NTNU | Norwegian University of Science and Technology

Operating Systems

Example solutions for Theoretical Exercise 3

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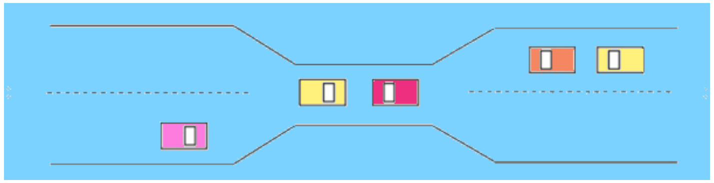
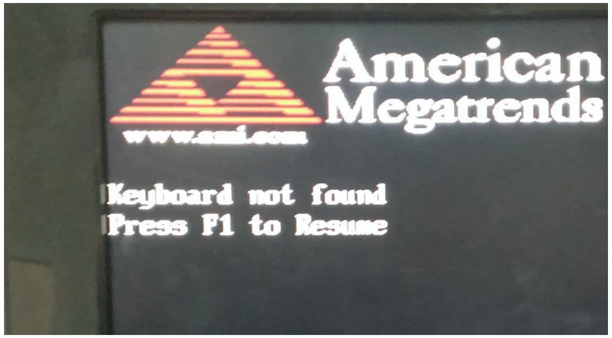
3.1 Deadlocks in real life

We have seen the crossroads example to demonstrate the problem in the lecture. List three other examples of deadlocks that are not related to a computer system environment.

- Another traffic example: a one-lane bridge in which a car from both directions has entered. It can be resolved if one car backs up



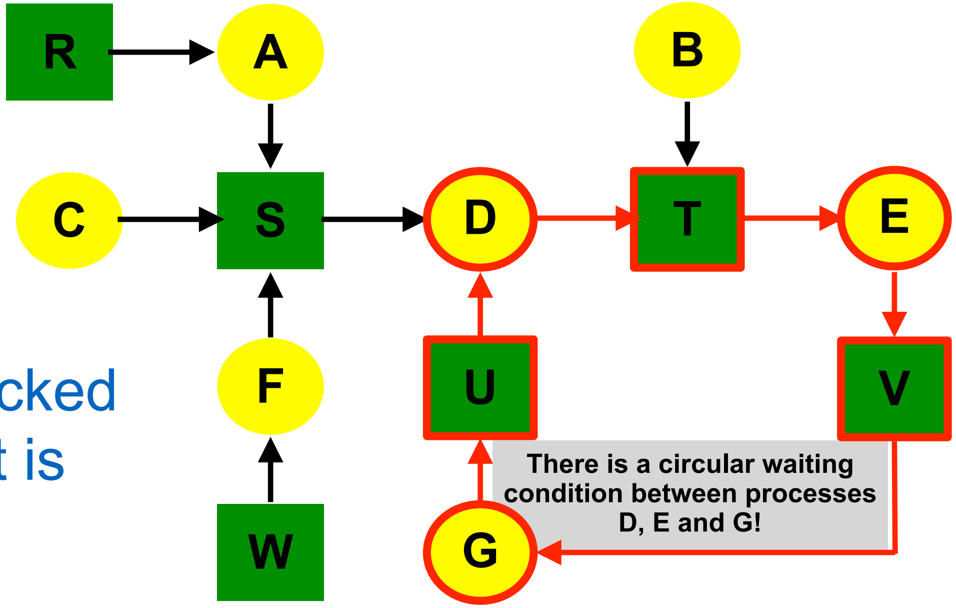


- A fun effect on some older PCs
- Problems of an introvert:
  "I don't really like to talk to someone before I get comfortable with them.
  I don't get comfortable with someone before I've been talking with them for a while."

3.2 Resource allocation graphs

Suppose that there is a resource deadlock in a system. Give an example to show that the set of processes deadlocked can include processes that are not in the circular chain in the corresponding resource allocation graph.

- This is shown in the example from lecture 7
  - Here we have a chain of processes D, E, G forming a chain in the resource graph
  - However, process **B** is also waiting for one of the deadlocked resources (T), even though it is not in a circular dependency



3.3 Deadlock conditions

Two processes, A and B, each need three records, 1, 2, and 3, in a database.
If both A and B request the records in the order 1, 2, 3, deadlock is not possible. However, if B asks for the records in the order 3, 2, 1, then a deadlock can occur.
With three resources, there are 3! = 6 possible combinations each process can request resources.
What fraction of all combinations is guaranteed to be deadlock free?

- Suppose that process A requests the records in the order 1, 2, 3. If process B also asks for 1 first, one of them will get it and the other will block.
- This situation is always deadlock free since the winner can now run to completion without interference.

3.3 Deadlock conditions

…What fraction of all combinations is guaranteed to be deadlock free?

- The other four combinations can be similarly reasoned about and shown to lead to possible deadlock:

  (1) 1 2 3: deadlock free
  (2) 1 3 2: deadlock free
  (3) 2 1 3: possible deadlock
  (4) 2 3 1: possible deadlock
  (5) 3 1 2: possible deadlock
  (6) 3 2 1: possible deadlock

  - So only one third of the cases are guaranteed to be deadlock free

3.4 Banker's algorithm

Consider a system that uses the banker's algorithm to avoid deadlocks. At some time a process P requests a resource R, but is denied even though R is currently available. Does it mean that if the system allocated R to P, the system would deadlock?

- No.
- An available resource is denied to a requesting process in a system using the banker's algorithm if there is a possibility that the system may deadlock by granting that request.
- It is certainly possible that the system may not have deadlocked if that request was granted.

3.5 C preprocessor

You want to define a C preprocessor macro to calculate the square of a given number x as follows:

```
#define SQUARE(x) (x * x)
```

Explain what is problematic with this macro definition and give an example of the problematic behavior.

- The C preprocessor performs only ***syntactic text expansion*** of macros, it does not know/understand C syntax or semantics!
- The parameter x is thus replaced by whatever is given as parameter to the macro invocation, e.g.
  `SQUARE(1+2)`
  (which you would expect to be 3*3 = 9) is expanded to
  `(1+2 * 1+2) = 1+2+2 = 5` (due to arithmetic precedence rules in C)
- There are many more ***macro pitfalls***, see e.g. https://gcc.gnu.org/onlinedocs/gcc-3.4.6/cpp/Macro-Pitfalls.html for details

3.6 ELF Segments

You are trying to analyze a binary program using the command `readelf -S prog` and obtain the following output (shortened):

```
Section Headers:
  [Nr] Name       Type       Address            Offset
       Size                  EntSize            Flags     Link  Info  Align
  [25] .data      PROGBITS   0000000000004000   00003000
       0000000000000010      0000000000000000   WA        0     0     8
```

Assume that you know that there are only global `int` variables and each variable uses four bytes. Can you tell how many global int variables are declared in the program?

- The size of the segment is `0000000000000010` (hex) = 16 bytes
- Thus, it can hold a maximum of 16/4 = 4 `int` variables
- However, the ***alignment requirement*** is a multiple of 8
  - Thus, 3 `ints` would also take 16 bytes (12 + 4 bytes alignment)
- So we cannot say if there are 3 or 4 `int` variables declared
  - …without further investigation (e.g., using `nm`)

3.7 ELF Symbols

Consider the following (very simple and useless) C program:

```
int foo;
int bar;
int main(int argc, char **argv) {
  int a, b;
}
```

Which ELF segment will the variables `foo` and `bar` be located in?

- Both are global uninitialized (in the source code) variables, which are automatically initialized to 0 by the C runtime. They are thus ***not*** stored in the data segment, but in the bss segment
- This saves space in the executable, since variables with initial value 0 do not need to be saved in the executable
- A global variable `int baz=42;` would be stored in data, since its value has to be set when the program starts

3.7 ELF Symbols

Consider the following (very simple and useless) C program:

```
int foo;
int bar;
int main(int argc, char **argv) {
  int a, b;
}
```

When running the `nm` command on the binary compiled from the program, variables `a` and `b` are not shown in the command's output. Explain why.

- `a` and `b` are local variables of the function `main`. Local variables cannot have a fixed address in memory (like global variables in data and bss), since we need a *separate copy* of the variable in case of a recursive call to the function the variables are declared in
- Thus, these variables are stored on the *stack*, which grows (and shrinks) when entering (leaving) a function
- Yes, you can also call `main` recursively…