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

Jan Faigl

Department of Computer Science
Faculty of Electrical Engineering
Czech Technical University in Prague

Lecture 02

**B3B36PRG – Programming in C**

# Overview of the Lecture

- Part 1 – Expressions
  - Expressions – Literals and Variables
  - Expressions – Operators
  - Associativity and Precedence
  - Assignment

*K. N. King: chapter 4 and 20*

- Part 2 – Control Structures: Selection Statements and Loops
  - Statements and Coding Styles
  - Selection Statements
  - Loops
  - Conditional Expression

*K. N. King: chapters 5 and 6*

- Part 3 – Assignment HW 01

# Part I

## Part 1 – Expressions

# Outline

# 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 – 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)

| | | |
|---|---|---|
| Decimal | 123 450932 | |
| Hexadecimal | 0x12 0xFAFF | (starts with `0x` or `0X`) |
| 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 typu `int`.

Rational literals

- `double` – by default, if not explicitly specified to be another type;
- `float` – suffix `F` or `f`;

```
float f = 10.f;
```

- `long double` – suffix `L` or `l`.

```
long double ld = 10.1l;
```

# 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.**

```
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');
```

- 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

| | | | | |
|---|---|---|---|---|
| 'w' | 'o' | 'r' | 'd' | '\0' |

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

# Literals – Enumeration (Constants of the Enumerated Type)

- The default values of the enumeration type constants start from 0 and the values can be explicitly prescribed.
- Without specifying a value, the next element has a value one higher than the previous one.
- Enumeration type constants can have the same values.

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

```
enum {
   SPADES = 10,
   CLUBS, // the value is 11
   HEARTS = 15,
   DIAMONDS = 13
};
```

```
enum {
   NUMBER_1 = 1,
   NUMBER_2 = 2,
   NUMBER_3 = 1,
   NUMBER_4, // the value is 2
};
```

*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) {
    ...
}
```

lec02/enum.c

# 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`;

    *None or more type quantifiers are allowed.*

  - **Type specifiers**: `void`, `char`, `short`, `int`, `long`, `float`, `double`, `signed`, `unsigned`. In addition, `struct` and `union` type specifiers can be used. Finally, own types defined by `typedef` can be used as well.

    *How many keywords are covered?*

```
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 = 100l; //constant long integer variable initialized by long literal
int i; // i variable of the common C integer type int that is not initialized
```

# Outline

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

# Operators

- Operators are selected characters (or sequences of characters) dedicated for writting 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 `−`.

    *Operator − modifies the sign of the expression.*
  - Modifying a variable : `++` and `−−`.
  - Logical negation: `!`.
  - Bitwise negation: `~`.
- Ternary operator – conditional expression `? :`.

# Variables, Assignment Operator, and Assignment Statement

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

*Or we can use CamelCase.*
*That is our coding style choice.*

```
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-value**⟩ = ⟨**expression**⟩

*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 ;.

# 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 reminder) `%`.
- 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.*

# Example – Arithmetic Operators 1/2

```c
int a = 10;
int b = 3;
int c = 4;
int d = 5;
int result;

result = a - b; // subtraction
printf("a - b = %i\n", result);

result = a * b; // multiplication
printf("a * b = %i\n", result);

result = a / b; // integer divison
printf("a / b = %i\n", result);

result = a + b * c; // priority of the operators
printf("a + b * c = %i\n", result);

printf("a * b + c * d = %i\n", a * b + c * d);         // -> 50
printf("(a * b) + (c * d) = %i\n", (a * b) + (c * d)); // -> 50
printf("a * (b + c) * d = %i\n", a * (b + c) * d);     // -> 350
```

lec02/arithmetic_operators.c

# Example – Arithmetic Operators 2/2

```c
#include <stdio.h>

int main(void)
{
   int x1 = 1;
   double y1 = 2.2357;
   float x2 = 2.5343f;
   double y2 = 2;

   printf("P1 = (%i, %f)\n", x1, y1);
   printf("P1 = (%i, %i)\n", x1, (int)y1);
   printf("P1 = (%f, %f)\n", (double)x1, (double)y1);
   printf("P1 = (%.3f, %.3f)\n", (double)x1, (double)y1);

   printf("P2 = (%f, %f)\n", x2, y2);

   double dx = (x1 - x2); // implicit data conversion to float
   double dy = (y1 - y2); // and finally to double

   printf("(P1 - P2)=(%.3f, %0.3f)\n", dx, dy);
   printf("|P1 - P2|^2=%.2f\n", dx * dx + dy * dy);
   return 0;
}
```

lec02/points.c

# Arithmetic Operators

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

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

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

# 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 reminder, 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.*

# 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 difference in writting programs that seem to be working and functional and a program that is correct.

# 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!

| **int i; int a;** | **value of i** | **value of a** |
|---|---|---|
| **i = 1; a = 9;** | **1** | **9** |
| **a = i++;** | **2** | **1** |
| **a = ++i;** | **3** | **3** |
| **a = ++(i++);** | **Not allowed! Value of i++ is not the l-value** | |

*For the unary operator `i++`, 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.*

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

# 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 | `x && y` | 1 if x and y is not 0; otherwise 0. |
| \|\| | Logical OR | `x || y` | 1 if at least one of x, y is not 0; otherwise 0. |
| ! | Logical NOT | `!x` | 1 if x is 0; otherwise 0. |

- **Operands && a || 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.

# Example – Short-Circuiting Behaviour 1/2

```c
#include <stdio.h>
#include <stdlib.h>

int fce_a(int n);
int fce_b(int n);

int main(int argc, char *argv[])
{
   if (argc > 1 && fce_a(atoi(argv[1])) && fce_b(atoi(argv[1])) )
   {
      printf("Both functions fce_a and fce_b pass the test\n");
   } else {
      printf("One of the functions does not pass the test\n");
   }
   return 0;
}

int fce_a(int n)
{
   printf("Calling fce_a with the argument '%d'\n", n);
   return n % 2 == 0;
}

int fce_b(int n)
{
   printf("Calling fce_b with the argument '%d'\n", n);
   return n > 2;
}
```

lec02/demo-short_circuiting.c

# 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.

# 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 | `x & y` | 1 if x and y is equal to 1 (bit-by-bit) |
| \| | Bitwise inclusive OR | `x \| y` | 1 if x or y is equal to 1 (bit-by-bit) |
| ˆ | Bitwise exclusive or (XOR) | `x ^ y` | 1 if only x or only y is 1 (bit-by-bit) |
| ∼ | Bitwise complement (NOT) | `~x` | 1 if x is 0 (bit-by-bit) |
| << | Bitwise left shift | `x << y` | Shift of x by y bits to the left |
| >> | Bitwise right shift | `x >> y` | Shift of x by y bits to the right |

# 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.
  - 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!

# 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

# 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 | `&x` | Pointer to x |
| * | Indirection | `*p` | Variable (or function) addressed by the pointer p. |
| [] | Array subscripting | `x[i]` | `*(x+i)` – item of the array `x` at the position `i`. |
| . | Structure/union member | `s.x` | Member `x` of the struct/union `s`. |
| -> | Structure/union member | `p->x` | 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.*

# Other Operators

| Operator | Name | Example | Result |
|---|---|---|---|
| () | Function call | `f(x)` | Call the function `f` with the argument `x`. |
| (type) | Cast | `(int)x` | Change the type of `x` to `int`. |
| sizeof | Size of the item | `sizeof(x)` | Size of `x` in bytes. |
| ? : | Conditional | `x ? y : z` | Do `y` if `x != 0`; otherwise `z`. |
| , | Comma | `x, y` | 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));
```

lec02/sizeof.c

- Example of the **comma** operator.

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

# Cast Operator

- Changing the variable type in runtime is called type cast.
- 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`.

  *C expects at least values of the* `int` *type.*
  - Operands are automatically cast to the `int` or `unsigned int`.

# Outline

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

# Operators Associativity and Precedence

- Binary operation op is **associative** on the set $\boldsymbol{S}$ if

$$(x \,\mathrm{op}\, y) \,\mathrm{op}\, z = x \,\mathrm{op} (y \,\mathrm{op}\, z), \text{ for each } x, y, z \in \boldsymbol{S}.$$

- 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.

# Outline

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

# 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

$$\langle \textbf{variable} \rangle = \langle \textbf{expression} \rangle$$

  *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.

```c
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:

$$\langle\textbf{variable}\rangle = \langle\textbf{variable}\rangle\ \langle\textbf{operator}\rangle\ \langle\textbf{expression}\rangle$$

- can be written as

$$\langle\textbf{variable}\rangle\ \langle\textbf{operator}\rangle = \langle\textbf{expression}\rangle$$

Example

```c
int i = 10;
double j = 12.6;

i = i + 1;
j = j / 0.2;
```

```c
int i = 10;
double j = 12.6;

i += 1;
j /= 0.2;
```

- Note that the assignment is an expression.

*The assignment of the value to the variable is a side effect.*

```c
int x, y;

x = 6;
y = x = x + 6;
```

# Compound Assignment

- A short version of the assignment to compute a new value of the variable from itself:

  ⟨**variable**⟩ = ⟨**variable**⟩ ⟨**operator**⟩ ⟨**expression**⟩

- can be written as

  ⟨**variable**⟩ ⟨**operator**⟩ = ⟨**expression**⟩

Example

```c
int i = 10;
double j = 12.6;

i = i + 1;
j = j / 0.2;
```

```c
int i = 10;
double j = 12.6;

i += 1;
j /= 0.2;
```

- Note that the assignment is an expression.

*The assignment of the value to the variable is a side effect.*

```c
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.
- By adding **the semicolon**, the assignment expression becomes the assignment statement.

# 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 behaves 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

# Outline

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

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

*Notice the coding styles.*

# 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.

  *Setup automatic formatting in your text editor.*

- 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.

```c
void function(void)
{ /* function block start */
   for (int i = 0; i < 10; ++i) {
      //inner for-loop block
      if (i == 5) {
         break;
      }
   }
}
```

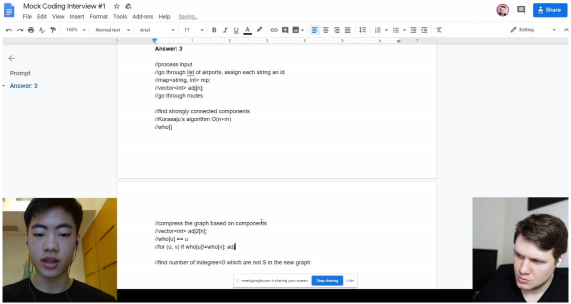
- Use English, especially for identifiers.
- Use nouns for variables.
- Use verbs for function names.

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

# 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/qz9tKlF431k

---

http://users.ece.cmu.edu/~eno/coding/CCodingStandard.html;
https://www.doc.ic.ac.uk/lab/cplus/cstyle.html;
http://en.wikipedia.org/wiki/Indent_style;
https://google.github.io/styleguide/cppguide.html;
https://www.kernel.org/doc/Documentation/process/coding-style.rst

# Compound Command and Nesting 1/2

Four nested levels.

```c
int get_sum_of_even_numbers(int from, int to)
{
   if (from < to) {
      int sum = 0;
      for (int number = from; number <= to; ++number) {
         if (number % 2 == 0) {
            sum += number;
         }
      } // end for loop
      return sum;
   } else {
      return 0;
   }
}
```

*We aim to have a more readable form.*

```c
int get_sum_of_even_numbers(int from, int to)
{
   if (from > to) return 0;
   int sum = 0;
   for (int number = from; number <= to; ++number) {
      sum += filter_odd(number);
   } // end for loop
   return sum;
}
```

Extraction (new function definition).

```c
int filter_odd(int number);

int get_sum_of_even_numbers(int from, int to)
{
   if (from < to) {
      int sum = 0;
      for (int number = from; number <= to; ++number) {
         sum += filter_odd(number);
      } // end for loop
      return sum;
   } else {
      return 0;
   }
}

int filter_odd(int number)
{
   if (number % 2 == 0) {
      return number;
   }
   return 0;
}
```

- Using extraction and inversion techniques, we reduce the nesting depth. https://youtu.be/CFRhGnuXG-4

# Compound Command and Nesting 2/2

Inversion (substitution of the input value conditions).

```c
int filter_odd(int number);

int get_sum_of_even_numbers(int from, int to)
{
   if (from > to) {
      return 0;
   }
   int sum = 0;
   for (int number = from; number <= to; ++number) {
      sum += filter_odd(number);
   } // end for loop
   return sum;
}

int filter_odd(int number)
{
   if (number % 2 == 0) {
      return number;
   }
   return 0;
}
```

Final cleanup.

```c
int filter_odd(int number);

int get_sum_of_even_numbers(int from, int to)
{
   if (from > to) return 0;
   int sum = 0;
   for (int number = from; number <= to; ++
    number) {
      sum += filter_odd(number);
   } // end for loop
   return sum;
}

int filter_odd(int number)
{
   return (number % 2 == 0) ? number : 0;
}
```

https://youtu.be/CFRhGnuXG-4

- Using extraction and inversion techniques, we reduce the nesting depth.

# 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`

# Outline

- Statements and Coding Styles
- Selection Statements
- Loops
- Conditional Expression

# Selection Statement – `if`

- `if (expression) statement`$_1$`; else statement`$_2$
- For `expression != 0` the `statement`$_1$ is executed; otherwise `statement`$_2$.

  *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.

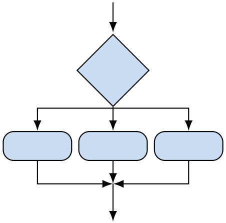
```c
int max;
if (a > b) {
   if (a > c) {
      max = a;
   }
}
```

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

# 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 constant_1: statements_1; break;
    case constant_2: statements_2; break;
    ...
    case constant_n: statements_n; break;
    default: statements_def; 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).*

# The switch Statement – Example

```c
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");
      break;
}
```

```c
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

# 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.

```c
int part = ?
switch(part) {
   case 1:
      printf("Branch 1\n");
      break;
   case 2:
      printf("Branch 2\n");
   case 3:
      printf("Branch 3\n");
      break;
   case 4:
      printf("Branch 4\n");
      break;
   default:
      printf("Default branch\n");
      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

# Outline

- Statements and Coding Styles
- Selection Statements
- Loops
- Conditional Expression

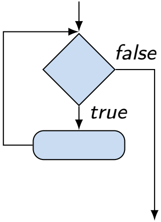
# Loops

- 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 is a part of the syntax.

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

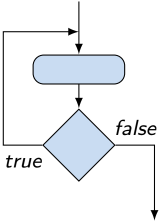
  - **while** – controlling variable is out of the syntax

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




- The **do** loop tests the controlling expression after the 1st loop is performed.

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



# The **for** Loop

- The basic form has four parts (three expressions and a single statement).

  `for (expr1; expr2; expr3) statement`

- All $\texttt{expr}_i$ are expressions and typically they are used for
  1. $\texttt{expr}_1$ – initialization of the controlling variable (side effect of the assignment expression);
  2. $\texttt{expr}_2$ – Test of the controlling expression;
  3. If $\texttt{expr}_2$ `!=0` the `statement` is executed; Otherwise the loop is terminated.
  4. $\texttt{expr}_3$ – updated of the controlling variable (performed at the end of the loop
- Any of the expressions $\texttt{expr}_i$ can be omitted.
- **break** statement – force termination of the loop.
- **continue** – force end of the current iteration of the loop.

  *The expression $\texttt{expr}_3$ is evaluated and test of the loop is performed.*

- An infinity loop can be written by omitting the expressions.

  `for (;;) {...}`

# 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 ()`

```
int i;
for (i = 0; i < 20; ++i) {
   if (i % 2 == 0) {
      continue;
   }
   printf("%3d", i);
}
putchar('\n');
```

lec02/continue.c

```
$ clang continue.c && ./a.out
1  3  5  7  9 11 13 15 17 19
```

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

lec02/demo-continue.c

```
$ clang demo-continue.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
i:7 i:8 i:9
```

# 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 ()`

```c
int i;
for (i = 0; i < 20; ++i) {
   if (i % 2 == 0) {
      continue;
   }
   printf("%3d", i);
}
putchar('\n');
```

lec02/continue.c

```
$ clang continue.c && ./a.out
1  3  5  7  9 11 13 15 17 19
```

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

lec02/demo-continue.c

```
$ clang demo-continue.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
i:7 i:8 i:9
```

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  - `while ()`
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```c
int i;
for (i = 0; i < 20; ++i) {
   if (i % 2 == 0) {
      continue;
   }
   printf("%3d", i);
}
putchar('\n');
```

lec02/continue.c

```
$ clang continue.c && ./a.out
1  3  5  7  9 11 13 15 17 19
```

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

lec02/demo-continue.c

```
$ clang demo-continue.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
i:7 i:8 i:9
```

# The continue Statement

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- The `continue` statement can be used inside the body of the loops.
  - `for ()`
  - `while ()`
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   if (i % 2 == 0) {
      continue;
   }
   printf("%3d", i);
}
putchar('\n');
```

lec02/continue.c

```
$ clang continue.c && ./a.out
1  3  5  7  9 11 13 15 17 19
```

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

lec02/demo-continue.c

```
$ clang demo-continue.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
i:7 i:8 i:9
```

# The break Statement – Force Termination of the Loop

- The program continues with the next statement after the loop.

- `break` example in the `while` loop.

```
int i = 10;
while (i > 0) {
   if (i == 5) {
      printf("i reaches 5, leave the loop\n");
      break;
   }
   i--; // or -i; or i -= 1; or i = i - 1;
   printf("End of the while loop i: %d\n", i);
}
```

```
$ clang break.c
$ ./a.out
End of the while loop i: 9
End of the while loop i: 8
End of the while loop i: 7
End of the while loop i: 6
End of the while loop i: 5
i reaches 5, leave the loop
```

lec02/break.c

- `continue` and `break` 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;
   }
}
```

```
$ clang demo-break.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
```

lec02/demo-break.c

# The break Statement – Force Termination of the Loop

- The program continues with the next statement after the loop.

- `break` example in the `while` loop.

```c
int i = 10;
while (i > 0) {
   if (i == 5) {
      printf("i reaches 5, leave the loop\n");
      break;
   }
   i--; // or -i; or i -= 1; or i = i - 1;
   printf("End of the while loop i: %d\n", i);
}
```

```
$ clang break.c
$ ./a.out
End of the while loop i: 9
End of the while loop i: 8
End of the while loop i: 7
End of the while loop i: 6
End of the while loop i: 5
i reaches 5, leave the loop
```

lec02/break.c

- `continue` and `break` example in the `for` loop.

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

```
$ clang demo-break.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
```

lec02/demo-break.c

# The break Statement – Force Termination of the Loop

- The program continues with the next statement after the loop.

  - `break` example in the `while` loop.

```c
int i = 10;
while (i > 0) {
   if (i == 5) {
      printf("i reaches 5, leave the loop\n");
      break;
   }
   i--; // or -i; or i -= 1; or i = i - 1;
   printf("End of the while loop i: %d\n", i);
}
```

```
$ clang break.c
$ ./a.out
End of the while loop i: 9
End of the while loop i: 8
End of the while loop i: 7
End of the while loop i: 6
End of the while loop i: 5
i reaches 5, leave the loop
```

lec02/break.c

  - `continue` and `break` example in the `for` loop.

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

```
$ clang demo-break.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
```

lec02/demo-break.c

# The break Statement – Force Termination of the Loop

- The program continues with the next statement after the loop.

- `break` example in the `while` loop.

```c
int i = 10;
while (i > 0) {
   if (i == 5) {
      printf("i reaches 5, leave the loop\n");
      break;
   }
   i--; // or -i; or i -= 1; or i = i - 1;
   printf("End of the while loop i: %d\n", i);
}
```

```
$ clang break.c
$ ./a.out
End of the while loop i: 9
End of the while loop i: 8
End of the while loop i: 7
End of the while loop i: 6
End of the while loop i: 5
i reaches 5, leave the loop
```

lec02/break.c

- `continue` and `break` example in the `for` loop.

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

```
$ clang demo-break.c
$ ./a.out
i:0
i:1 i:2 i:3
i:4 i:5 i:6
```

lec02/demo-break.c

# The goto Statement

- goto allows transfing the control to the defined label. *It can be used only within a function body.*
- Syntax `goto label;`.
- The goto can jump only outside of the particular block, it jumps to a statement.
- Label is not a statement! *Add empty statement ; if necessary.*

```c
int test = 3;
for (int i = 0; i < 3; ++i) {
   for (int j = 0; j < 5; ++j) {
      if (j == test) {
         goto loop_out;
      }
      fprintf(stdout, "Loop i: %d j: %d\n", i, j);
   }
}
return 0;
loop_out:
fprintf(stdout, "After loop\n"); // goto can jump to a label that represents statement (there must be an address to be jumped at).
return -1;
```

lec02/goto.c

# 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; ++i) {
      printf("i-j: %i-%i\n", i, j);
      if (j == 2) {
         goto outer;
      }
   }
}
outer:
;
```

lec02/demo-goto.c

# Nested Loops

- The **break** statement terminates the inner loop.

```c
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;
      }
   }
}
```

```
i-j: 0-0
i-j: 0-1
i-j: 1-0
i-j: 1-1
i-j: 2-0
i-j: 2-1
```

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

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

lec02/demo-goto.c

# 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;
      }
   }
}
```

```
i-j: 0-0
i-j: 0-1
i-j: 1-0
i-j: 1-1
i-j: 2-0
i-j: 2-1
```

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

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

lec02/demo-goto.c

# 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;
      }
   }
}
```

```
i-j: 0-0
i-j: 0-1
i-j: 1-0
i-j: 1-1
i-j: 2-0
i-j: 2-1
```

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

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

```
i-j: 0-0
i-j: 0-1
i-j: 0-2
```

lec02/demo-goto.c

# Example – isPrimeNumber() 1/2

```c
#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;
}
```

lec02/demo-prime.c

- Once the first factor is found, call break to terminate the loop.

*It is not necessary to test other numbers.*

# 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 define 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.

# Outline

- Statements and Coding Styles
- Selection Statements
- Loops
- Conditional Expression

# Conditional Expression – Example Greatest Common Divisor

```
int getGreatestCommonDivisor(int x, int y)
{
   int d;
   if (x < y) {
      d = x;
   } else {
      d = y;
   }
   while ( (x % d != 0) || (y % d ! = 0)) {
      d = d - 1;
   }
   return d;
}
```

- The same with the conditional expression **$expr_1$ ? $expr_2$ : $expr_3$** can be as follows.

```
int getGreatestCommonDivisor(int x, int y)
{
   int d = x < y ? x : y;
   while ( (x % d != 0) || (y % d ! = 0)) {
      d = d - 1;
   }
   return d;
}
```

lec02/demo-gcd.c

# Conditional Expression – Example Greatest Common Divisor

```
int getGreatestCommonDivisor(int x, int y)
{
   int d;
   if (x < y) {
      d = x;
   } else {
      d = y;
   }
   while ( (x % d != 0) || (y % d ! = 0)) {
      d = d - 1;
   }
   return d;
}
```

- The same with the conditional expression **$expr_1$ ? $expr_2$ : $expr_3$** can be as follows.

```
int getGreatestCommonDivisor(int x, int y)
{
   int d = x < y ? x : y;
   while ( (x % d != 0) || (y % d ! = 0)) {
      d = d - 1;
   }
   return d;
}
```

lec02/demo-gcd.c

# 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`
  - Assesment of the input values.
- Deadline: 15.03.2025, 23:59 AoE.

*AoE – Anywhere on Earth.*

# 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

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# Part V

## Appendix

# Outline

- Coding Example
- Summary of the Operators and Precedence

# 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 possible.

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

- Convert program `argv[1]` by `atoi()`, if given.
- Decompose the program into printing 7× line.
- Implement the program infrastructure first.
- Then, focus on logic to particular lines controlled by a suitably designed **expressions**.

# Coding Example – Assignment

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** ** ** ** ** ** ** ** ** ** ** **
*** *** *** *** *** *** *** *** ***
***********************************
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** ** ** ** ** ** ** ** ** ** ** **
* * * * * * * * * * * * * * * * * *
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- Convert program `argv[1]` by `atoi()`, if given.
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# 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 $\langle 11, 67\rangle$, 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.
- Peform 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.

```c
#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 $\langle 11, 67 \rangle$, 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.
- Peform 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.

```c
...
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 $\langle 11, 67\rangle$, 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.
- Peform 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.

```c
// 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 $\langle 11, 67 \rangle$, 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.
- Peform 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.

```c
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 $\langle 11, 67 \rangle$, 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.
- Peform 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.

```c
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.

# Outline

# Summary of the Operators and Precedence 1/3

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

# Summary of the Operators and Precedence 2/3

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

# Summary of the Operators and Precedence 3/3

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

K. N. King: Page 735

http://en.cppreference.com/w/c/language/operator_precedence