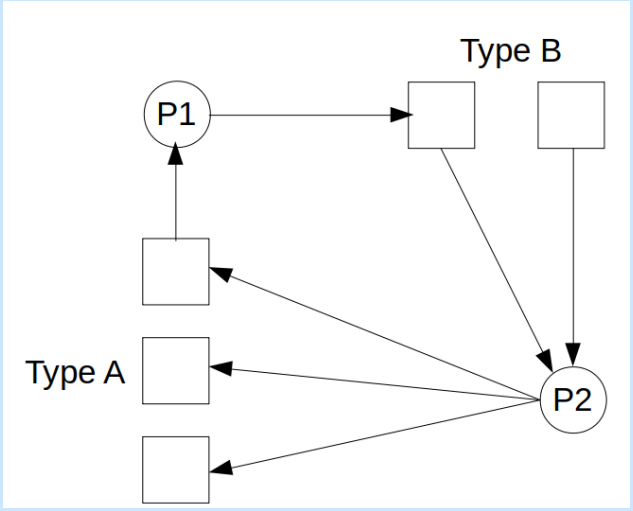
(b) Is the state safe?

Proposal for solution:

- Step 1: Give `P1` the requested resources (1x`A`, 1x`B`).
- Step 2: After `P1` has finished and its resources released, give all resources to `P2`.
- => safe sequence found
- => because there is no deadlock and we have a safe sequence => the state is safe!

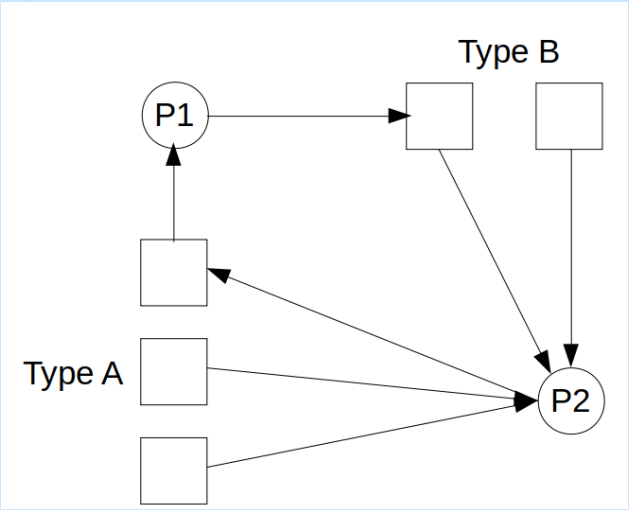
(c) Find a sequence of operations which would cause a deadlock!

Proposal for solution: When `P1` gets one type A resource and `P2` gets the two type B resources, there is a deadlock.



(d) Is it allowed to fulfil the request of `P2` for the two resources of type B?

Proposal for solution: If `P2` also gets the three resources of type A, then it can do its job and will end at some time. So the state would be safe. But if `P1` would get a resource of type A, then a deadlock would be created.



Exercise 10.3: Deadlocks behaviour

(a) What happens on a deadlock on a desktop system?

Proposal for solution:

- A freeze of one or more applications can happen
- If a deadlock in the kernel happens, a reboot may be required
- Criticality: low/mid; usually, ‚only the work of hours' may be lost

(b) What happens on a deadlock on a server system?

Proposal for solution:

- A freeze of one or more server applications can happen
- If a deadlock in the kernel happens, a reboot may be required
- Criticality: mid; important business services (e.g. webshop) are not reachable and money could be lost

(c) What happens on a deadlock on a smartphone?

Proposal for solution:

- A freeze of one or more apps can happen
- If a deadlock in the kernel happens, a reboot may be required
- Criticality: low; calling/chatting/...is not possible

(d) What happens on a deadlock on a safety critical realtime system (e.g. in a car)?

Proposal for solution:

- A freeze of one or more devices can happen
- Criticality: high; Human life is in danger

Exercise 10.4: Deadlocks analysis on existing C code

(a) Update the `OS_exercises` repository with `git pull`.

Proposal for solution: `git pull`

(b) Change into the `OS_exercises/sheet_10_deadlocks/deadlock_code_analysis` directory.

Proposal for solution:

```
cd sheet_10_deadlocks/deadlock_code_analysis
```

(c) Inspect the `deadlock_analysis.c`.

(d) Build and run the program.

Proposal for solution:

```
make
./deadlock_analysis
```

(e) Does the program work correctly? Is there an error?

Proposal for solution: The program starts, but it seems to block. There might be a deadlock.

(f) Try to analyse the behaviour.

Proposal for solution: The problem is the order of the P/V operations on the semaphores: They are not in the same order.

(g) Fix the bug.

Proposal for solution:

```c
#include <stdio.h>     //printf, perror
#include <stdlib.h>    //EXIT_FAILURE, EXIT_SUCCESS
#include <string.h>    //sprintf
#include <unistd.h>    //open, close, read, write
#include <pthread.h>   //pthread_*
#include <fcntl.h>     //flags: O_CREAT, O_EXCL
#include <semaphore.h> //sem_open, sem_wait, sem_post, sem_close, sem_unlink
#include <errno.h>     //errno

#define SEMAPHORE1_NAME "/sem1"          //name of semaphore
#define SEMAPHORE2_NAME "/sem2"          //name of semaphore
sem_t*   semaphore1 = NULL;              //pointer to semaphore
sem_t*   semaphore2 = NULL;              //pointer to semaphore
const int     PERM  = 0600;              //permission to the semaphore (read + write)

void create_semaphore() {
    semaphore1 = sem_open(SEMAPHORE1_NAME, O_CREAT, PERM, 1);
    if(semaphore1 == SEM_FAILED) {
        perror("Error when creating the semaphore ...\n");
        exit(EXIT_FAILURE);
    }
    semaphore2 = sem_open(SEMAPHORE2_NAME, O_CREAT, PERM, 1);
    if(semaphore2 == SEM_FAILED) {
        perror("Error when creating the semaphore ...\n");
```

```
25          exit(EXIT_FAILURE);
26      }
27  }
28
29  void close_semaphore() {
30      if(sem_close(semaphore1) == -1) {
31          perror("Error can't close semaphore ...\n");
32          exit(EXIT_FAILURE);
33      }
34      if(sem_close(semaphore2) == -1) {
35          perror("Error can't close semaphore ...\n");
36          exit(EXIT_FAILURE);
37      }
38  }
39
40  void delete_semaphore() {
41      if(sem_unlink(SEMAPHORE1_NAME) == -1) {
42          switch(errno)
43          {
44          case EACCES:        //fall through
45          case ENAMETOOLONG:
46              perror("Error can't delete (unlink) semaphore ...\n");
47              exit(EXIT_FAILURE);
48              break;
49          case ENOENT: //semaphore already deleted, no error should be printed!
50              break;
51          }
52      }
53      if(sem_unlink(SEMAPHORE2_NAME) == -1) {
54          switch(errno)
55          {
56          case EACCES:        //fall through
57          case ENAMETOOLONG:
58              perror("Error can't delete (unlink) semaphore ...\n");
59              exit(EXIT_FAILURE);
60              break;
61          case ENOENT: //semaphore already deleted, no error should be printed!
62              break;
63          }
64      }
65  }
66
67  void* worker1() {
68      printf("w1 started\n");
69
70      for(int i = 0; i < 5; ++i){
71          sem_wait(semaphore1); usleep(10);
72          sem_wait(semaphore2);
73              printf("w1 in critical area: working...\n");
74              sleep(1);
75          sem_post(semaphore2);
76          sem_post(semaphore1);
77          sleep(1);
78      }
79
80      printf("w1 ends\n");
81      return NULL;
82  }
83
```

```
84  void* worker2() {
85      printf("w2 started\n");
86
87      for(int i = 0; i < 5; ++i){
88          sem_wait(semaphore1); usleep(10);
89          sem_wait(semaphore2);
90              printf("w2 in critical area: working...\n");
91              sleep(1);
92          sem_post(semaphore2);
93          sem_post(semaphore1);
94          sleep(1);
95      }
96
97      printf("w2 ends\n");
98      return NULL;
99  }
100
101 int main(int argc, char** argv){
102     //create semaphores
103     delete_semaphore();
104     create_semaphore();
105
106     //start worker thread
107     pthread_t thread_w1;
108     pthread_t thread_w2;
109
110     int thread_create_state = -1;
111     thread_create_state = pthread_create(&thread_w1, NULL, &worker1, NULL);
112     if(thread_create_state != 0) {
113         printf("Failed creating thread\n");
114         exit(EXIT_FAILURE);
115     }
116     thread_create_state = pthread_create(&thread_w2, NULL, &worker2, NULL);
117     if(thread_create_state != 0) {
118         printf("Failed creating thread\n");
119         exit(EXIT_FAILURE);
120     }
121
122
123     //Wait for the termination of all threads
124     pthread_join(thread_w1, NULL);
125     pthread_join(thread_w2, NULL);
126
127     //close & delete semaphores
128     close_semaphore();
129     delete_semaphore();
130
131     return EXIT_SUCCESS;
132 }
```

(h) Build and run the program.

Proposal for solution:

```
1  make
2  ./deadlock_analysis
```

Now it should work as expected.