

EECS 22: Advanced C Programming

Lecture 4

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Lecture 4: Overview

- Review of the C Programming Language
 - Control Flow Charts
 - Structured Programming
 - Sequential statements
 - Conditional statements
 - Repetition statements
 - Arbitrary jump statements
 - Structured Program Composition
 - Example **Average.c**

Structured Programming

- Control Flow Statements
 - Sequential execution
 - Compound statements
 - Conditional execution
 - `if` statement
 - `if-else` statement
 - `switch` statement
 - Iterative execution
 - `while` loop
 - `do-while` loop
 - `for` loop
 - Unstructured execution
 - `goto` statement

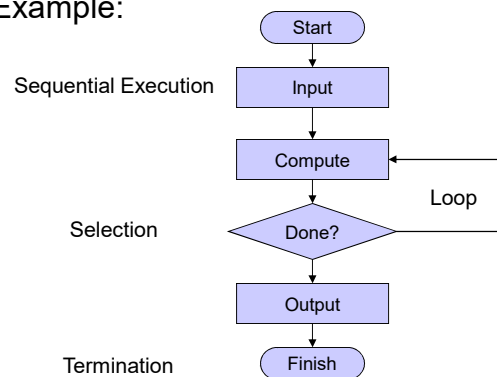
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Structured Programming

- Control Flow Chart
 - Graphical representation of program control flow
 - Example:



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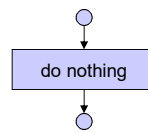
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Structured Programming

- Empty Statement Blocks
 - empty compound statement
 - does nothing (no operation, no-op)
 - Example:

Flow chart:

```
{
  /* nothing */
}
```



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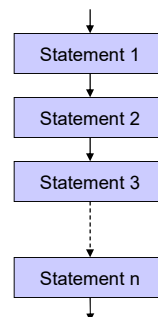
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Structured Programming

- Compound Statement Blocks
 - Sequence of statements grouped by braces: { }
 - *Sequential* execution of a sequence of statements
- Example:

Flow chart:

```
{
  /* statement 1 */
  /* statement 2 */
  /* statement 3 */
  /* ... */
  /* statement n */
}
```



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Structured Programming

- Compound Statement Blocks
 - Sequence of statements grouped by braces: { }
 - Compound statements may have *local variables!*
- Example:

```

{ /* declarations */
  /* definitions */

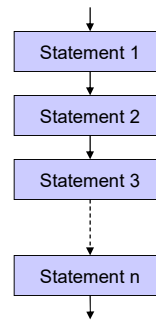
  /* statement 1 */
  /* statement 2 */
  /* statement 3 */

  /* ... */

  /* statement n */
}

```

Flow chart:



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Structured Programming

- Compound Statement Blocks
 - Sequence of statements grouped by braces: { }
 - *Indentation* increases readability of the code
 - proper indentation is highly recommended!
- Example:

```

/* some statements... */
if (x < 0) {
    printf("%d is negative!", x);
    /* handle negative values of x... */
    if (x < -100) {
        printf("%d is too small!", x);
        /* handle the problem... */
    } /* fi */
} /* fi */
if (x > 0) {
    printf("%d is positive!", x);
    /* handle positive values of x... */
} /* fi */
/* more statements... */

```

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Structured Programming

- Compound Statement Blocks
 - Sequence of statements grouped by braces: { }
- *Indentation* increases readability of the code
 - proper indentation is highly recommended!
- Example:

```

/* some statements... */
indentation level 0 if (x < 0) {
indentation level 1     printf("%d is negative!", x);
indentation level 1     /* handle negative values of x... */
                        if (x < -100) {
indentation level 2     /* handle the problem... */
                        } /* fi */
indentation level 1     } /* fi */
indentation level 0 if (x > 0) {
indentation level 1     printf("%d is positive!", x);
indentation level 1     /* handle positive values of x... */
                        } /* fi */
indentation level 0 /* more statements... */

```

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Structured Programming

- Compound Statement Blocks
 - Sequence of statements grouped by braces: { }
- *Avoid single statements!*
 - Wrapping in braces is highly recommended!
 - Indentation can be misleading! (*C is not Python!*)
- Example:

```

/* some statements... */
if (x < 0)
    printf("%d is negative!", x);

if (x > 0)
    printf("%d is positive!", x);

/* more statements... */

```

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Structured Programming

- Compound Statement Blocks
 - Sequence of statements grouped by braces: { }
- *Avoid single statements!*
 - Wrapping in braces is highly recommended!
 - Indentation can be misleading! (*C is not Python!*)
- Example:

```
/* some statements... */
if (x < 0)
    printf("%d is negative!", x);
    y = sqrt(-x); /* ERROR! */

if (x > 0)
    printf("%d is positive!", x);
    y = sqrt(x); /* ERROR! */

/* more statements... */
```

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Structured Programming

- Compound Statement Blocks
 - Sequence of statements grouped by braces: { }
- *Avoid single statements!*
 - Wrapping in braces is highly recommended!
 - Indentation can be misleading! (*C is not Python!*)
- Example:

```
/* some statements... */
if (x < 0) {
    printf("%d is negative!", x);
    y = sqrt(-x);
} /* fi */

if (x > 0) {
    printf("%d is positive!", x);
    y = sqrt(x);
} /* fi */

/* more statements... */
```

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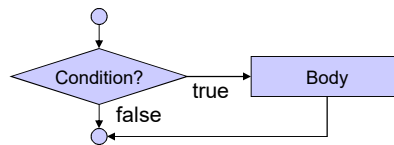
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Structured Programming

- Selection: **if** statement

- Flow chart:



- Example:

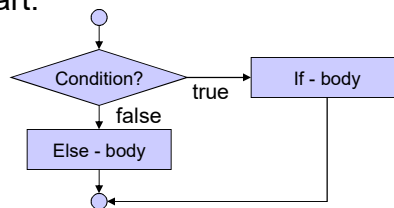
```

if (grade >= 60)
{ printf("You passed.");
} /* fi */
  
```

Structured Programming

- Selection: **if-else** statement

- Flow chart:



- Example:

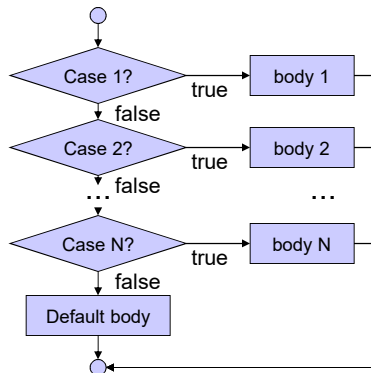
```

if (grade >= 60)
{ printf("You passed.");
} /* fi */
else
{ printf("You failed.");
} /* esle */
  
```

Structured Programming

- Selection: **switch** statement

– Flow chart:



Example:

```

switch(LetterGrade)
{ case 'A':
  { printf("Excellent!");
    break; }
  case 'B':
  case 'C':
  case 'D':
  { printf("Passed.");
    break; }
  case 'F':
  { printf("Failed!");
    break; }
  default:
  { printf("Invalid grade!");
    break; }
} /* hctiws */
  
```

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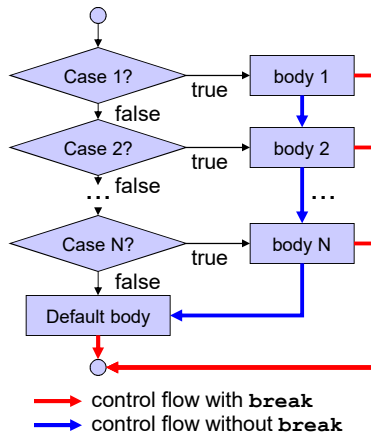
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Structured Programming

- Selection: **break** in **switch** statement

– Flow chart:



Example:

```

switch(LetterGrade)
{ case 'A':
  { printf("Excellent!");
    break; }
  case 'B':
  case 'C':
  case 'D':
  { printf("Passed.");
    break; }
  case 'F':
  { printf("Failed!");
    break; }
  default:
  { printf("Invalid grade!");
    break; }
} /* hctiws */
  
```

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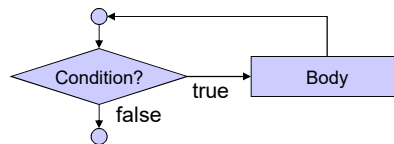
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Structured Programming

- Repetition: **while** loop

- Flow chart:



- Example:

```
int product = 2;
while (product < 1000)
{ product *= 2;
  } /* elihw */
```

- Note:

- The condition is evaluated at the *beginning* of each loop!

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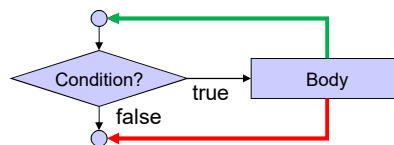
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Structured Programming

- Repetition: **break/continue** in **while** loop

- Flow chart:



- Control flow:

- control flow with **break**
- control flow with **continue**

- Note:

- The condition is evaluated at the *beginning* of each loop!

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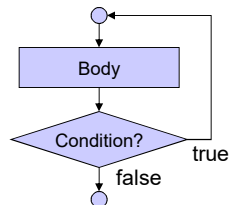
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Structured Programming

- Repetition: **do-while** loop

- Flow chart:



- Example:

```
int product = 2;
do { product *= 2;
    } while (product < 1000);
```

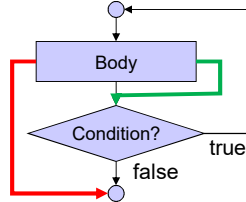
- Note:

- The condition is evaluated at the *end* of each loop!

Structured Programming

- Repetition: **break/continue** in **do-while** loop

- Flow chart:



- Control flow:

- control flow with **break**
- control flow with **continue**

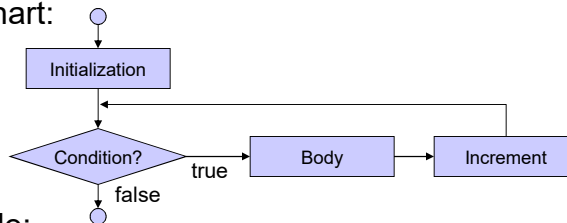
- Note:

- The condition is evaluated at the *end* of each loop!

Structured Programming

- Repetition: **for** loop

– Flow chart:



– Example:

```

for(i = 0; i < 10; i++)
{ printf("i = %d\n", i);
} /* eof */
  
```

– Syntax:

- `for(initialization; condition; increment)`
`{ body }`

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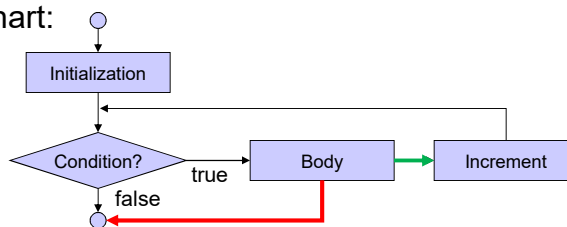
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Structured Programming

- Repetition: **break**/**continue** in **for** loop

– Flow chart:



– Control flow:

→ control flow with **break**

→ control flow with **continue**

– Syntax:

- `for(initialization; condition; increment)`
`{ body }`

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Arbitrary Control Flow

- Arbitrary jumps: `goto` statement
 - `goto` statement jumps to the specified *labeled* statement (within the same function)

– Example:

```
begin:  count = 0;
        goto next;
repeat: if (count > 100)
        { goto end; }
next:   count++;
        if (count == 77)
        { goto next; }
        goto repeat;
end:    printf("%d", count);
```

– Warning:

- `goto` statement allows *un-structured* programming!
- `goto` statement should be avoided whenever possible!

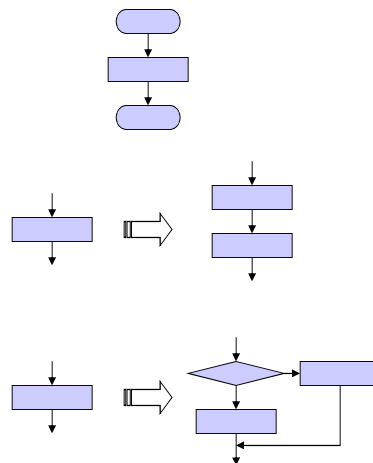
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Structured Program Composition

- Initial flow chart
 - Start
 - Program body
 - Finish
- Statement sequences
 - Statement blocks can be concatenated
 - Sequential execution
- Nested control structures
 - control structures can be placed wherever statement blocks can be placed in the code



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Structured Program Composition

- Example:
 - Initial flow chart

```

graph TD
    Start([Start]) --> Process[Process]
    Process --> End([End])
    
```

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Structured Program Composition

- Example:
 - Sequential composition

```

graph TD
    Start([Start]) --> P1[Process 1]
    P1 --> P2[Process 2]
    P2 --> End([End])
    subgraph SequentialComposition [Sequential Composition]
        P1
        P2
    end
    
```

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Structured Program Composition

- Example:
 - insertion of another sequential statement

The flowchart illustrates a sequential process. It starts with an oval representing the beginning of the program. An arrow points down to a dashed rectangular box containing two rectangular process blocks stacked vertically. Below this box, an arrow points down to a single rectangular process block. Finally, an arrow points down to an oval representing the end of the program.

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Structured Program Composition

- Example:
 - insertion of **if-else** statement

The flowchart illustrates a program structure with an if-else statement. It starts with an oval representing the beginning of the program. An arrow points down to a rectangular process block. Below this, an arrow points down to a dashed rectangular box containing a diamond-shaped decision block. From the right side of the diamond, an arrow points to a rectangular process block. From the bottom of the diamond, an arrow points down to another rectangular process block. From the right side of the second process block, an arrow loops back to the right side of the diamond. Below the dashed box, an arrow points down to a final rectangular process block. Finally, an arrow points down to an oval representing the end of the program.

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Structured Program Composition

- Example:
 - insertion of sequential statement

The flowchart shows a sequence of operations: a start node, a process box, a decision diamond, another process box, and a final end node. A dashed box highlights a new process box and a second process box being inserted between the first process box and the decision diamond. Arrows indicate the flow from the start to the first process box, then to the decision diamond, then to the second process box, then to the new process box, and finally to the end node.

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Structured Program Composition

- Example:
 - insertion of **if-else** statement

The flowchart shows a sequence of operations: a start node, a process box, a decision diamond, another process box, and a final end node. A dashed box highlights a new decision diamond and two process boxes being inserted between the first process box and the decision diamond. Arrows indicate the flow from the start to the first process box, then to the decision diamond, then to the first process box of the if-else block, then to the second process box, then to the second process box of the if-else block, and finally to the end node.

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Structured Program Composition

- Example:
 - insertion of sequential statement

The flowchart shows a sequence of operations: a start node, a process box, a decision diamond, a process box, a decision diamond, a process box, a loop body (two process boxes enclosed in a dashed box), a process box, and an end node. Arrows indicate the flow from the start node through the first process box to the first decision diamond. From this diamond, one path goes to the second process box, and another path goes to the second decision diamond. From the second decision diamond, one path goes to the third process box, and another path goes to the loop body. The loop body consists of two sequential process boxes. After the loop body, the flow goes to the fourth process box, then to the second decision diamond, and finally to the end node.

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Structured Program Composition

- Example:
 - insertion of sequential statement (twice)

The flowchart shows a sequence of operations: a start node, a process box, a decision diamond, a process box, a decision diamond, a process box, a loop body (three process boxes enclosed in a dashed box), a process box, and an end node. Arrows indicate the flow from the start node through the first process box to the first decision diamond. From this diamond, one path goes to the second process box, and another path goes to the second decision diamond. From the second decision diamond, one path goes to the third process box, and another path goes to the loop body. The loop body consists of three sequential process boxes. After the loop body, the flow goes to the fourth process box, then to the second decision diamond, and finally to the end node.

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Structured Program Composition

- Example:
 - insertion of **switch** statement
 - etc. ...

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Structured Program Example

- Example **Average.c**
- Task:
 - Compute the average of a set of floating point values
 - The user enters the values consecutively
 - The user enters -1 when done
 - Sentinel-controlled repetition
 - Print the number of values entered and the calculated average
- Caution:
 - The average of 0 values is undefined!

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Structured Program Example

- Average of values: `Average.c` (part 1/3)

```

/* Average.c: compute the average of a set of numbers */
/*
/* author: Rainer Doemer
/*
/* modifications:
/* 10/10/04 RD sentinel controlled loop
/* 10/10/04 RD initial version

#include <stdio.h>

/* main function */
int main(void)
{
    /* variable definitions */
    int counter;
    double value;
    double total;
    double average;
    ...

```

Structured Program Example

- Average of values: `Average.c` (part 2/3)

```

...

/* input and computation section */
counter = 0;
total = 0.0;
while (1)
{ printf("Please enter a value (or -1 to quit): ");
  scanf("%lf", &value);
  if (value == -1.0)
  { break;
    } /* fi */
  total += value;
  counter++;
} /* elihw */

...

```

Structured Program Example

- Average of values: **Average.c** (part 3/3)

```
...  
  
/* computation and output section */  
printf("%d values entered.\n", counter);  
if (counter >= 1)  
{ average = total / counter;  
  printf("The average is %f.\n", average);  
} /* fi */  
  
/* exit */  
return 0;  
} /* end of main */  
  
/* EOF */
```

Structured Program Example

- Example session: **Average.c**

```
% vi Average.c  
% gcc Average.c -o Average -Wall -ansi -std=c99  
% ./Average  
Please enter a value (or -1 to quit): 2  
Please enter a value (or -1 to quit): 3  
Please enter a value (or -1 to quit): 4  
Please enter a value (or -1 to quit): 5  
Please enter a value (or -1 to quit): -1  
4 values entered.  
The average is 3.500000.  
% ./Average  
Please enter a value (or -1 to quit): -1  
0 values entered.  
%
```