

Writing Program in C Expressions and Control Structures (Statements and Loops)

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Lecture 02

PRG – Programming in C

Overview of the Lecture

- Part 1 – Expressions
 - Expressions – Literals and Variables
 - Expressions – Operators
 - Associativity and Precedence
 - Assignment
- Part 2 – Control Structures: Selection Statements and Loops
 - Statements and Coding Styles
 - Selection Statements
 - Loops
 - Conditional Expression
- Part 3 – Assignment HW 01
- Part 4 – Coding example (optional)

K. N. King: chapter 4 and 20

K. N. King: chapters 5 and 6

Part I Part 1 – Expressions

Expressions

- Expression** prescribes calculation value of some given input.
- Expression is composed of **operands**, **operators**, and **brackets**.
- Expression can be formed of
 - literals,
 - variables,
 - constants,
 - unary and binary operators,
 - function call,
 - brackets.
- The order of operation evaluation is prescribed by the operator **precedence** and **associativity**.

```
10 + x * y    // order of the evaluation 10 + (x * y)
10 + x + y    // order of the evaluation (10 + x) + y
```

* has higher priority than +
+ is associative from the left-to-right

- The evaluation order can be prescribed by **fully parenthesized expression**.

Simply: If you are not sure, use brackets.

Literals – Enumeration

- By default, values of the enumerated type starts from 0 and each other item increase the value about one, values can be explicitly prescribed.

```
enum {
    WHITE,
    BLACK,
    RED,
    GREEN,
};

enum {
    ERROR_OK = 0, // EXIT_SUCCCESS
    ERROR_INPUT = 100,
    ERROR_RANGE = 101
};
```

The enumeration values are usually written in uppercase.

- Type – enumerated constant is the **int** type.
- Value of the enumerated literal can be used in loops.

```
enum { WHITE = 0, BLACK, RED, GREEN, BLUE, NUM_COLORS };

for (int color = WHITE; color < NUM_COLORS; ++color) {
    ...
}
```

Literals – Integer and Rational

- Integer values are stored as one of the integer type (keywords): **int**, **long**, **short**, **char** and their **signed** and **unsigned** variants. *Further integer data types are possible.*
- Rational numbers (data types **float** and **double**) can be written with floating point – 13.1; or with mantissa and exponent – 31.4e-3 or 31.4E-3. *Scientific notation*
- Floating point numeric types depends on the implementation (usually as IEEE-754-1985).

	Integer literals (values)	Rational literals
Decimal	123 450932	<ul style="list-style-type: none">double – by default, if not explicitly specified to be another type;float – suffix F or f;long double – suffix L or l.
Hexadecimal	0x12 0xFAFF (starts with 0x or 0X)	<ul style="list-style-type: none">float f = 10.f;long double ld = 10.11;
Octal	0123 0567 (starts with 0)	
unsigned	12345U (suffix U or u)	
long	12345L (suffix L or l)	
unsigned long	12345ul (suffix Ul or ul)	
long long	12345LL (suffix LL or ll)	

Without suffix, the literal is of the type `int`.

Variable Definition

- The variable definition has a general form **declaration-specifiers variable-identifier;**
- Declaration specifiers are following.
 - Storage classes:** at most one of the **auto**, **static**, **extern**, **register**;
 - Type quantifiers:** **const**, **volatile**, **restrict**;
 - Type specifiers:** **void**, **char**, **short**, **int**, **long**, **float**, **double**, **signed**, **unsigned**.

None or more type quantifiers are allowed.

In addition, **struct** and **union** type specifiers can be used. Finally, own types defined by **typedef** can be used as well.

```
float f = 10.1f; // float variable initialized by float literal
const double pi = 3.14; //const double variable initialized to 3.14
unsigned char v = 255; //one byte integer variable with the full range 0..255
const unsigned long l = 1001; //constant long integer variable initialized by long literal
int i; // i variable of the common C integer type int that is not initialized
```

Literals – Characters and Text Strings

- Character literal is single (or multiple) character in apostrophe.
 - 'A', 'B' or '\n'
- Value of the single character literal is the ASCII code of the character.
 - '0' ~ 48, 'A' ~ 65
 - Value of character out of ASCII (greater than 127) depends on the compiler.
- Type of the character constant (literal).
 - Character constant is the int type.**
- Text string is a sequence of characters enclosed in quotation marks.
 - "A string with the end of line \n".
 - String literals separated by white spaces are joined to single one.
 - "A string literal" "with the end of the line \n" is concatenate into "A string literal with end of the line \n"
 - String literal is stored in the array of the type **char** terminated by the **null character '\0'**. A string literal "word" is stored as

```
char c = '8'; // Letter of the digit 8
int v = c - '0'; // Conversion to int value 8

char a = '0'; // Test a letter is upper case
_Bool upper = (a >= 'A' && a <= 'Z');

char i = '5'; // Test a letter is a digit
_Bool digit = (i >= '0' && i <= '9');
```

```
'w' 'o' 'r' 'd' '\0'
```

The size of the array must be **+1 item longer** to store `\0`!

Operators

- Operators are selected characters (or sequences of characters) dedicated for writing expressions.
- Five types of **binary operators** can be distinguished.
 - Arithmetic** operators – additive (addition/subtraction) and multiplicative (multiplication/division);
 - Relational** operators – comparison of values (less than, greater than, ...);
 - Logical** operators – logical **AND** and **OR**;
 - Bitwise** operators – bitwise **AND**, **OR**, **XOR**, bitwise shift (left, right);
 - Assignment operator** = – a variables (l-value) is on its left side.
- Unary operators
 - Indicating positive/negative value: **+** and **-**.
 - Modifying a variable: **++** and **--**.
 - Logical negation: **!**.
 - Bitwise negation: **~**.
- Ternary operator – conditional expression **? :**

Operator – modifies the sign of the expression.

Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Variables, Assignment Operator, and Assignment Statement

- Variables are defined by the type and name.
 - Name of the variable are in lowercase.
 - Multi-word names can be written with underscore `_`. *Or we can use CamelCase.*
 - Each variable is defined at a new line.


```
int n;
int number_of_items;
int numberOfItems;
```
- Assignment is setting the value to the variable, i.e., the value is stored at the memory location referenced by the variable name.
- Assignment operator

$$(l\text{-value}) = \langle \text{expression} \rangle$$

Expression is literal, variable, function calling, ...

 - The side is the so-called **l-value – location-value, left-value**

It must represent a memory location where the value can be stored.
 - Assignment is an expression and we can use it everywhere it is allowed to use the expression of the particular type.
- Assignment statement is the assignment operator `=` and `;`.

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Basic Arithmetic Expressions

- For an operator of the numeric types `int` and `double`, the following operators are defined.

Also for char, short, and float numeric types.

 - Unary operator for changing the sign `-`;
 - Binary addition `+` and subtraction `-`;
 - Binary multiplication `*` and division `/`.
- For integer operator, there is also
 - Binary module (integer remainder) `%`.
- If both operands are of the same type, the results of the arithmetic operation is the same type.
- In a case of combined data types `int` and `double`, the data type `int` is converted to `double` and the results is of the `double` type.

Implicit type conversion.

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Example – Arithmetic Operators 1/2

```
1 int a = 10;
2 int b = 3;
3 int c = 4;
4 int d = 5;
5 int result;
6
7 result = a - b; // subtraction
8 printf("a - b = %i\n", result);
9
10 result = a * b; // multiplication
11 printf("a * b = %i\n", result);
12
13 result = a / b; // integer division
14 printf("a / b = %i\n", result);
15
16 result = a + b * c; // priority of the operators
17 printf("a + b * c = %i\n", result);
18
19 printf("a * b + c * d = %i\n", a * b + c * d); // -> 50
20 printf("(a * b) + (c * d) = %i\n", (a * b) + (c * d)); // -> 50
21 printf("a * (b + c) * d = %i\n", a * (b + c) * d); // -> 350
```

lec02/arithmetic_operators.c

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Example – Arithmetic Operators 2/2

```
1 #include <stdio.h>
2
3 int main(void)
4 {
5     int x1 = 1;
6     double y1 = 2.2357;
7     float x2 = 2.5343f;
8     double y2 = 2;
9
10    printf("P1 = (%i, %f)\n", x1, y1);
11    printf("P1 = (%i, %i)\n", x1, (int)y1);
12    printf("P1 = (%f, %f)\n", (double)x1, (double)y1);
13    printf("P1 = (%.3f, %.3f)\n", (double)x1, (double)y1);
14
15    printf("P2 = (%f, %f)\n", x2, y2);
16
17    double dx = (x1 - x2); // implicit data conversion to float
18    double dy = (y1 - y2); // and finally to double
19
20    printf("(P1 - P2)=(%.3f, %.0.3f)\n", dx, dy);
21    printf("|P1 - P2|^2=%.2f\n", dx * dx + dy * dy);
22    return 0;
23 }
```

lec02/points.c

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Arithmetic Operators

- Operands of arithmetic operators can be of any arithmetic type.

The only exception is the operator for the integer remainder % defined for the int type.

*	Multiplication	<code>x * y</code>	Multiplication of x and y
/	Division	<code>x / y</code>	Division of x and y
%	Reminder	<code>x % y</code>	Reminder from the x / y
+	Addition	<code>x + y</code>	Sum of x and y
-	Subtraction	<code>x - y</code>	Subtraction x and y
+	Unary plus	<code>+x</code>	Value of x
-	Unary minus	<code>-x</code>	Value of -x
++	Increment	<code>++x/x++</code>	Incrementation before/after the evaluation of the expression x
--	Decrement	<code>--x/x--</code>	Decrementation before/after the evaluation of the expression x

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Integer Division

- The results of the division of the operands of the `int` type is the integer part of the division.

E.g., 7/3 is 2 and -7/3 is -2
- For the integer remainder, it holds $x \% y = x - (x/y) * y$.

E.g., 7 % 3 is 1 -7 % 3 is -1 7 % -3 is 1 -7 % -3 is -1
- C99:** The result of the integer division of negative values is the value closer to 0.
 - It holds that $(a/b)*b + a \% b = a$.

For older versions of C, the results depends on the compiler.

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Implementation-Defined Behaviour

- The C standard deliberately leaves parts of the language unspecified.
- Thus, some parts depend on the implementation, such as compiler, environment, or computer architecture.

E.g., Reminder behavior for negative values and version of the C prior C99.
- The reason for that is the focus of C on efficiency, i.e., match the hardware behavior.
- Having it in mind, it is best to avoid writing programs that depend on implementation-defined behavior.

K.N.King: Page 55

That is one example of writing programs that seem to be working and functional and a program that is correct.

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Unary Arithmetic Operators

- Unary operator (`++` and `--`) change the value of its operand.

The operand must be the l-value, i.e., an expression that has memory space, where the value of the expression is stored, e.g., a variable.

 - It can be used as **prefix** operator, e.g., `++x` and `--x`;
 - or as **postfix** operator, e.g., `x++` and `x--`.
 - In each case, the **final value of the expression is different!**

<code>int i; int a;</code>	value of i	value of a
<code>i = 1; a = 9;</code>	1	9
<code>a = i++;</code>	2	1
<code>a = ++i;</code>	3	3
<code>a = ++(i++);</code>	Not allowed! Value of i++ is not the l-value	

For the unary operator ++, it is necessary to store the previous value of i and then the variable i is incremented. The expression ++i only increments the value of i. Therefore, ++i can be more efficient.

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Relational Operators

- Operands of relational operators can be of arithmetic type, pointers (of the same type) or one operand can be `NULL` or pointer of the `void` type.

<	Less than	<code>x < y</code>	1 if x is less than y; otherwise 0
<=	Less than or equal	<code>x <= y</code>	1 if x is less then or equal to y; otherwise 0
>	Greater than	<code>x > y</code>	1 if x is greater than y; otherwise 0
>=	Greater than or equal	<code>x >= y</code>	1 if x is greater than or equal to y; otherwise 0
==	Equal	<code>x == y</code>	1 if x is equal to y; otherwise 0
!=	Not equal	<code>x != y</code>	1 if x is not equal to y; otherwise 0

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Logical operators

- Operands can be of arithmetic type or pointers.
- Resulting value 1 means **true**, 0 means **false**.
- In the expressions **&&** (Logical AND) and **||** (Logical OR), the left operand is evaluated first.
- If the results is defined by the left operand, the right operand is not evaluated.

Short-circuiting behavior – it may speed evaluation of complex expressions in runtime.

&&	Logical AND	<code>x && y</code>	1 if x and y is not 0; otherwise 0.
 	Logical OR	<code>x y</code>	1 if at least one of x, y is not 0; otherwise 0.
!	Logical NOT	<code>!x</code>	1 if x is 0; otherwise 0.

- Operands **&&** and **||** have the **short-circuiting behavior**, i.e., the second operand is not evaluated if the result can be determined from the value of the first operand.

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Example – Short-Circuiting Behaviour 1/2

```

1 #include <stdio.h>
2 #include <stdlib.h>
3
4 int fce_a(int n);
5 int fce_b(int n);
6
7 int main(int argc, char *argv[])
8 {
9     if (argc > 1 && fce_a(atoi(argv[1])) && fce_b(atoi(argv[1])))
10    {
11        printf("Both functions fce_a and fce_b pass the test\n");
12    } else {
13        printf("One of the functions does not pass the test\n");
14    }
15    return 0;
16 }
17
18 int fce_a(int n)
19 {
20    printf("Calling fce_a with the argument '%d'\n", n);
21    return n % 2 == 0;
22 }
23
24 int fce_b(int n)
25 {
26    printf("Calling fce_b with the argument '%d'\n", n);
27    return n > 2;
28 }

```

lec02/demo-short_circuiting.c

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Example – Short-Circuiting Behaviour 2/2 – Tasks

- In the example `lec02/demo-short_circuiting.c`
 - Test how the logical expressions (a function call) are evaluated.
 - Identify what functions `fce_a()` and `fce_b()` are implementing.
 - Rename the functions appropriately.
 - Identify the function headers and why they have to be stated above the main function.
 - Try to split implementation of the functions to a separate module.

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Bitwise Operators

- Bitwise operators treat operands as a series of bits.

Low-Level Programming – A programming language is low level when its programs require attention of the irrelevant. K.N.King: Chapter 20.

&	Bitwise AND	<code>x & y</code>	1 if x and y is equal to 1 (bit-by-bit)
 	Bitwise inclusive OR	<code>x y</code>	1 if x or y is equal to 1 (bit-by-bit)
^	Bitwise exclusive or (XOR)	<code>x ^ y</code>	1 if only x or only y is 1 (bit-by-bit)
~	Bitwise complement (NOT)	<code>~x</code>	1 if x is 0 (bit-by-bit)
<<	Bitwise left shift	<code>x << y</code>	Shift of x by y bits to the left
>>	Bitwise right shift	<code>x >> y</code>	Shift of x by y bits to the right

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Bitwise Shift Operators

- Bitwise shift operators shift the binary representation by a given number of bits to the left or right.
 - Left shift – Each bit shifted off a zero bit enters at the right.
 - a zero bit enters at the left – for positive values or unsigned types.
 - for negative values, the entered bit can be either 0 (logical shift) or 1 (arithmetic shift right). Depends on the compiler.
 - Right shift – Each bit shift off.
 - a zero bit enters at the left – for positive values or unsigned types.
 - for negative values, the entered bit can be either 0 (logical shift) or 1 (arithmetic shift right). Depends on the compiler.
- Bitwise shift operators **have lower precedence than the arithmetic operators!**
 - `i << 2 + 1` means `i << (2 + 1)`

Do not be surprised – parenthesized the expression!

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Example – Bitwise Expressions

```

#include <inttypes.h>

uint8_t a = 4;
uint8_t b = 5;

a      dec: 4 bin: 0100
b      dec: 5 bin: 0101
a & b  dec: 4 bin: 0100
a | b  dec: 5 bin: 0101
a ^ b  dec: 1 bin: 0001

a >> 1 dec: 2 bin: 0010
a << 1 dec: 8 bin: 1000

```

lec02/bits.c

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Operators for Accessing Memory

Here, for completeness, details in the further lectures.

- In C, we can directly access the memory address of the variable. *We need in `scanf()`!*
- The access is realized through a pointer. *It is an integer value, typically long.*

It allows great options and also understand data representation and memory access models.

Operator	Name	Example	Result
&	Address	<code>&x</code>	Pointer to x
*	Indirection	<code>*p</code>	Variable (or function) addressed by the pointer p.
[]	Array subscripting	<code>x[i]</code>	<code>*(x+i)</code> – item of the array x at the position i.
.	Structure/union member	<code>s.x</code>	Member x of the struct/union s.
->	Structure/union member	<code>p->x</code>	Member x of the struct/union addressed by the pointer p.

*It is not allowed an operand of the & operator is a bit field or variable of the register class, because it has to be addressable memory space. Operator of the indirect address * allows to access to the memory using pointers.*

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Other Operators

Operator	Name	Example	Result
()	Function call	<code>f(x)</code>	Call the function f with the argument x.
(type)	Cast	<code>(int)x</code>	Change the type of x to int.
sizeof	Size of the item	<code>sizeof(x)</code>	Size of x in bytes.
?:	Conditional	<code>x ? y : z</code>	Do y if x != 0; otherwise z.
,	Comma	<code>x, y</code>	Evaluate x and then y, the result is the result of the last expression.

- The operand of `sizeof()` can be a type name or expression.


```
int a = 10;
printf("%lu %lu\n", sizeof(a), sizeof(a + 1.0));
```
- Example of the **comma** operator.


```
for (c = 1, i = 0; i < 3; ++i, c += 2) {
    printf("i: %d c: %d\n", i, c);
}
```

lec02/sizeof.c

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Expressions – Literals and Variables Expressions – Operators Associativity and Precedence Assignment

Cast Operator

- Changing the variable type in runtime is called type case.
- Explicit cast is written by the name of the type in `()`, e.g.


```
int i;
float f = (float)i;
```
- Implicit cast is made automatically by the compiler during the program compilation.
- If the new type can represent the original value, the value is preserved by the cast.
- Operands of the **char**, **unsigned char**, **short**, **unsigned short**, and the bit field types can be used everywhere where it is allowed to use **int** or **unsigned int**.
 - Operands are automatically cast to the **int** or **unsigned int**. *C expects at least values of the int type.*

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Operators Associativity and Precedence

- Binary operation `op` is **associative** on the set **S** if $(x \text{ op } y) \text{ op } z = x \text{ op } (y \text{ op } z)$, for each $x, y, z \in S$.
- For not associative operators, it is required to specify the order of evaluation.
 - Left-associative – operations are grouped from the left.
 - E.g., $10 - 5 - 3$ is evaluated as $(10 - 5) - 3$.
 - Right-associative – operations are grouped from the right.
 - E.g., $3 + 5^2$ is 28 or $3 \cdot 5^2$ is 75 vs $(3 \cdot 5)^2$ is 225.
- The assignment is right-associative.
 - E.g., $y=y+8$.
 - First, the whole right side of the operator `=` is evaluated, and then, the results are assigned to the variable on the left.
- The order of the operator evaluation can be defined by the **fully parenthesized expression**.

Summary of the Operators and Precedence 1/3

Precedence	Operator	Associativity	Name
1	<code>++</code>	L→R	Increment (postfix)
	<code>--</code>		Decrementation (postfix)
	<code>()</code>		Function call
	<code>[]</code>		Array subscripting
	<code>· -></code>		Structure/union member
	2	<code>++</code>	R→L
<code>--</code>			Decrementation (prefix)
<code>!</code>			Logical negation
<code>~</code>			Bitwise negation
<code>- +</code>			Unary plus/minus
<code>*</code>			Indirection
<code>&</code>			Address
<code>sizeof</code>			Size

Summary of the Operators and Precedence 2/3

Precedence	Operator	Associativity	Name
3	<code>()</code>	R→L	Cast
4	<code>*, /, %</code>	L→R	Multiplicative
5	<code>+ -</code>		Additive
6	<code>>>, <<</code>		Bitwise shift
7	<code><, >, <=, >=</code>		Relational
8	<code>==, !=</code>		Equality
9	<code>&</code>		Bitwise AND
10	<code>^</code>		Bitwise exclusive OR (XOR)
11	<code> </code>		Bitwise inclusive OR (OR)
12	<code>&&</code>		Logical AND
13	<code> </code>		Logical OR

Summary of the Operators and Precedence 3/3

Precedence	Operator	Associativity	Name
14	<code>? :</code>	R→L	Conditional
15	<code>=</code>		Assignment
	<code>+=, -=</code>		additive
	<code>*=, /=, %=</code>	R→L	multiplicative
	<code><<=, >>=</code>		bitwise shift
	<code>&=, ^=, =</code>		Bitwise AND, XOR, OR
15	<code>,</code>	L→R	Comma

K. N. King: Page 735
http://en.cppreference.com/w/c/language/operator_precedence

Simple Assignment

- Set the value to the variable.
 - Store the value into the memory space referenced by the variable name.
- The form of the assignment operator is $(\text{variable}) = (\text{expression})$
 - Expression is literal, variable, function call, ...
- C is statically typed programming language.
 - A value of an expression can be assigned only to a variable of the same type.
 - Otherwise the type cast is necessary.
 - Example of the implicit type cast.


```
int i = 320.4; // implicit conversion from 'double' to 'int' changes value from 320.4 to 320 [-Wliteral-conversion]
char c = i; // implicit truncation 320 -> 64
```
- C is type safe only within a limited context of the compilation, e.g., for `printf("%d\n", 10.1)`; a compiler reports an error.
- In general, C is not type safe. *In runtime, it is possible to write out of the allocated memory space.*

Compound Assignment

- A short version of the assignment to compute a new value of the variable from itself: $(\text{variable}) = (\text{variable}) (\text{operator}) (\text{expression})$
 - can be written as $(\text{variable}) (\text{operator}) = (\text{expression})$
- Example**
- ```
int i = 10; int i = 10;
double j = 12.6; double j = 12.6;
i = i + 1; i += 1;
j = j / 0.2; j /= 0.2;
```
- Note that the assignment is an expression.
    - The assignment of the value to the variable is a side effect.
- ```
int x, y;
x = 6;
y = x = x + 6;
```

Assignment Expression and Assignment Statement

- The statement performs some action and it is terminated by ;


```
robot_heading = -10.23;
robot_heading = fabs(robot_heading);
printf("Robot heading: %f\n", robot_heading);
```
- Expression has **type and value**.


```
23      int type, value is 23
14+16/2 int type, value is 22
y=8     int type, value is 8
```
- Assignment is an expression and its value is assigned to the left side.
- The assignment expression becomes the assignment statement by adding the semicolon.

Undefined Behaviour

- There are some statements that can cause **undefined behavior** according to the C standard.
 - $c = (b = a + 2) - (b - 1)$;
 - $j = i * i++$;
- The program may behave differently according to the used compiler, but may also not compile or may not run; or it may even crash and behave erratically or produce meaningless results.
- It may also happened if variables are used without initialization.
- Avoid statements that may produce undefined behavior!**
 - A further detailed example of undefined behavior and code optimization with its analysis is in Lecture 09.

Part II

Part 2 – Control Structures: Selection Statements and Loops

Statements and Coding Styles Selection Statements Loops Conditional Expression

Statement and Compound Statement (Block)

- Statement is terminated by ;
 - Statement consisting only of the semicolon is empty statement.
- Block consists of sequences of declarations and statements.
- ANSI C, C89, C90: Declarations must be placed prior other statements.
 - It is not necessary for C99.
- Start and end of the block is marked by the curly brackets { and }.
- A block can be inside other block.

```

void function(void) /* function block start */
{ /* function block start */
  { /* inner block */
    for (i = 0; i < 10; ++i)
    { /* inner for-loop block */
      //inner for-loop block
    }
  }
}

```

Note the coding styles.

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Statements and Coding Styles Selection Statements Loops Conditional Expression

Coding Style

- It supports clarity and readability of the source code.
 - https://www.gnu.org/prep/standards/html_node/Writing-C.html
- Formatting of the code is the fundamental step.
 - Appropriate identifiers.
 - Train yourself in coding style even at the cost of slower coding!
 - Readability and clarity is important, especially during debugging!
 - Notice, sometimes it can be better to start from scratch
 - Recommend coding style.


```

1 void function(void)
2 { /* function block start */
3   for (int i = 0; i < 10; ++i) {
4     /*inner for-loop block
5     if (i == 5) {
6       break;
7     }
8   }
9 }

```

 - Use English, especially for identifiers.
 - Use nouns for variables.
 - Use verbs for function names.


Lecturer's preference: indent shift 3, space characters rather than tabular.

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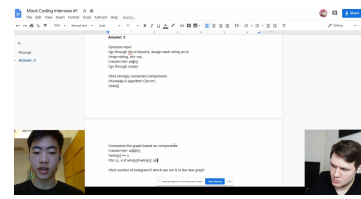
Statements and Coding Styles Selection Statements Loops Conditional Expression

Coding Style – Code Clarity and Readability

- There are many different coding styles.
- Inspire yourself by existing recommendations and by reading representative source codes.



Clean Code - Uncle Bob / Lesson 1 <https://youtu.be/7EmboKQH81M>



Google Coding Interview with a High School Student <https://youtu.be/qz9tk1F431k>

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Statements and Coding Styles Selection Statements Loops Conditional Expression

Control Statements

- Selection Statement
 - Selection Statement: if () or if () ... else
 - Switch Statement: switch () case ...
- Control Loops
 - for ()
 - while ()
 - do ... while ()
- Jump statements (unconditional program branching)
 - continue
 - break
 - return
 - goto

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Statements and Coding Styles Selection Statements Loops Conditional Expression

Selection Statement – if

- if (expression) statement₁; else statement₂
- For expression != 0 the statement₁ is executed; otherwise statement₂.
 - The statement can be the compound statement.
- The else part is optional.
- Selection statements can be nested and cascaded.
 - Why You Shouldn't Nest Your Code – <https://youtu.be/CFRhgNuXG-4>.

```

int max;
if (a > b) {
  if (a > c) {
    max = a;
  }
}

```

```

int max;
if (a > b) {
  ...
} else if (a < c) {
  ...
} else if (a == b) {
  ...
} else {
  ...
}

```

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Statements and Coding Styles Selection Statements Loops Conditional Expression

The switch Statement

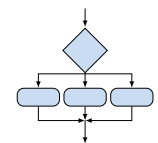
- Allows to branch the program based on the value of the expression of the enumerate (integer) type, e.g., int, char, short, enum.
- The form is


```

switch (expression) {
  case constant1: statements1; break;
  case constant2: statements2; break;
  ...
  case constantn: statementsn; break;
  default: statementsdef; break;
}

```

 - where constants are of the same type as the expression and statements_i is a list of statements.
 - Switch statements can be nested.
 - Semantics: First the expression value is calculated. Then, the statements under the same value are executed. If none of the branch is selected, statements_{def} under default branch as performed (optional).



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Statements and Coding Styles Selection Statements Loops Conditional Expression

The switch Statement – Example

```

switch (v) {
  case 'A':
    printf("Upper 'A'\n");
    break;
  case 'a':
    printf("Lower 'a'\n");
    break;
  default:
    printf("It is not 'A' nor 'a'\n");
}

```

```

if (v == 'A') {
  printf("Upper 'A'\n");
} else if (v == 'a') {
  printf("Lower 'a'\n");
} else {
  printf("It is not 'A' nor 'a'\n");
}

```

lec02/switch.c

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Statements and Coding Styles Selection Statements Loops Conditional Expression

The Role of the break Statement

- The statement break terminates the branch. If not presented, the execution continues with the statement of the next case label.

Example

```

1 int part = ?
2 switch(part) {
3   case 1:
4     printf("Branch 1\n");
5     break;
6   case 2:
7     printf("Branch 2\n");
8     break;
9   case 3:
10    printf("Branch 3\n");
11    break;
12   case 4:
13    printf("Branch 4\n");
14    break;
15   default:
16    printf("Default branch\n");
17    break;
}

```

- part ← 1 Branch 1
- part ← 2 Branch 2 Branch 3
- part ← 3 Branch 3
- part ← 4 Branch 4
- part ← 5 Default branch

lec02/demo-switch_break.c

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Statements and Coding Styles Selection Statements Loops Conditional Expression

Loops

- The for and while loop statements test the controlling expression before the enter to the loop body.
 - for – initialization, condition, change of the controlling variable can be a part of the syntax.


```

for (int i = 0; i < 5; ++i) {
  ...
}

```
 - while – controlling variable out of the syntax


```

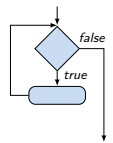
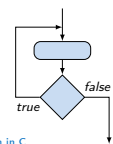
int i = 0;
while (i < 5) {
  i += 1;
}

```
- The do loop tests the controlling expression after the first loop is performed.


```

int i = -1;
do {
  i += 1;
} while (i < 5);

```

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The for Loop

- The basic form has four parts (three expressions and a single statement).
`for (expr1; expr2; expr3) statement`
- All `expr1` are expressions and typically they are used for
 - `expr1` – initialization of the controlling variable (side effect of the assignment expression);
 - `expr2` – Test of the controlling expression;
 - If `expr2 != 0` the `statement` is executed; Otherwise the loop is terminated.
 - `expr3` – updated of the controlling variable (performed at the end of the loop)
- Any of the expressions `expr1` can be omitted.
- `break` statement – force termination of the loop.
- `continue` – force end of the current iteration of the loop.
The expression `expr3` is evaluated and test of the loop is performed.
- An infinity loop can be written by omitting the expressions.
`for (;;) {...}`

The goto Statement

- `goto` allows transing the control to the defined label.
It can be used only within a function body.
- Syntax `goto label;`
- The jump `goto` can jump only outside of the particular block, it can jump to a statement.
- It can be used only within a function block.


```

1 int test = 3;
2 for (int i = 0; i < 3; ++i) {
3   for (int j = 0; j < 5; ++j) {
4     if (j == test) {
5       goto loop_out;
6     }
7     fprintf(stdout, "Loop i: %d j: %d\n", i, j);
8   }
9 }
10 return 0;
11 loop_out:
12 fprintf(stdout, "After loop\n"); // goto can jump to a label that
13 return -1;

```

Example – isPrimeNumber() 2/2

- The value of `(int)sqrt((double)n)` is not changing in the loop.


```

for (int i = 2; i <= (int)sqrt((double)n); ++i) {
  ...
}

```
 - We can use the `comma operator` to initialize the `maxBound` variable.


```

for (int i = 2, maxBound = (int)sqrt((double)n);
     i <= maxBound; ++i) {
  ...
}

```
 - Or, we can declare `maxBound` as a constant variable.


```

_Bool ret = true;
const int maxBound = (int)sqrt((double)n);
for (int i = 2; i <= maxBound; ++i) {
  ...
}

```
- E.g., Compile and run `demo-prime.c`: `clang demo-prime.c -lm; ./a.out 13`.*

The continue Statement

- It transfers the control to the evaluation of the controlling expression.
- The `continue` statement can be used inside the body of the loops.
 - `for ()`
 - `while ()`
 - `do...while ()`
- Examples


```

int i;
for (i = 0; i < 20; ++i) {
  if (i % 2 == 0) {
    continue;
  }
  printf("%d\n", i);
}

```

Nested Loops

- The `break` statement terminates the inner loop.


```

for (int i = 0; i < 3; ++i) {
  for (int j = 0; j < 3; ++j) {
    printf("i-j: %i-%i\n", i, j);
    if (j == 1) {
      break;
    }
  }
}

```
- The outer loop can be terminated by the `goto` statement.


```

for (int i = 0; i < 5; ++i) {
  for (int j = 0; j < 3; ++j) {
    printf("i-j: %i-%i\n", i, j);
    if (j == 2) {
      goto outer;
    }
  }
}
outer:

```

Conditional Expression – Example Greatest Common Divisor

- ```

1 int getGreatestCommonDivisor(int x, int y)
2 {
3 int d;
4 if (x < y) {
5 d = x;
6 } else {
7 d = y;
8 }
9 while ((x % d != 0) || (y % d != 0)) {
10 d = d - 1;
11 }
12 return d;
13 }

```
- The same with the conditional expression `expr1 ? expr2 : expr3` can be as follows.
 

```

1 int getGreatestCommonDivisor(int x, int y)
2 {
3 int d = x < y ? x : y;
4 while ((x % d != 0) || (y % d != 0)) {
5 d = d - 1;
6 }
7 return d;
8 }

```

### The break Statement – Force Termination of the Loop

- The program continue with the next statement after the loop.
- Example in the `while` loop.
 

```

int i = 10;
while (i > 0) {
 if (i == 5) {
 printf("i reaches 5, leave the loop\n");
 break;
 }
 i--;
 printf("End of the while loop i: %d\n", i);
}

```
- Example in the `for` loop.
 

```

for (int i = 0; i < 10; ++i) {
 printf("i: %i ", i);
 if (i % 3 != 0) {
 continue;
 }
 printf("\n");
 if (i > 5) {
 break;
 }
}

```

### Example – isPrimeNumber() 1/2

- ```

#include <stdbool.h>
#include <math.h>
_Bool isPrimeNumber(int n)
{
  _Bool ret = true;
  for (int i = 2; i <= (int)sqrt((double)n); ++i) {
    if (n % i == 0) {
      ret = false;
      break;
    }
  }
  return ret;
}

```
- Once the first factor is found, call `break` to terminate the loop.
It is not necessary to test other numbers.

Part III

Part 3 – Assignment HW 01

HW 01 – Assignment

Topic: ASCII art

Mandatory: 2 points; Optional: none; Bonus : none

- **Motivation:** Have a fun with loops and user parametrization of the program.
- **Goal:** Acquire experience using loops and inner loops.
- **Assignment** <https://cw.fel.cvut.cz/wiki/courses/b3b36prg/hw/hw01>
 - Read parameters specifying a picture of small house using selected ASCII chars. https://en.wikipedia.org/wiki/ASCII_art
 - Assessment of the input values.
- **Deadline:** 16.03.2024, 23:59 AoE.

AoE – Anywhere on Earth.

Part IV Part 4 – Coding Example (optional)

Coding Example – Assignment

- Implement a program that prints the pattern with seven lines.
 - The default width n is 27 characters or it is read as the first program argument (if given).
 - The width n needs to be odd number, or the program returns 100.
 - It holds $11 \leq n \leq 67$, or the program returns 101.
 - On success, the program prints seven lines and returns 0.
 - Avoid “magic numbers” in the program whenever is it possible.
- ```
 * * * * *
 * * * * *
 * * * * *
 * * * * *
 * * * * *
 * * * * *
 * * * * *
```
- Convert program `argv[1]` by `atoi()`, if given.
  - Decompose the program into printing  $7 \times$  line.
  - Implement the program infrastructure first.
  - Then, focus on logic to particular lines controlled by a suitably designed expressions.

## Coding Example – Implementation Strategy 1/4

- Define return (error) values to make the code clean (0, 100, 101), e.g., using `enum`.
  - Define valid range (11,67), e.g., using `#define`.
  - Ensure accessing passed arguments to the program only if they are passed to the program.
  - Ensure the number of lines  $n$  is a valid value or set the error program return value.
  - Perform any operation only if arguments (values) are valid.
  - Split printing 7 lines into two for loops, with one print line call between the loops.
  - Implement a function to print the line pattern.
- ```
#include <stdio.h> //for putchar()
#include <stdlib.h> //for atoi()

enum {
    ERROR_OK = 0,
    ERROR_INPUT = 100,
    ERROR_RANGE = 101
};

#define MIN_VALUE 11
#define MAX_VALUE 67

#define LINES 3

// Print line of the with n using character
// in c and space; with k continuous
// characters c followed by space.
void print(char c, int n, int k);
```

Coding Example – Implementation Strategy 2/4

- Define return (error) values to make the code clean (0, 100, 101), e.g., using `enum`.
 - Define valid range (11,67), e.g., using `#define`.
 - Ensure accessing passed arguments to the program only if they are passed to the program.
 - Ensure the number of lines n is a valid value or set the error program return value.
 - Perform any operation only if arguments (values) are valid.
 - Split printing 7 lines into two for loops, with one print line call between the loops.
 - Implement a function to print the line pattern.
- ```
...
int main(int argc, char *argv[])
{
 int ret = ERROR_OK;
 int n = argc > 1 ? atoi(argv[1]) : 27; //
 // convert argv[1] or use default value

 ret = n % 2 == 0 ? ERROR_INPUT : ret; //
 // ensure n is odd number
 if (!ret &&
 (n < MIN_VALUE || n > MAX_VALUE)) {
 ret = ERROR_RANGE; //ensure n is in the
 // closed interval [MIN_VALUE, MAX_VALUE]
 }
 ...
 return ret;
}
```

## Coding Example – Implementation Strategy 3/4

- Define return (error) values to make the code clean (0, 100, 101), e.g., using `enum`.
  - Define valid range (11,67), e.g., using `#define`.
  - Ensure accessing passed arguments to the program only if they are passed to the program.
  - Ensure the number of lines  $n$  is a valid value or set the error program return value.
  - Perform any operation only if arguments (values) are valid.
  - Split printing 7 lines into two for loops, with one print line call between the loops.
  - Implement a function to print the line pattern.
- ```
// print a line with n characters with the
// pattern: k-times c, then space.
// the line ends by new line character '\n'.
void print(char c, int n, int k);

int main(int argc, char *argv[])
{ ...
  if (!ret) { // only if ret == ERROR_OK
    for (int l = 1; l <= LINES; ++l) {
      print('*', n, l); // print l x '*'
    }
    print('*', n, n); // print n x '*'
    for (int l = LINES; l > 0; --l) {
      print('*', n, l); // print l x 'x'
    }
  }
  return ret;
}
```

Coding Example – Implementation Strategy 4/4

- Define return (error) values to make the code clean (0, 100, 101), e.g., using `enum`.
 - Define valid range (11,67), e.g., using `#define`.
 - Ensure accessing passed arguments to the program only if they are passed to the program.
 - Ensure the number of lines n is a valid value or set the error program return value.
 - Perform any operation only if arguments (values) are valid.
 - Split printing 7 lines into two for loops, with one print line call between the loops.
 - Implement a function to print the line pattern.
- ```
void print(char c, int n, int k)
{
 for (int i = 0; i < n; ++i) {
 putchar((i+1) % (k+1) ? c : ' ');
 }
 putchar('\n');
}
```
- The line consists of  $n$  characters; so  $n$  characters has to be printed.
  - Space is placed after each  $k$  characters of  $c$ .
  - Multiple of  $k$  can be detected by the remainder after division, the operator `%`.
  - We need to handle  $i$  starts from 0.
  - The space is every  $(k+1)$ -th character.

## Coding Example – Implementation Strategy 4(b)/4

- Define return (error) values to make the code clean (0, 100, 101), e.g., using `enum`.
  - Define valid range (11,67), e.g., using `#define`.
  - Ensure accessing passed arguments to the program only if they are passed to the program.
  - Ensure the number of lines  $n$  is a valid value or set the error program return value.
  - Perform any operation only if arguments (values) are valid.
  - Split printing 7 lines into two for loops, with one print line call between the loops.
  - Implement a function to print the line pattern.
- ```
void print(char c, int n, int k)
{
    int i, j;
    for (i = j = 0; i < n; ++i, ++j) {
        if (j == k) {
            putchar(' ');
            j = 0;
        } else {
            putchar(c);
        }
    }
    putchar('\n');
}
```
- Use extra counter j for space as every k -th printed character.
 - Enjoy comma operator to increment j within the `for` loop.

Summary of the Lecture

Topics Discussed

- Expressions
 - Operators – Arithmetic, Relational, Logical, Bitwise, and others
 - Operator Associativity and Precedence
 - Assignment and Compound Assignment
 - Implementation-Defined Behaviour
 - Undefined Behaviour
- Coding Styles
- Select Statements
- Loops
- Conditional Expression

- Next: Data types, memory storage classes, function call