CMPSCI 377: Operating Systems

Homework 3 Solutions: Deadlocks and Memory Management

1. (10 pts) **Deadlock.** Short answer questions:

   (a) A system has six tape drives (a, b, c, d, e, f), with n threads competing for them. Each thread may need two of the drives. For what values of n is the system deadlock free?

   Solution: One thread. For two threads for example, we can get deadlock with the following:

   Example

```
Thread 1:
   a.Wait();
   b.Wait();
   ...
```

```
Thread 2:
   b.Wait();
   a.Wait();
```

   (b) Can a system be in a state that is neither deadlocked nor safe? If yes, give an example system.

   Solution: Yes. For example, given 3 units of resource A, if thread 1 has 2 units of A and its maximum is 3, and thread 2 has 1 and its maximum is 2. This state is not a safe, but if neither thread ever requests an additional unit of A, then it is not deadlocked.

2. (20 pts) **Deadlock** Problem 8.9 from the textbook.

   Using the terminology defined in class (also defined in Sec 7.6.2), we have

   (a) $\sum_{i=1}^{n} Max_i < m + n$

   (b) $Max_i \geq 1$ for all i
   Also, $Need_i = Max_i - Alloc_i$. Assume there exists a deadlock. Then:

   (c) $\sum_{i=1}^{n} Alloc_i = m$

   Using (a) we get: $\sum Need_i + \sum Alloc_i = \sum Max_i < m + n$
   Using (c) we get: $\sum Need_i + m < m + n$
   That is, $\sum_{i=1}^{n} Need_i < n$

   This imples that there exists a process P_i such that $Need_i = 0$. Since $Max_i \geq 1$, it follows that P_i has at least one resource it can release. Hence, the system cannot be in a deadlock state.

3. (10 pts) **Deadlock.** Consider the following system snapshot using the data structures in the Banker's algorithm, with resources A, B, C, and D, and processes P_0 to P_4.

	Allocation				Max				Available				Need			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
									3	2	1	0				
P_0	3	0	0	2	6	0	1	2					3	0	1	0
P_1	1	0	0	0	1	7	5	0					0	7	5	0
P_2	1	3	5	4	2	3	5	6					1	0	0	2
P_3	0	6	3	2	1	6	5	2					1	0	2	0
P_4	0	0	1	4	1	6	5	6					1	6	4	2

Using Banker's algorithm answer the following questions.

(a) How many resources of type A, B, C, and D are there?

Solution: (allocation + available) $\{5,9,9,12\}$ + $\{3,2,1,0\}$ = $\{8.11,10,12\}$

(b) What is the content of the *Need* matrix?

Solution: See above table.

(c) Is the system in a safe state? Why?

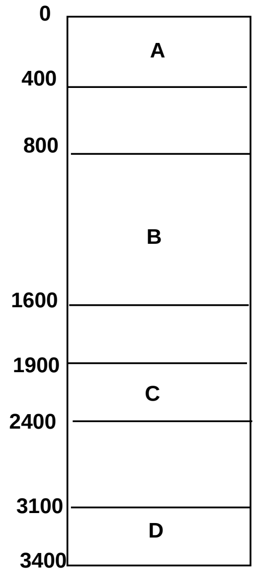
Solution: Yes, P_0 can finish with its current resources and what's in available. When it finishes, avail becomes $\{6,2,1,2\}$. Now, P_2 can complete and then avail would be: $\{7,5,6,6\}$. Now, P_3 can complete and then avail would be: $\{7,11,9,8\}$. Then either P_1 or P_4 can complete, followed by the other.

(d) If a request from process P_4 arrives for additional resources of (1,2,0,0), can the Banker's algorithm grant the request immediately? Show the new system state, and other criteria.

Solution: No the request cannot be granted because all of none of the process are able to request their max number of resources, i.e., for all processes $i = 0, 4$, need(i) $>$ avail(i).

	Allocation				Max				Available				Need			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
									2	0	1	0				
P_0	3	0	0	2	6	0	1	2					3	0	1	0
P_1	1	0	0	0	1	7	5	0					0	7	5	0
P_2	1	3	5	4	2	3	5	6					1	0	0	2
P_3	0	6	3	2	1	6	5	2					1	0	2	0
P_4	0	0	1	4	1	6	5	6					0	4	4	2

4. (10 pts) Consider a segmented memory system with memory allocated as shown below.



Suppose the following actions occur:

- Process E starts and requests 300 memory units.
- Process A requests 400 more memory units.
- Process B exits.
- Process F starts and requests 800 memory units.
- Process C exits.
- Process G starts and requests 900 memory units.

(a) Describe the contents of memory after each action using the first-fit algorithm.

- E requests 300: E is allocated in 400-700
- A requests 400 more: cannot fit because the entire process is allocated in a single continuous chunk of memory in a segmented memory system. Need to compact memory: move B to 1100-1900, move E to 2400-2800, give A additional addresses 400-800
- B exits: there is a hole between 800-1900
- F requests 800: F is allocated in 800-1600
- C exits: there is a hole between 1600-2400
- G requests 900: no hole that is big enough. Compact memory: move E to 2800-3100, G is allocated in 1600-2500

(b) Describe the contents of memory after each action using the best-fit algorithm.

- E requests 300: E is allocated in 1600-1900
- A requests 400 more: this 400 is allocated in 400-800
- B exits: there is a hole between 800-1600
- F requests 800: F is allocated in 800-1600
- C exits: there is a hole between 1900-3100
- G requests 900: G is allocated in 1900-2800

(c) How would worst fit allocate memory?

- E requests 300: E is allocated in 2400-2700
- A requests 400 more: this additional 400 is allocated in 400-800
- B exits: there is a hole between 800-1900
- F requests 800: F is allocated in 800-16000
- C exits: there is a hole between 1600-2400
- G requests 900: no hole big enough. Need to compact: move E to 2800-3100, give 1600-2500 to G

(d) For this example, which algorithm is best?

For this example, best-fit is best.