Advanced Flow Control

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Previously, we have talked about

- Conditional Statements
  - `if-else`
  - `if-else if` ladder
- Loops
  - `for` loop
  - `while` loop

Issues in Previous Lab

- Forgetting semicolon `;`
  - In C, all statements ends with `;`
  - `printf("hello world!);` , `verse1();` , `double pi = 3.14;` , `return 0;`
- Conditional statements do not have to end with `;`

```c
if(a == 1){
    printf("a equals to 1\n");
} // NO semicolon
```

- Loops do not have to end with `;`

```c
while(a <= 1){
    printf("looping...\n"); a = a + 1;
} // NO semicolon
```

Issues in Previous Lab

- Semicolon **signals the end of the previous statement** and prepares CPU for the next statement to be executed.
- In some other programming languages (such as python), the end of a statement is signaled by a line break.
  - ```
    # This is python code
    print("test1") # end of a statement
    print("test2")
    ```
- By using `;`, you can write multiple statements in one line:
  - `printf("looping...\n"); a = a + 1;`
  - This is not allowed in python.
    ```

Issues in Previous Lab

- In `if-else if` ladder, the order matters!

```
if (condition1){
    statment1;
} else if(condition2){
    statment2;
} else if(condition3){
    statment3;
}
...
else{ //optional
    statement0;
}
```

- The program will check conditions **sequentially**.
- Once a true condition is found
    - It executes the associated statements.
    - then **bypasses the rest of the ladder**.

Issues in Previous Lab

- Write an `if-else if` ladder, so it prints
  - `divided by 15`, if `a` can be divided by 15.
  - `divided by 5` if the number can **only be** divided by 5 but not by 15.
  - ```
    if(a % 15 == 0){ //this must be first!
        printf("divided by 15\n");
    }else if(a % 5 == 0){
        printf("divided by 5, but not 15!\n");
    }
    ```
    ```

Today's Lecture

- Nested if-else
- Nested loop
- Advanced loop control
- Recursion

Nested If-Else

- You can write conditional statement inside another conditional statement.

```
if(score >= 40){
    printf("congratulations! ");
    if(score >=70){
        printf("first class!\n");
    }else{
        printf("passed!\n");
    }
}else{
    printf("student has failed!\n");
}
```

- The code prints out
  - `student has failed!` if `score < 40`.
  - `congratulations! passed!` if `40 <=score < 70`.
  - `congratulations! first class!` if `score >= 70`.

Nested If-Else

- In some cases, nested `if-else` can be translated into a single `if-else if` ladder.

```
if(score >= 70){
    printf("congratulations!");
    printf("first class!\n");
else if (score >= 40){
    printf("congratulations!");
    printf("passed!\n");
}else{
    printf("student has failed!\n");
}
```

- Which one to use depends on which one leads to a cleaner code.
    - Notice, in the first example, `score < 40` and `40 <=score < 70` shares the first `printf`.

Nested Loops

- Similarly, you can write one loop inside another loop.

```
for (int i = 1; i <= 4; i=i+1){
    // print i-th line
    for (int j = 1; j <= 4; j=j+1){
        printf("*");
    }
    printf("\n"); // change line
}
```

- It prints out a block of `*`

```
****
****
****
****
```

Nested Loops

- Last year's exam question (simplified): Write a C program which prints out

```
*
**
***
****
```

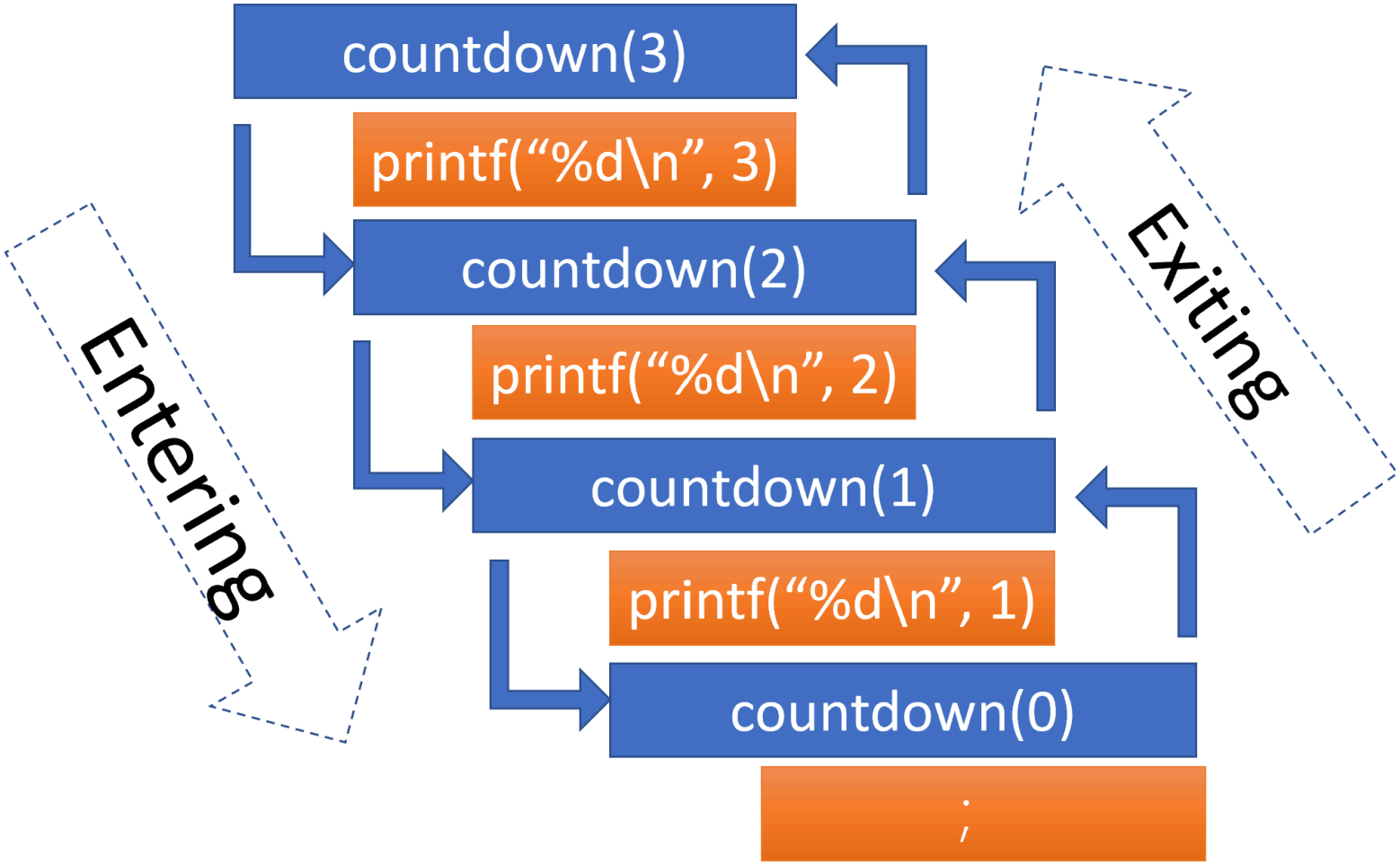
  - Try it yourself!

Early Loop Exit

- `break;` statement will exit the loop immediately.
- Find the smallest integer `a` from 1 to 100 that satisfies the inequality `a*a + a > 321`.
- ```
  int a = 1;
  while(a <= 100){
      if(a*a + a > 321){
          printf("%d\n", a);
          break; // exit the while loop immediately.
      }
      a = a + 1;
  }
  ```
- No need to continue the search after you have found one as the question asks for the smallest.
  ```

Early Loop Restart

- `continue;` statement will restart the loop immediately.
- Once the program encounters a `continue;` statement, it will **skip over the rest** of the statements in the loop and start the next iteration immediately.

```
int i;
for(i = 1; i < 10; i= i + 1){
    if(i % 2 == 0){
        continue; //skip all even numbers
    }
    printf("%d ", i);
}
printf("\n");
// print 1 3 5 7 9
```

Early Loop Restart

- What will happen if you run the code below?

```
int i = 1;
while(i < 10){
    if(i % 2 == 0){
        continue;
    }
    printf("%d ", i);
    i = i + 1
}
// ???
```

Take a guess.

- `1 3 5 7 9`
- `2 4 6 8`
- other

Early Loop Restart

Answer: it will print out `1` then stuck (loop will not stop).

`continue` will skip overall statements in the loop body, including the increment of `i`.

Recursion

- You **cannot** define a function inside another function.
- You can **call** a function inside another function.
  - **A function can call itself!**
  - A function calling itself is called recursion.

Recursion

- ```
  void countdown_to_1(int n){
      if(n >= 1 ){
          printf("%d\n", n);
          countdown_to_1(n - 1);
      }
  }

  void main(){
      countdown_to_1(3);
  }
  ```

- Prints out `3 2 1.`
- For each `n >0` , it prints out `n` and initiate `countdown` with a smaller number `n-1` .
  ```

Calling a Function: Recursion



Recursive function must have an entering and exiting path!

Recursion

What will happen if we do

```
    void countdown_to_1(int n){
        printf("%d\n", n);
        countdown_to_1(n - 1);
    }

    void main(){
        countdown_to_1(3);
    }
```

Conclusion

In this lecture, we talked about some more advanced flow-control techniques:

- Nested `if-else`
- Nested loops
- Early loop stop and restart
- Recursion

Homework 1

1. Download today's lab files from github, unzip and place them into your labpack.
    - The same you did for the last week's lab.
2. Double click lab3.bat to run the labpack.

Homework 2

1. Open `nestedif.c`, trace the execution using debugger (by pressing F5 then step over).
2. Make sure you understand the workflow of nested if.
3. Make modifications on `nestedif.c`, so the program outputs:
    - `student has failed!` if `score < 40`.
    - `congratulations! passed!` if `40 <=score < 50`.
    - `congratulations! 2:2` if `50 <=score < 60`.
    - `congratulations! 2:1` if `60 <=score < 70`.
    - `congratulations! first class!` if `score >= 70`.

Homework 3 (Submit)

Open `max.c`

Write a function `max` at the specified place. The function takes three integer inputs: `a,b,c`. It returns the maximum.

Homework 4

1. Open `nestedfor.c`, trace the execution using debugger (by pressing F5 then step over).
2. Make sure you understand the workflow of the nested loops.
3. Make modifications on `nestedif.c`, so the program outputs:

```
*
***
*****
*******
*********
```

   You must use for loop for that.
   This is the actual exam question from the last year.

Homework 5 (Submit)

Open `prime.c`.

Write a program that prints out all prime numbers from 1 to 1000. To do this question you need to use conditional statements and a nested loop.

See the next slide if you want some hints. Otherwise, stay on this slide until you finish.

Homework 5 (submit)

You can imagine a program with the following structure:

```
for i from 1 to 1000
    numfactors = 0
    for j from 1 to i
        if(i can be divided by j)
            numfactors = numfactors + 1

    if numfactors equls to 2 //primes have only 2 factors.
        print out i
```

- The above code is NOT C code. Please translate them into C code.
- This algorithm can be made more efficient (how?)

Submission

- Please creating a zip file containing both `max.c` and `prime.c` files
    - Please search online for help if you are not sure how to create a zip file.
- Rename the file to `ab1234.zip` where `ab1234` is your email account before the @ symbol.
- Uploaded it to the blackboard.