Introducing C

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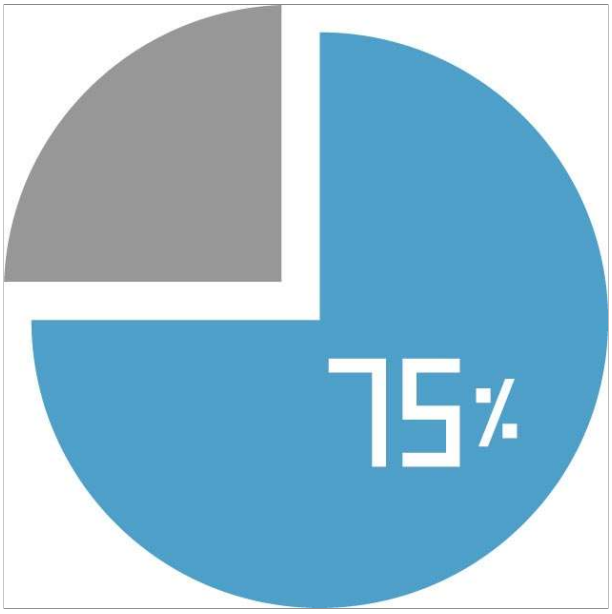
Sep. 27, 2021

Questionnaire



75% of students are new to programming.

To C Beginners

From Beginners to Masters

Programming

De-programming

What is C?

C is a *computer* programming language (PL).

You communicate your ideas to computers via PLs.

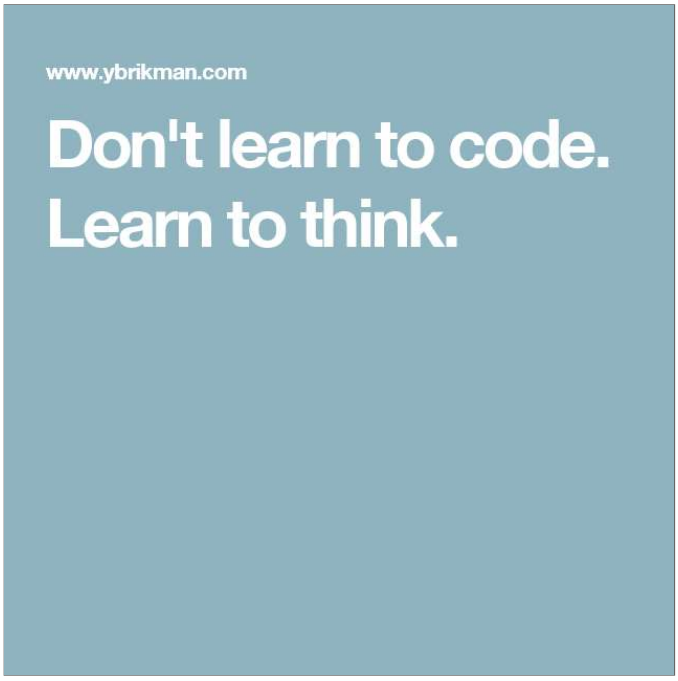
What is C?

Programming is *NOT* (only) about languages.

Programming is not about C.

You learn C to express YOUR IDEAS.

How to Learn (1)?



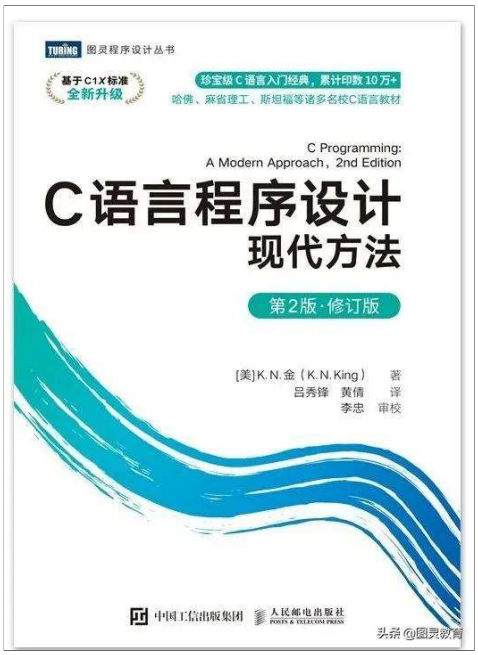
How to Learn (2)?

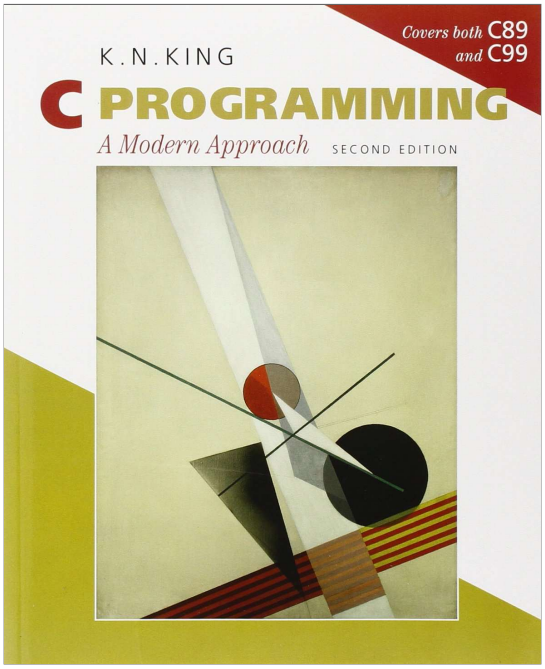
"无他, 但手熟尔"

How to Learn (3)?

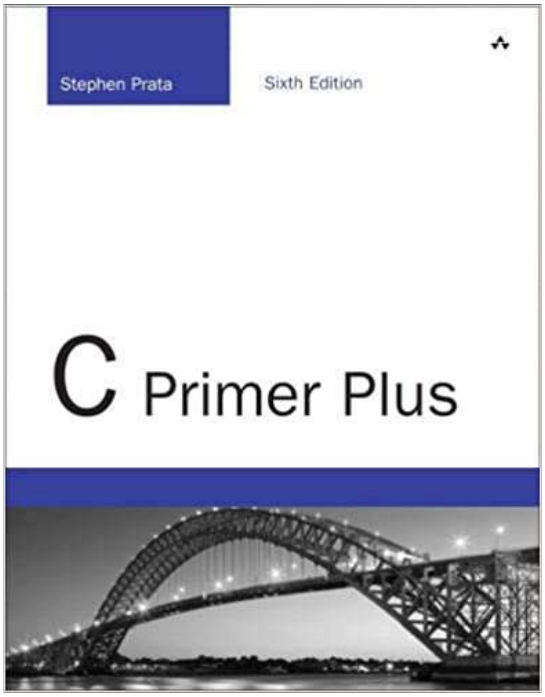
How many *bugs* have you ever produced?

C Programming:
A Modern Approach

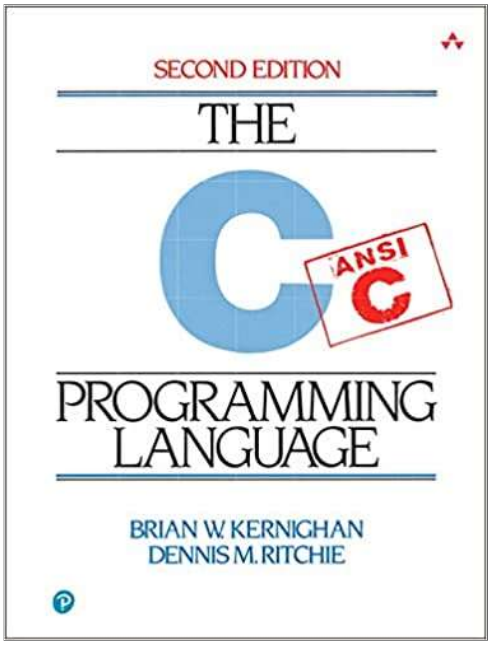


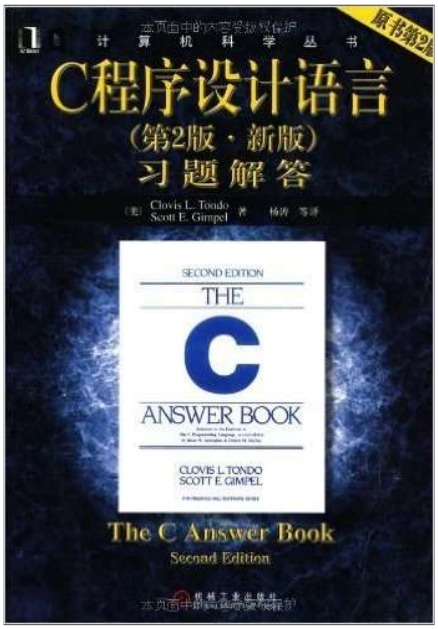


C Primer Plus



K&R C Bible


SECOND EDITION
THE
C
ANSI
C
PROGRAMMING
LANGUAGE
BRIAN W. KERNIGHAN
DENNIS M. RITCHIE


计 算 机 科 学 丛 书
C程序设计语言
(第2版·新版)
习题解答
Clovis L. Tondo
Scott E. Gimpel
SECOND EDITION
THE
C
ANSI C
ANSWER BOOK
CLOVIS L. TONDO
SCOTT E. GIMPEL
The C Answer Book
Second Edition

K&R

Brian W. Kernighan (1942 ~)

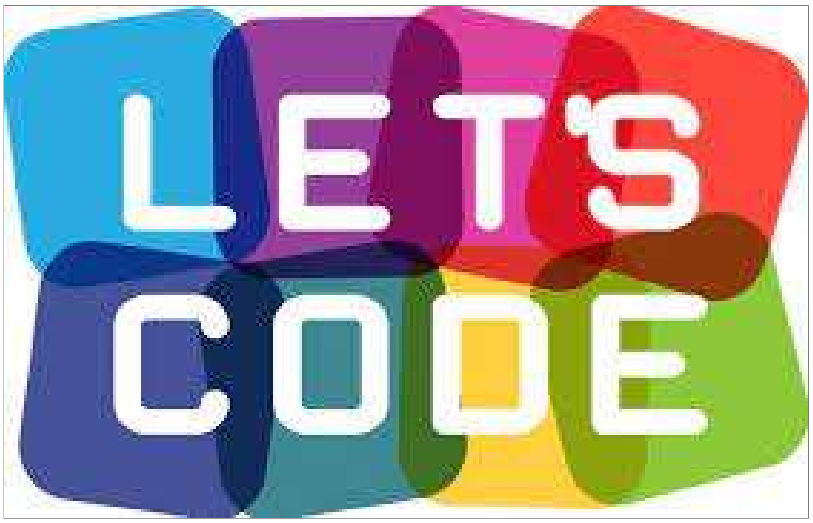
Dennis M. Ritchie (1941 ~ 2011)

Examination and Scores

- ~~考勤~~
- ~~期中测试~~
- ~~期末笔试~~
- 期末机试 (30 分)
- 编程练习 (70 分)
- 奖励

编程练习: 每周基础训练 (40 分) + 学期项目 (30 分; 2 个)

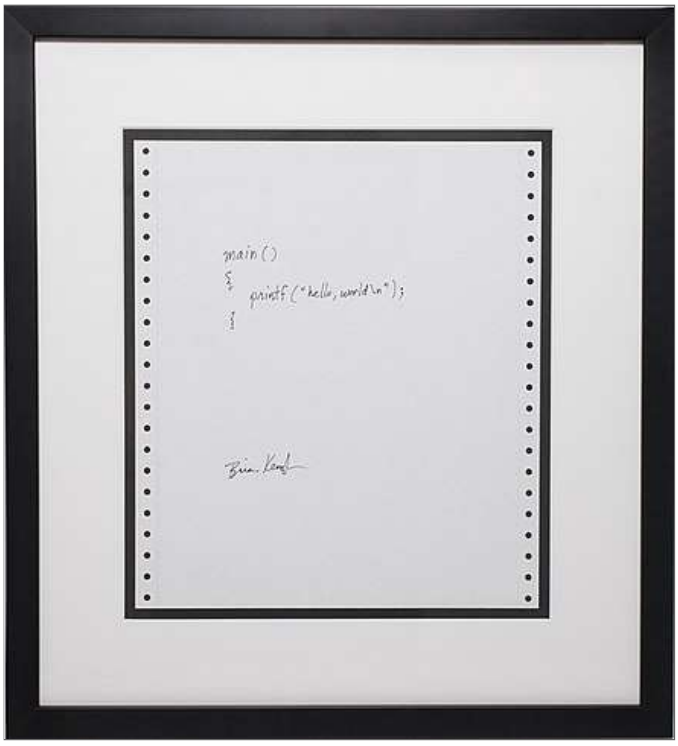
Q&A


LET'S
CODE

CLion

"你有你的选择, 而我选择 CLion"

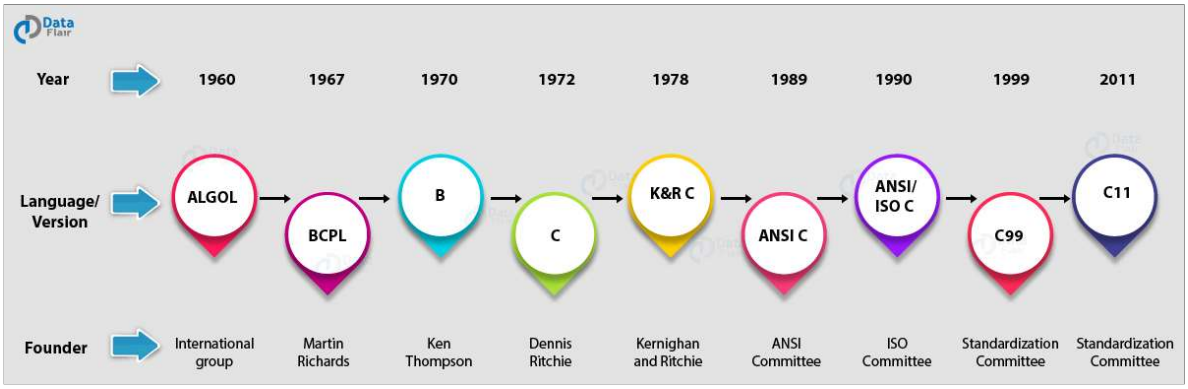
Hello World (K&R C)



Hello World (Standard C)

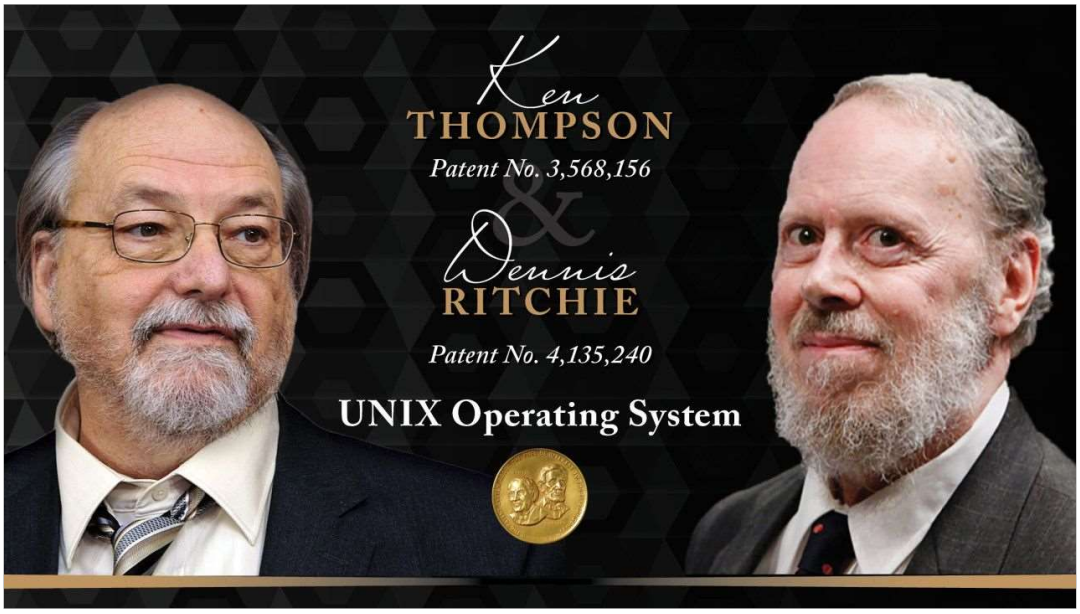
```c
#include <stdio.h>

int main() {
  printf("Hello World\n");
  return 0;
}
```

Brief History of C



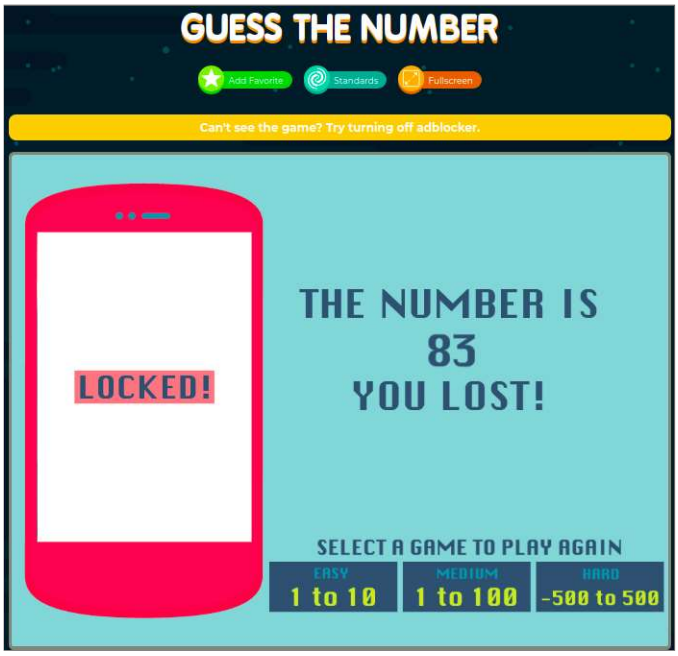
You do *not* have to become a *language lawyer*.

Brief History of C



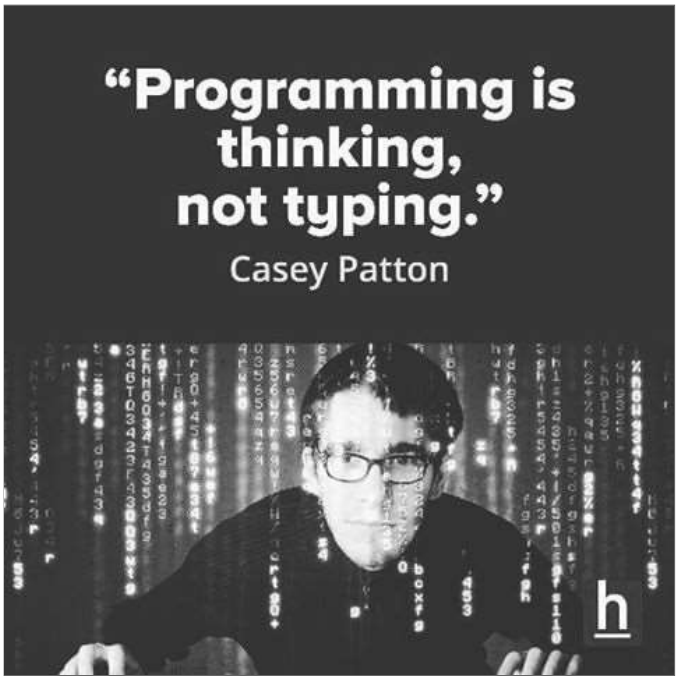
Turing Award (1983)

Game: Guess the Number



Guess the Number

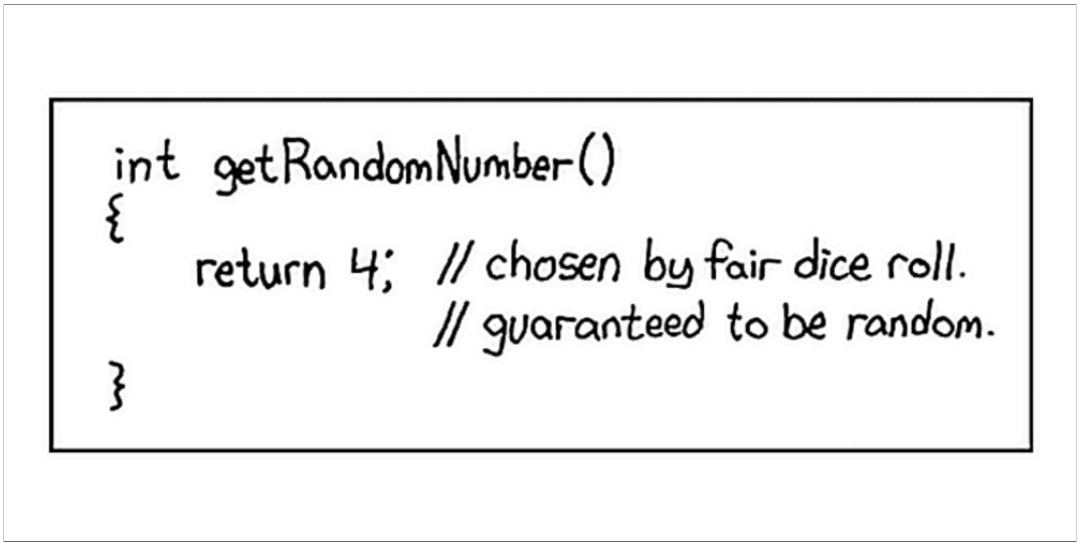
Game: Guess the Number



You think. I will type it for you.

How to Obtain a Random Number?

How to Obtain a Random Number?

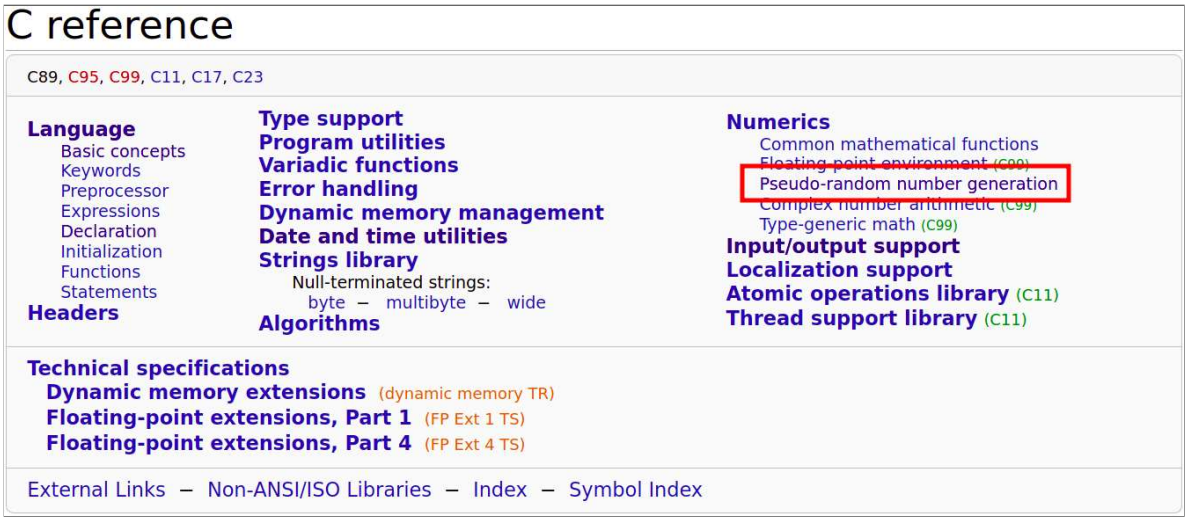


How to Obtain a Random Number?

$s \qquad f(s) \qquad f(f(s)) \qquad \ldots$

pseudo-random number sequence

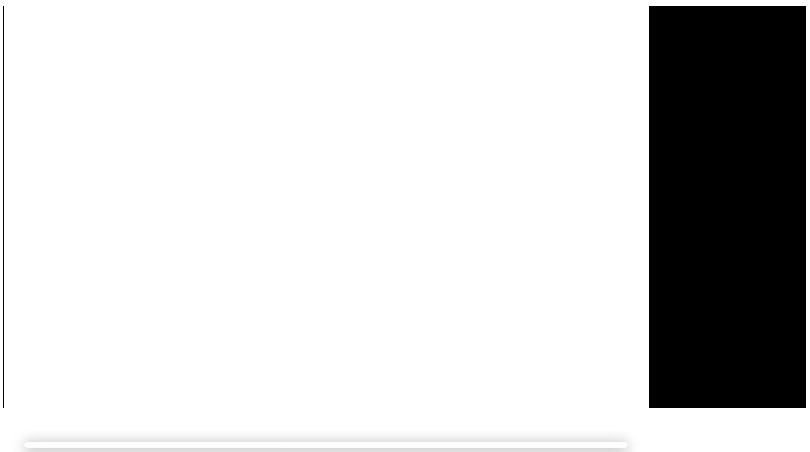
How to Obtain a Random Number?



https://en.cppreference.com/w/c

Code Style

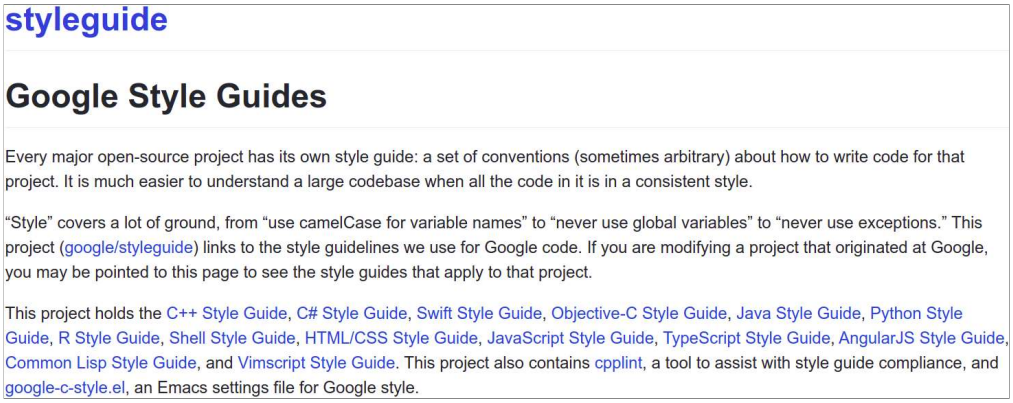
Braces



Tabs vs. Spaces

Code Style in CLion

Programming Style Guide



styleguide

Google Style Guides

Every major open-source project has its own style guide: a set of conventions (sometimes arbitrary) about how to write code for that project. It is much easier to understand a large codebase when all the code in it is in a consistent style.

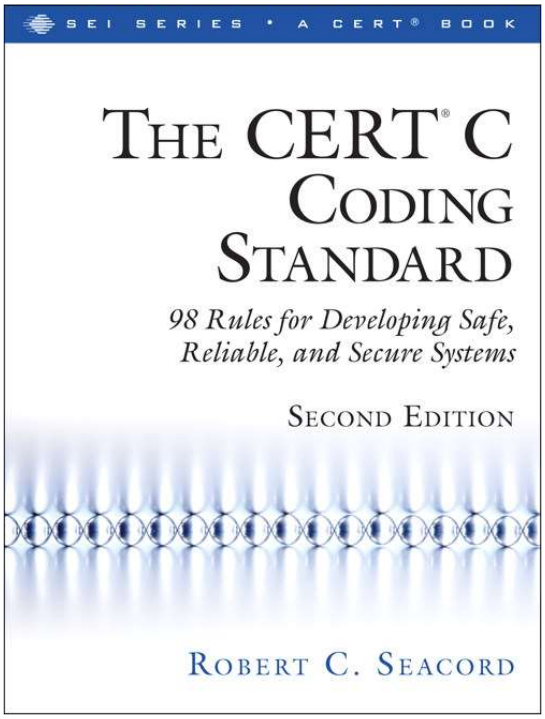
“Style” covers a lot of ground, from “use camelCase for variable names” to “never use global variables” to “never use exceptions.” This project (google/styleguide) links to the style guidelines we use for Google code. If you are modifying a project that originated at Google, you may be pointed to this page to see the style guides that apply to that project.

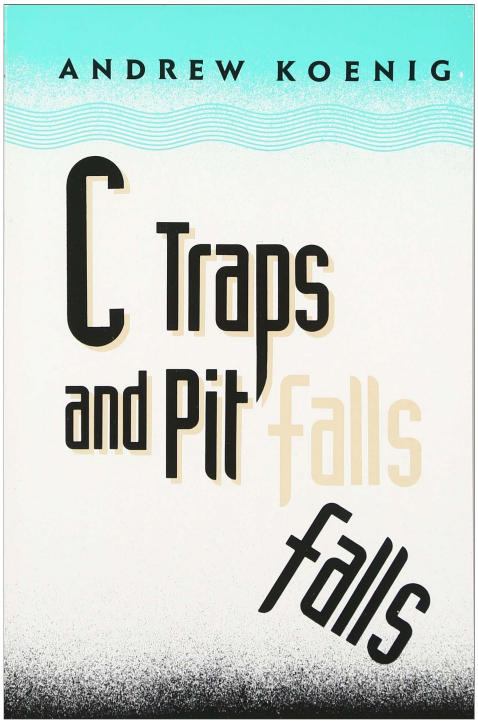
This project holds the C++ Style Guide, C# Style Guide, Swift Style Guide, Objective-C Style Guide, Java Style Guide, Python Style Guide, R Style Guide, Shell Style Guide, HTML/CSS Style Guide, JavaScript Style Guide, TypeScript Style Guide, AngularJS Style Guide, Common Lisp Style Guide, and Vimscript Style Guide. This project also contains cpplint, a tool to assist with style guide compliance, and google-c-style.el, an Emacs settings file for Google style.

Google Style Guides

华为C语言编程指南.pdf

Secure C


SEI SERIES • A CERT® BOOK
THE CERT® C CODING STANDARD
98 Rules for Developing Safe, Reliable, and Secure Systems
SECOND EDITION
ROBERT C. SEACORD


ANDREW KOENIG
C Traps and Pitfalls

How to Obtain a Random Number (Revisited)?

G.OTH.03 禁用rand函数产生用于安全用途的伪随机数

【描述】
rand()函数生成的随机数是可以预测的，所以禁止使用rand()函数生成的随机数用于安全用途，必须使用安全的随机数生成方式，如：类Unix平台的/dev/random文件。

典型的安全用途场景包括（但不限于）以下几种：

- 会话标识SessionID的生成；
- 挑战算法中的随机数生成；
- 验证码的随机数生成；
- 用于密码算法用途（例如用于生成IV、盐值、密钥等）的随机数生成。

What is Next?

- Variables and Types (`int`, `double`)
- Math: computer arithmetic
- Input/Ouput (I/O)

- Branching: "if/else", "switch/case"
- Looping: "while", "do/while", "for"
- Jumps: "break", "continue", "goto"

- Functions & Libraries

Keeping Programming

GitHub Classroom @ Bilibili

No Plagiarism!!!

前两次各扣 10 分, 第三次总分降为 60 分 $(\times 60\%)$

Resources

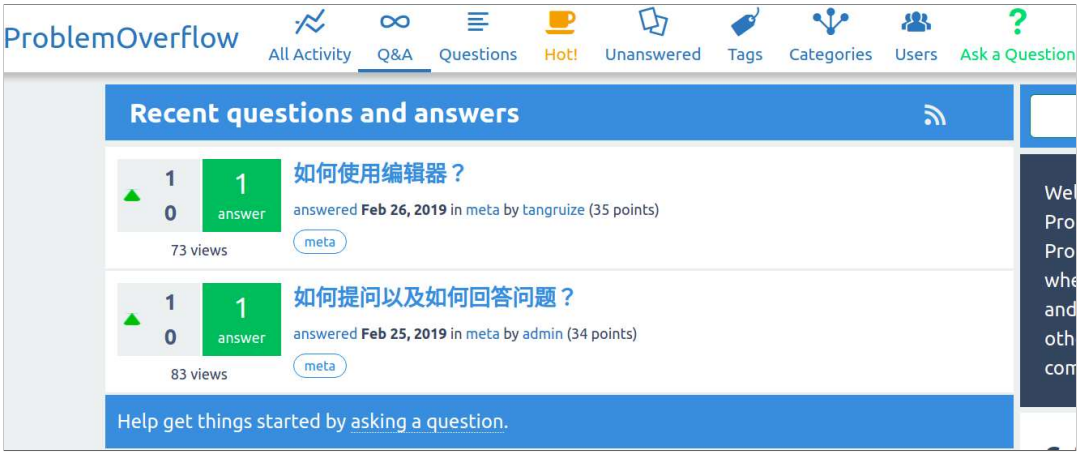
6735 99232 2021-C-PL

Resources

教学立方 PedagogySquare

发布课件、资料、调查问卷等

Resources



problemoverflow.cn


SEE
YOU
NEXT
WEEK

Variables, Types, IO

Hengfeng Wei

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Oct. 11, 2021

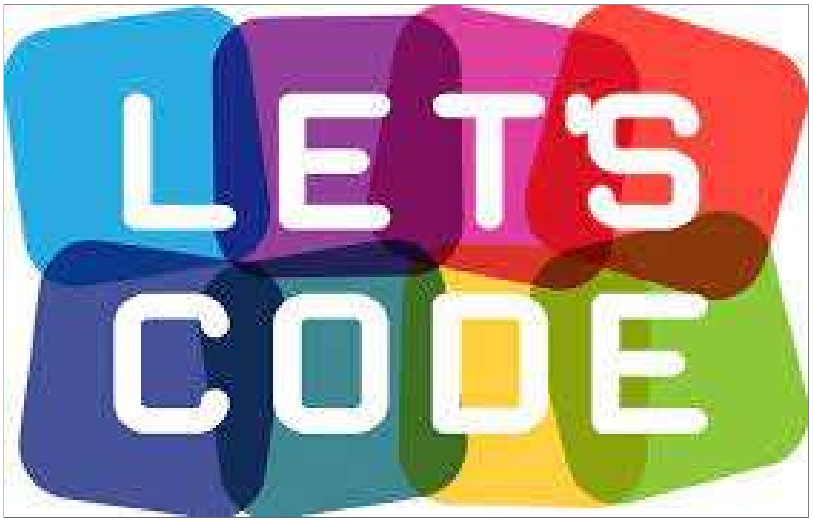
Overview

Variables (变量)　Constants (常量)
Data Types (数据类型)

Operators (运算符)　Expressions (表达式)
Assignment Statements (赋值语句)

I/O (Input/Output; 输入输出)

"Talk is Cheap. Show me the Code."



circle.c sphere.c mol.c admin.c

Circle

Given a radius (10) of a circle,
to compute its circumference and area.
$L = 2\pi r \quad S = \pi r^2$

- 每个结果各占一行
- 小数点后保留两位

Declaration (声明)

```
int radius = 10;
```

- Introduce a *variable* called `radius`.
- You can use `radius` later.
- The type of `radius` is `int` (integer).
- `radius` is *initialized* (初始化) to `10`.
- You can *assign* (赋值) other values to `radius`.
- `radius` refers to a *location* (`&radius`) in memory.

Definition (定义)

`int radius = 10;` is also a *definition*.

Any definitions are declarations.
~~All declarations are definitions~~ (at least for now).

Identifiers (标识符)

```
int radius = 10;
```

The name `radius` is an *identifier*.

- made up of letters, numbers, and underscores
- do *not* start with a number

Identifiers

- Use meaningful identifiers
- `surface_area` *vs.* `surfaceArea`

Operators and Expressions

```
double circumference = 2 * PI * radius;
```

Assignment Statements

```
double circumference = 0;

circumference = 2 * PI * radius;
```

Sphere

Given a radius (100) of a sphere,
to compute its surface area and volume.
$A = 4\pi r^2 \quad V = \frac{4}{3}\pi r^3$

- 每个结果各占一行
- 小数点后保留四位
- 每个结果至少占15字符, 左对齐
    - _____ : surface_area
    - _____ : volume

mol

---

6 克氧气的物质的量是多少?

$$Q = 6/32 \times 6.02 \times 10^{23}$$

两种格式输出, 结果均使用科学计数法表示

- 第一行结果, 小数点后保留三位
- 第二行结果, 保留五位有效数字

Data Types

- `int` ($\approx \mathbb{Z}$)
- `double` ($\approx \mathbb{R}$)
- `char` (Character; 字符)
- `C string` (char array; 字符数组)

int ≈ ℤ

INT_MIN INT_MAX

printf("INT_MIN = %d \t INT_MAX = %d\n", INT_MIN, INT_MAX);

A (Naive) Administration System

- Name (EN)
- Gender (F/M)
- Birthday (mm-dd-yyyy)
- Weekday (Xyz.)
- C
- Music
- Medicine
- Mean (.d)
- Standard Deviation (.dd)
- Ranking (%)

A (Naive) Administration System

- 每组信息占一行
- 各项信息使用 "TAB" 间隔
- 各项信息要遵循特定格式要求

罗大佑

Data Types: char

	_0	_1	_2	_3	_4	_5	_6	_7	_8	_9	_A	_B	_C	_D	_E	_F
0_ 0	NUL 0000	SOH 0001	STX 0002	ETX 0003	EOT 0004	ENQ 0005	ACK 0006	BEL 0007	BS 0008	HT 0009	LF 000A	VT 000B	FF 000C	CR 000D	SO 000E	SI 000F
1_ 16	DLE 0010	DC1 0011	DC2 0012	DC3 0013	DC4 0014	NAK 0015	SYN 0016	ETB 0017	CAN 0018	EM 0019	SUB 001A	ESC 001B	FS 001C	GS 001D	RS 001E	US 001F
2_ 32	SP 0020	! 0021	" 0022	# 0023	$ 0024	% 0025	& 0026	' 0027	(0028	) 0029	* 002A	+ 002B	, 002C	- 002D	. 002E	/ 002F
3_ 48	0 0030	1 0031	2 0032	3 0033	4 0034	5 0035	6 0036	7 0037	8 0038	9 0039	: 003A	; 003B	< 003C	= 003D	> 003E	? 003F
4_ 64	@ 0040	A 0041	B 0042	C 0043	D 0044	E 0045	F 0046	G 0047	H 0048	I 0049	J 004A	K 004B	L 004C	M 004D	N 004E	O 004F
5_ 80	P 0050	Q 0051	R 0052	S 0053	T 0054	U 0055	V 0056	W 0057	X 0058	Y 0059	Z 005A	[005B	\ 005C	] 005D	^ 005E	_ 005F
6_ 96	` 0060	a 0061	b 0062	c 0063	d 0064	e 0065	f 0066	g 0067	h 0068	i 0069	j 006A	k 006B	l 006C	m 006D	n 006E	o 006F
7_ 112	p 0070	q 0071	r 0072	s 0073	t 0074	u 0075	v 0076	w 0077	x 0078	y 0079	z 007A	{ 007B	| 007C	} 007D	~ 007E	DEL 007F

- `isdigit isalpha isalnum`
- `islower isupper tolower toupper`
- `isspace` (including , `\n`, `\t`)

Data Types: C string

```
char first_name[] = "Tayu";
```

A C string is an array of characters.

'\0': terminating null character

'T', 'a', 'y', 'u', '\0'

```
char first_name[5] = "Tayu";
char first_name[10] = "Tayu";
```

~~`char first_name[2] = "Tayu";`~~

```
int printf(const char *format, ...);
```

- `format`: format string (格式串)
- `...`: variable argument list (可变长参数列表)

```
int printf(const char *format, ...);
```

The `format` string consists of

- ordinary characters (not %)
- conversion specifications (转换说明)
    - each of which is introduced by %

```
int printf(const char *format, ...);
```

Escape sequence (转义序列)

- \n: Newline
- \t: Horizontal Tab
- \": Double quotation mark
- \' : Single quotation mark
- \\: Backslash
- \b: Backspace

```
int printf(const char *format, ...);
```

%specifier	Argument	Output
%d (%i)	int	decimal ([-]dddd)
%f	double	decimal ([-]ddd.ddd)
%e (%E)	double	decimal ([-]d.ddde[+-]dd)
%g (%G)	double	%f or %e

```
int printf(const char *format, ...);
```

%specifier	Argument	Output
%c	int	character
%s	pointer to a char array	string
%%		%

"It is up to you to ensure that
the type of the actual argument
matches the type expected by conversion specifiers."

printf

%[flags][width][.precision]specifier

```
int printf(const char *format, ...);
```

- flags
  - -: left-justified (otherwise, right-justified)
  - +: always begin with a plus or minus *sign*

%[flags][width][.precision]specifier

```
int printf(const char *format, ...);
```

- width
  - *minimum* field width
  - padded with spaces if it has fewer characters

printf

`%[flags][width][.precision]specifier`

```
int printf(const char *format, ...);
```

- %d, %i: *minimum* number of digits
  - expanded with leading zeros when needed
- %f, %e, %E: *number* of digits after '.'
  - default is 6
- %g, %G: *maximum* number of significant digits
- %s: *maximum* number of characters

```
int scanf(const char *format, ...);
```

- `format`: format string (格式串)
- `...`: variable argument list (可变长参数列表)

```
int scanf(const char *format, ...);
```

The `format` string consists of

- white-space characters
- ordinary characters
  - neither % nor white-spaces
- conversion specifications
  - each of which is introduced by %

```
int scanf(const char *format, ...);
```

- Scan the input stream from left to right
- Identify expected items as long as possible

```
int scanf(const char *format, ...);
```

%specifier	Matched Item	Argument
%d	skip white-spaces; matches an `int`	pointer to `int`
%le, %lf, %lg	skip white-spaces; matches a `double`	pointer to `double`
%e, %f, %g	skip white-spaces; matches a `float`	pointer to `float`

%specifier	Matched Item	Argument
%c	a character	pointer to a `char`
%s	a sequence of non-white-spaces	pointer to a `char` array
%[abc]	scanlist	pointer to a `char` array
%[^abc]	not in scanlist	pointer to a `char` array
%%	%	

%[⋆][width]specifier

```
int scanf(const char *format, ...);
```

- ⋆: assignment-suppressing
- width: *maximum* field width

"It is up to you to ensure that
the type of each actual argument pointer
matches the type expected by conversion specifiers."

References

printf @ cppreference

scanf @ cppreference

References

Do not use `scanf`. Use . . . instead.

If, For, Array

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Oct. 18, 2021

Review

Variables Constants Data Types

Operators Expressions Assignment Statements

I/O (Input/Output)

Constants

- int: 42
- double: 3.14
- char: 'c'
- string: "Hello World"

Literal constants (字面常量)

```
const double PI = 3.14159;
```
PI is still a *variable*.

Overview

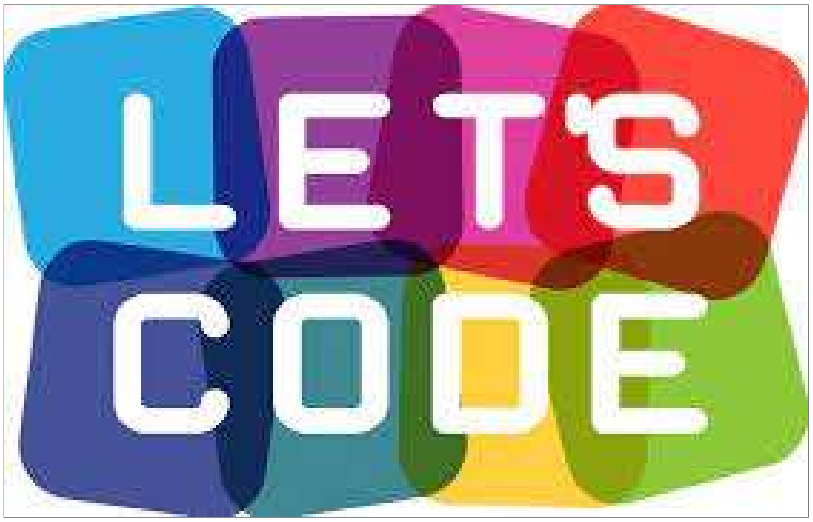
If Statement (If 语句)

For Statement (For 语句)

Logical Expressions (逻辑表达式)

Array (数组)

"Talk is Cheap. Show me the Code."



min leap
sum.c min.c

Min

Min of Two

Given two integers a and b,
to compute their minimum.

$min = \min\{a, b\}$

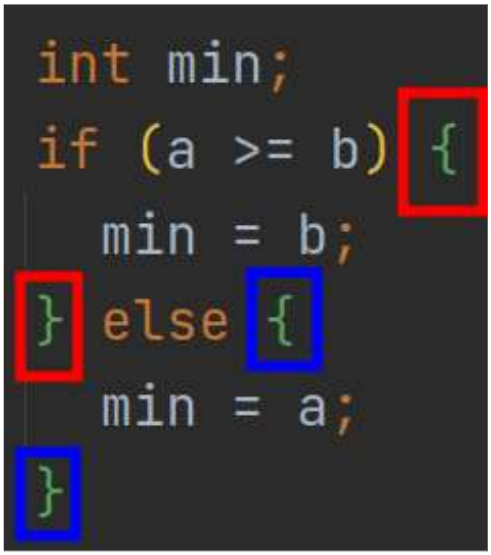
`if`

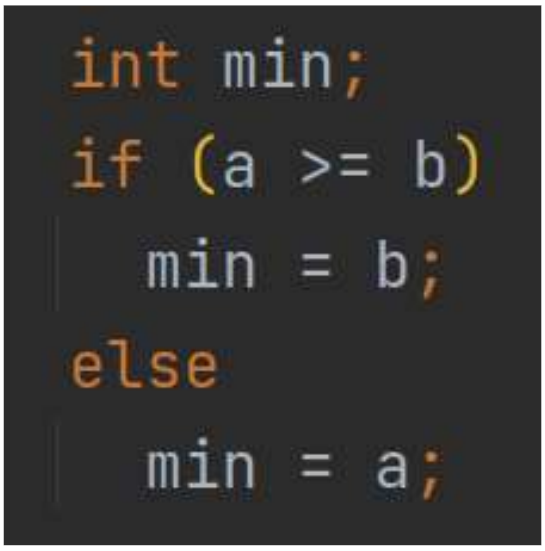
```
int min;
if (a >= b) {
  min = b;
} else {
  min = a;
}
```

The `else` part is *optional*.

`if`

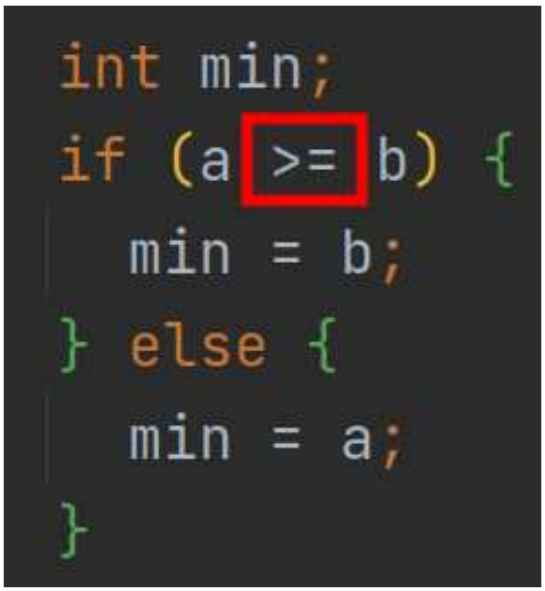
Multiple declarations and statements surrounded by `{}`





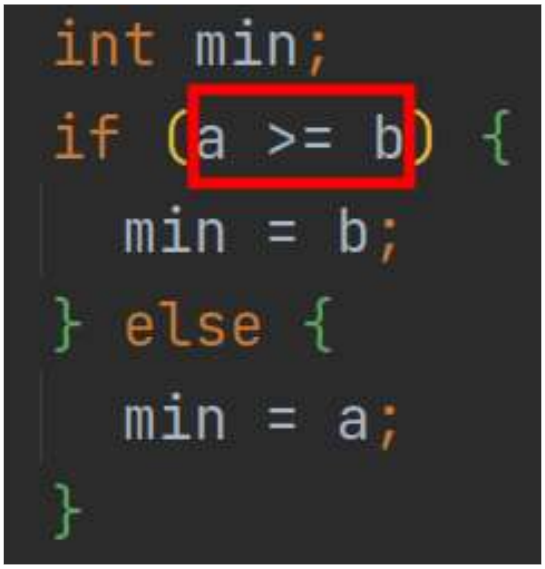
Always Use `{}`!

Relational Operators (关系运算符)



- >=
- <=
- >
- <
- == (equal to)
- != (not equal to)

Relational Expressions (关系表达式)



Relational expressions have values 0 (`false`) or 1 (`true`).
In C, non-zero numbers are treated as 1 (`true`).

?:

```
min = a >= b ? b : a;
```

Conditional Expression (条件表达式)
Ternary Operator (三目运算符)

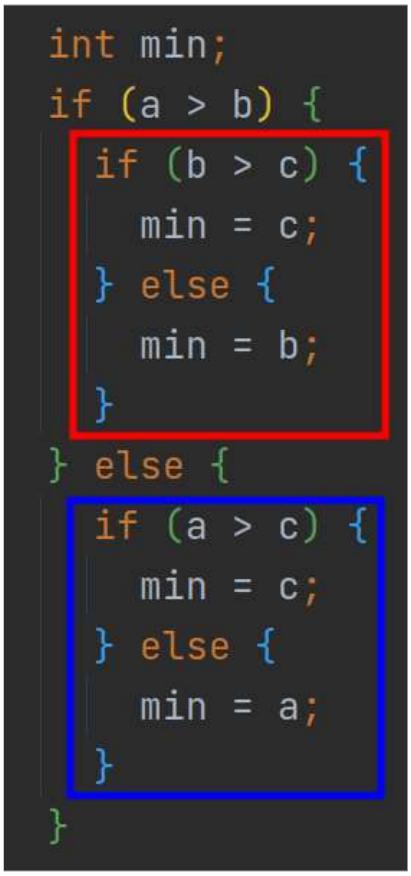
Do Not Use it Too Much!

Min of Three

Given three integers a, b, and c,
to compute their minimum.

$min = \min\{a, b, c\}$

Nested `if`



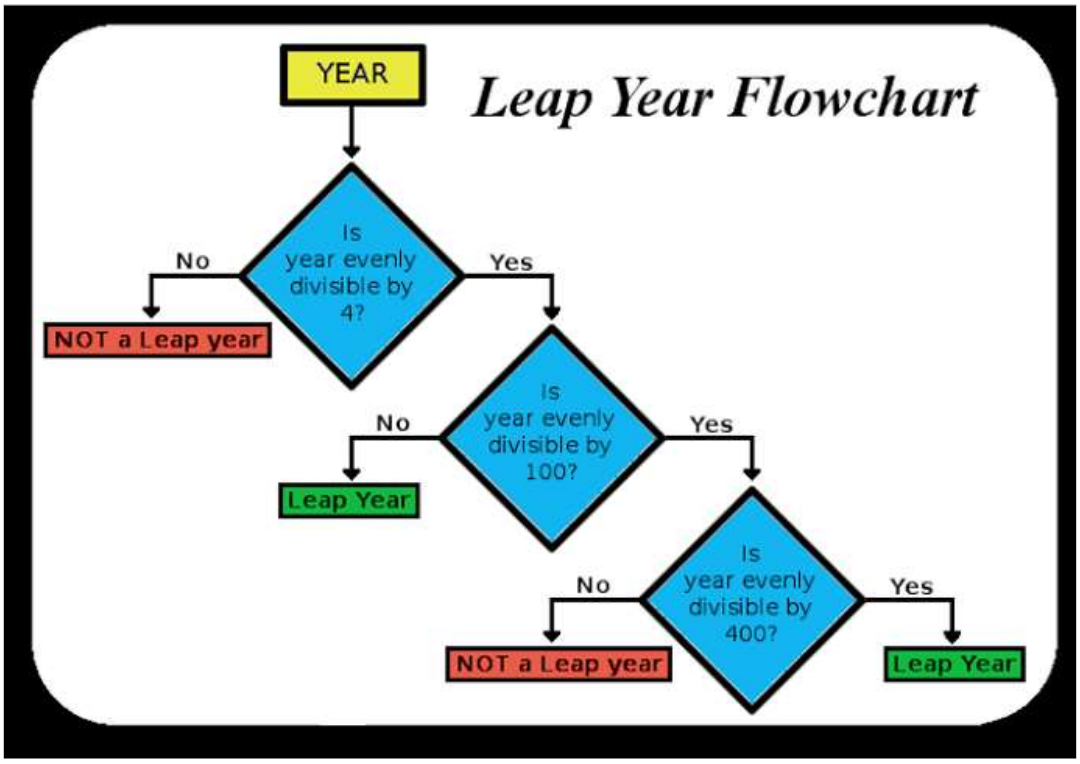
Min of a Set of Numbers

Given a set A of integers,
to compute their minimum.

$min = \min A$

Leap Year

Leap Year (1): Nested `if`



Leap Year (2): Nested `if`

---

if (*year* is not divisible by 4) **then** (it is a common year)
else if (*year* is not divisible by 100) **then** (it is a leap year)
else if (*year* is not divisible by 400) **then** (it is a common year)
else (it is a leap year)

Leap Year (3): `else-if`

```
if (year % 4 != 0) {
    printf( format: "The year %d is a common year.\n", year);
} else if (year % 100 != 0) {
    printf( format: "The year %d is a leap year.\n", year);
} else if (year % 400 != 0) {
    printf( format: "The year %d is a common year.\n", year);
} else {
    printf( format: "The year %d is a leap year.\n", year);
}
```

Leap Year (4): The Ultimate Version

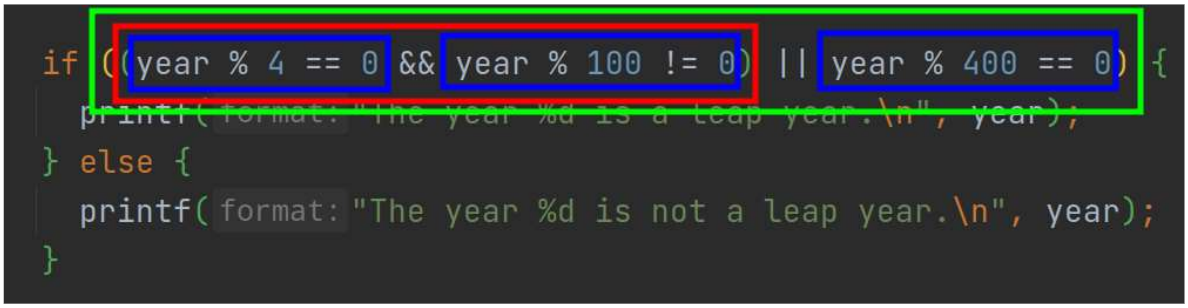
A year is a leap year *if*

- it is divisible by 4 but not by 100,
- except that years divisible by 400 are leap years.

Logical Operators (逻辑运算符)

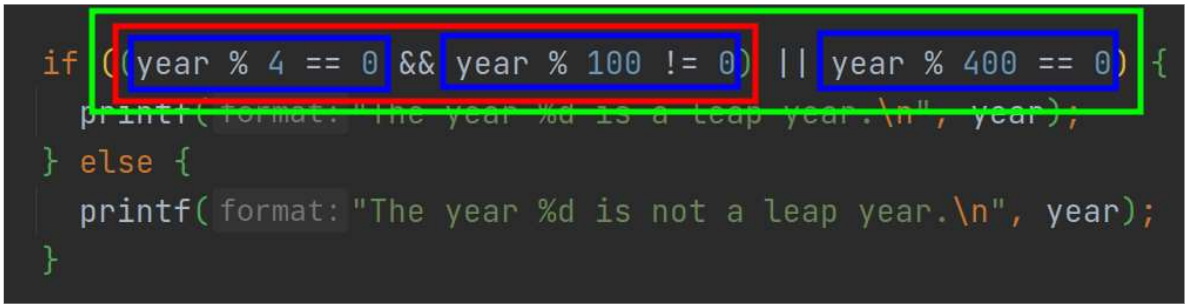
```
if ((year % 4 == 0 && year % 100 != 0) || year % 400 == 0) {
    printf( format: "The year %d is a leap year.\n", year);
} else {
    printf( format: "The year %d is not a leap year.\n", year);
}
```

Logical Expressions (逻辑表达式)



Logical expressions have values `0` (`false`) or `1` (`true`).

Short-circuit Evaluation



- year = 25
- year = 80

Sum

Given an integer $n \geq 0$, to compute $\sum_{i=1}^{n} i$.

Increment/Decrement Operators (`++`, `--`)

- `i++`
  - increment `i` *after* its value has been used
- `++i`
  - increment `i` *before* its value is used

Increment/Decrement Operators (++, --)

```
i = 2;
j = i * i++;
```

Undefined Behavior (未定义行为)

For Statement

```
for ( <expression> ; <expression> ; <expression> )
    <statement>
```

```
for (initialization; condition; increment/decrement)
    statement
```

```
int sum = 0;
for (int i = 1; i <= n; i++) {
  sum += i;
}
```

Min of a Set of Numbers

Given a set A of integers,
to compute their minimum.

$min = \min A$

```
#define NUM 5
```

Symbolic Constants (符号常量)

`#define` is a *pre-processing directive* (预处理指令).

`int numbers[NUM] = {0};` has a *constant* size.

- `NUM` is known at *compiler* time.

Array Initializer

`int numbers[NUM] = {0};`

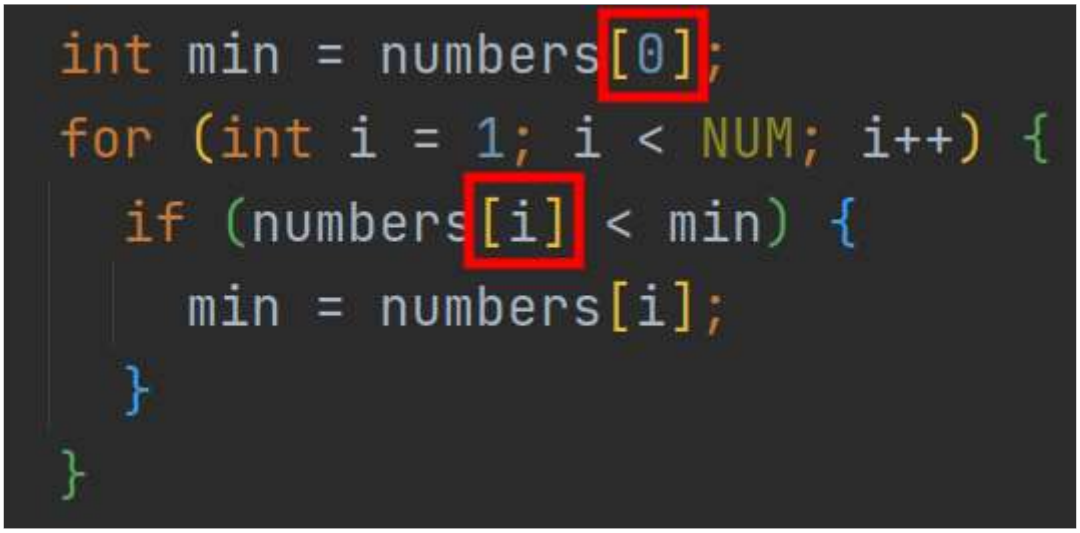
- `int numbers[NUM] = {1};`
  - `{1, 0, 0, 0, 0}`
- `int numbers[] = {0};`
  - `{0}`
- `int numbers[NUM] = {[2] = 1};`
  - `{0, 0, 1, 0, 0}`
  - See Section 8.1.3

Array Initializer

```
int numbers[NUM] = {0};
```

- ~~`int numbers[NUM] = {};`~~
  - Forbidden in `C99` (Unfortunately)
  - Allowed by GCC by default (Unfortunately)
- ~~`int numbers[NUM];`~~
  - May contain garbage values
- ~~`int numbers[];`~~
  - You must specify the size so that the compiler can allocate memory for it.

Array Members



[]: *subscript* operator (下标运算符)

For a While

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Oct. 25, 2021

Review

If Statement

For Statement

Logical Expressions

Array

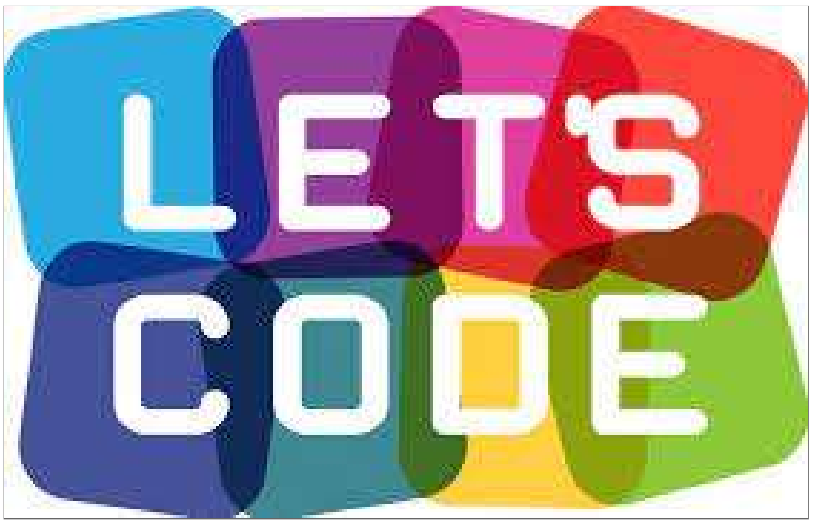
Overview

For Statement (More Examples)

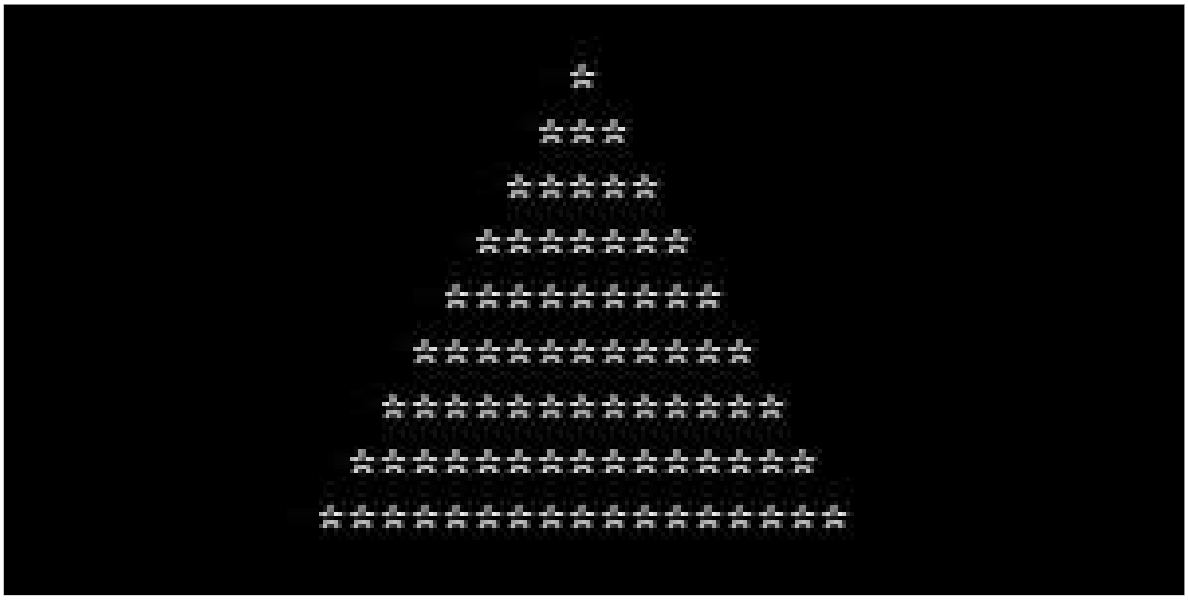
While (Do-While) Statement

`break` Statement

"Talk is Cheap. Show me the Code."

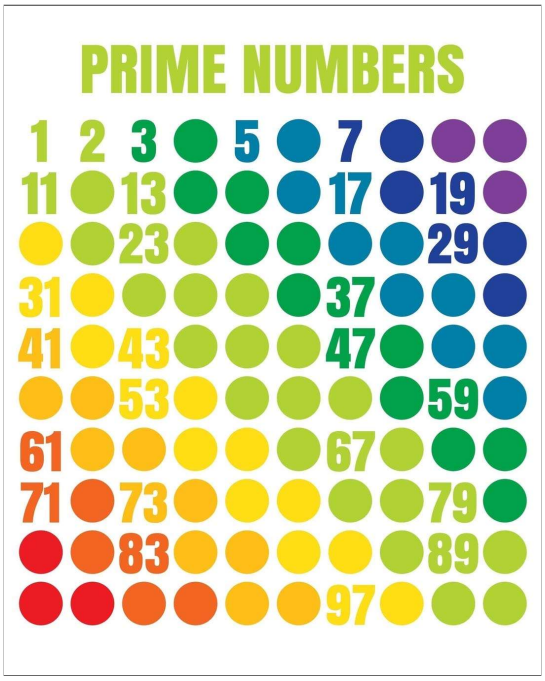


Stars Pyramid



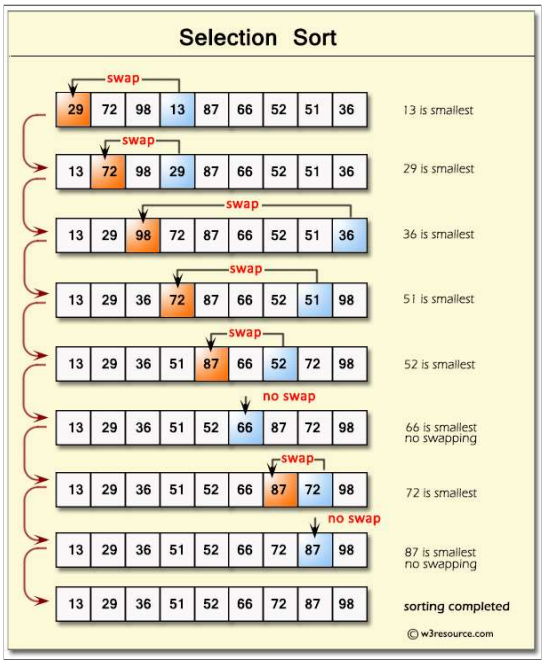
stars.c

Prime Numbers



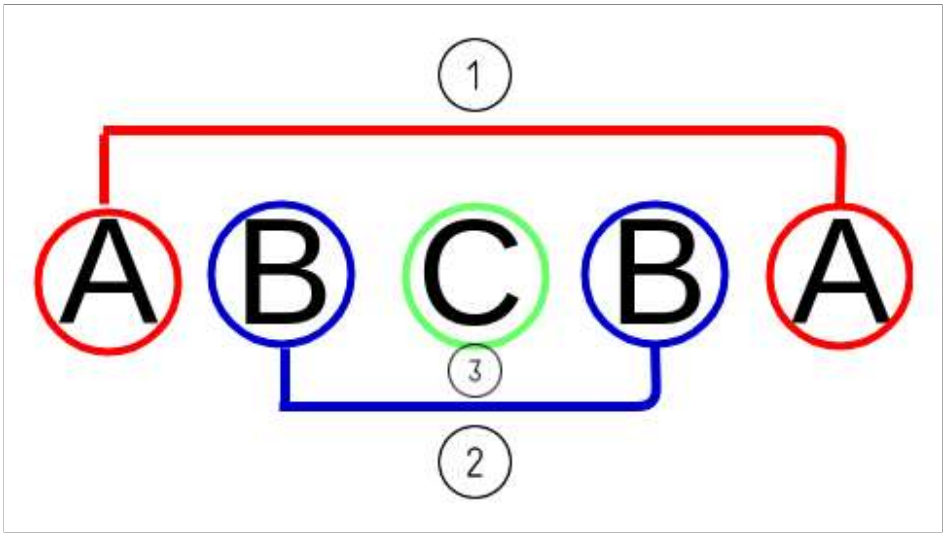
prime.c primes.c

Selection Sort



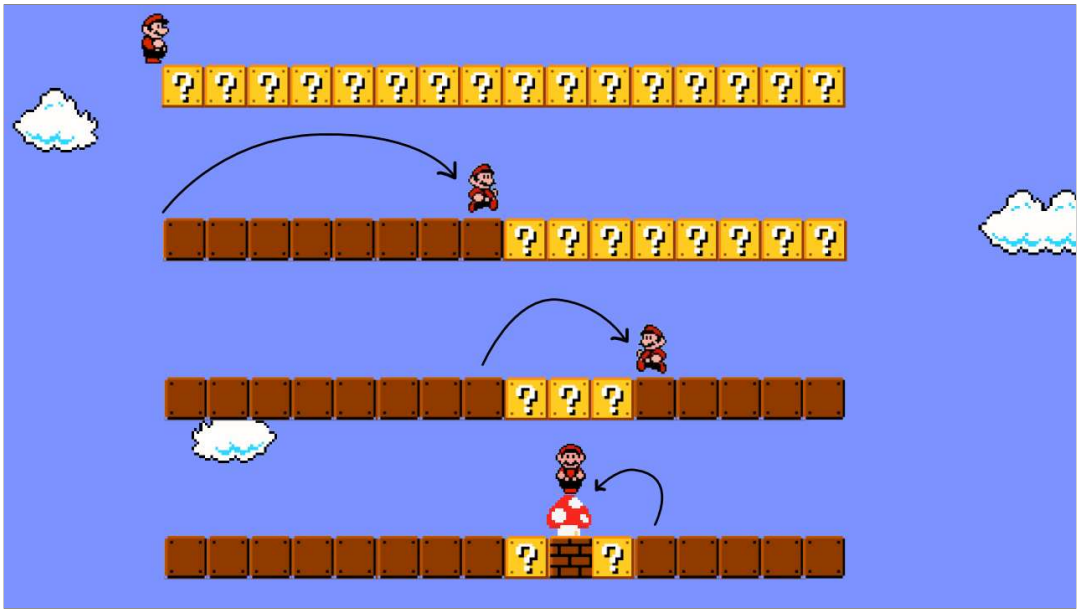
selection-sort.c

Palindrome



palindrome.c

Binary Search



binary-search.c

Number of Digits

digits-while.c　　digits-do-while.c

Counting

counting-if.c counting-switch.c

Loops

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Nov. 01, 2021

No Plagiarism!!!

No Plagiarism!!!

第一次作业抄袭现象触目惊心

助教们敦促蚂老师召开了紧急磋商会议

会上大家对作业进行了反思, 并制定了严厉的抄袭处罚措施

No Plagiarism!!!

- 当次作业计 0 分
- 前两次抄袭总评各扣 10 分
- 第三次抄袭总评直接判为不及格 $(\times 60\%)$

No Plagiarism!!!

助教与第一次作业(疑似)抄袭的同学进行了亲切友好的交谈

口头警告, 算作一次抄袭记录, 不作总评扣分处理

Review

For Statement (More Examples)

While (Do-While) Statement

break

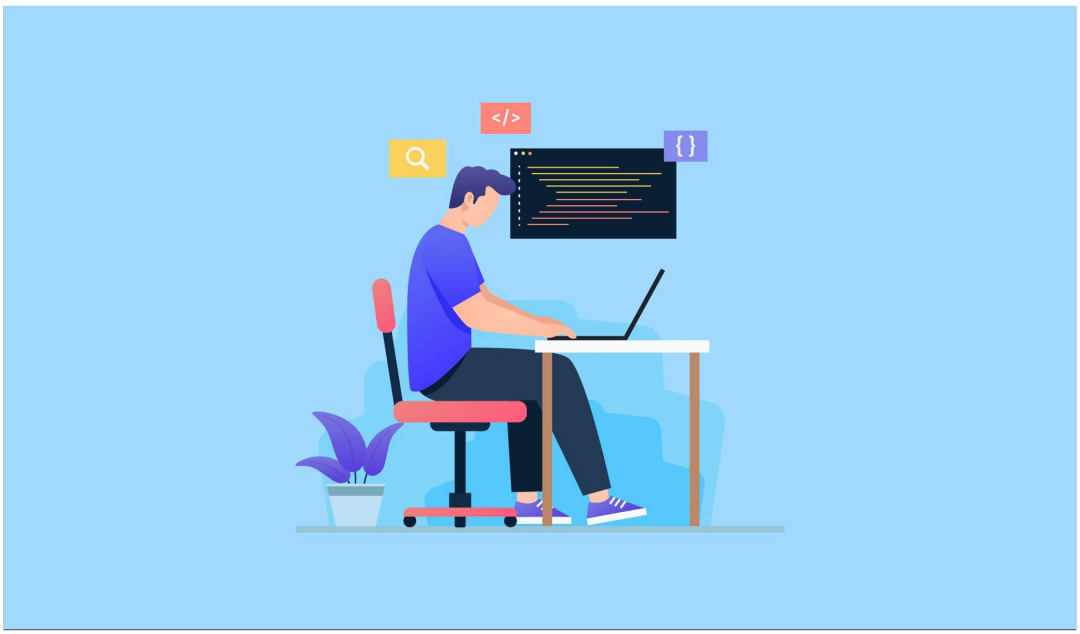
Overview

Loops (More Examples)

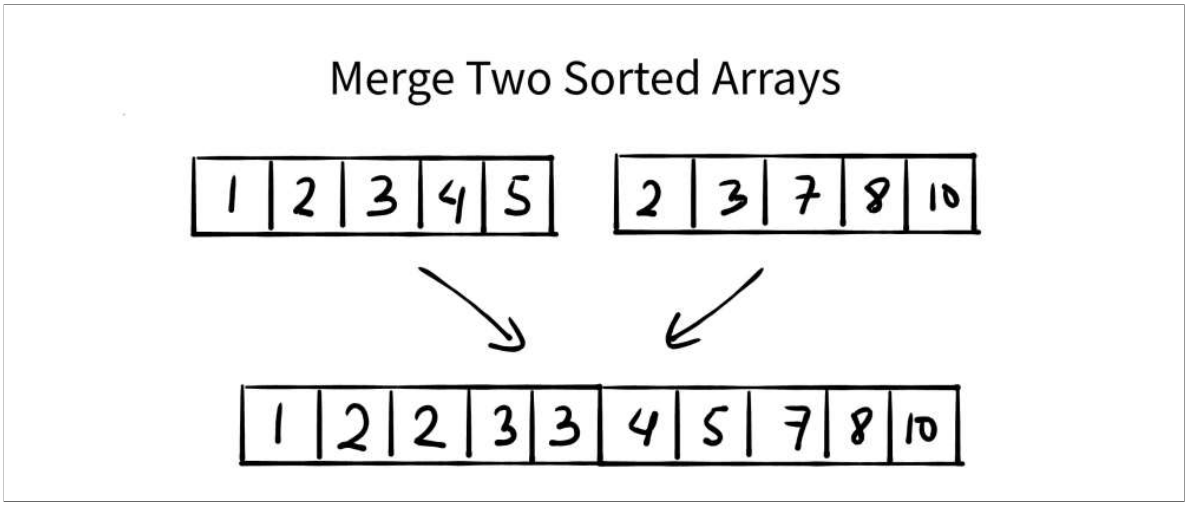
Multidimensional Arrays (多维数组)

continue, goto

"Talk is Cheap. Show me the Code."

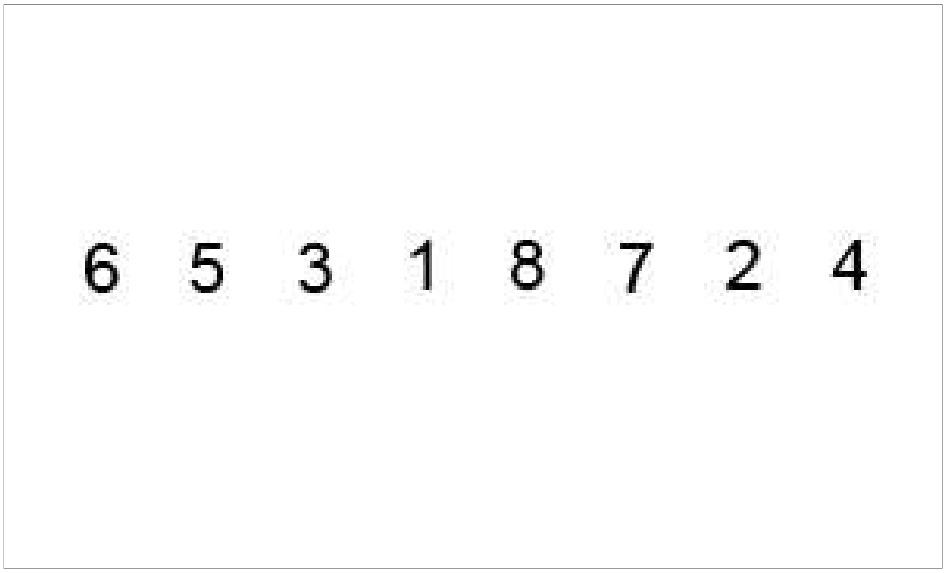


Merge



merge.c

Bubble Sort



bubble-sort.c

Conway's Game of Life

John Horton Conway (1937 ∼ 2020)

playgameoflife.com

Conway's Game of Life

- Any live cell with two or three live neighbours survives.
- All other live cells die in the next generation.

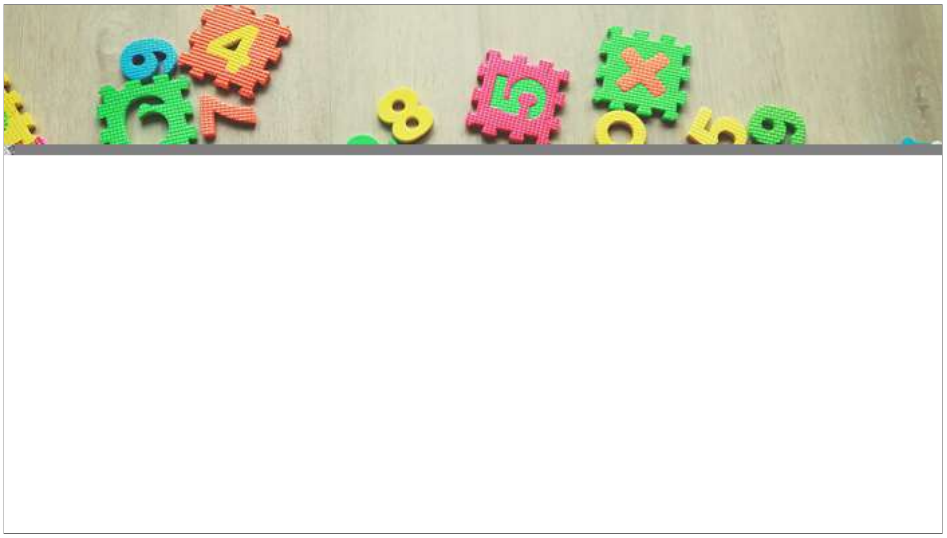
- Any dead cell with three live neighbours becomes a live cell.
- All other dead cells stay dead.

Conway's Game of Life @ wiki

Conway's Game of Life

game-of-life.c

Counting



counting-if.c counting-switch.c

Jump Statements

break　　continue　　goto
common.c　　continue.c

Function

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Nov. 08, 2021

Review

Loops (More Examples)

Multidimensional Arrays

Overview

Functions

"Talk is Cheap. Show me the Code."

Re-writing Programs using Functions

Recursion

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Nov. 15, 2021

Review

Functions

- Function Declaration
- Function Definition
- Arrays as Parameters
- Pass by Value

Overview

Recursive Functions (Recursion)

A function that calls (调用) itself.

Recursion

Thinking Recursively

It is a looooooog way to go to master recursion!!!

Recursion: Systems Implementation

- Programs run in memory (内存; 記憶體).
- Memory = Stack (栈区) + Heap (堆区) + · · ·
- Each function call has its own stack frame (栈帧).
- Stack grows/shrinks with function calls and returns.

Recursion: Systems Implementation

Visualization of Function Calls @ C Tutor

Recursion: Mathematical Induction

- Base Case (基础情况)
- Inductive Step (归纳步骤)

"Talk is Cheap. Show me the Code."

Min

---

min-re.c

Sum

sum-re.c

Fibonacci Sequence

$0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, \ldots$

- $F_0 = 0$
- $F_1 = 1$
- $F_n = F(n-1) + F(n-2) \qquad (n > 1)$

`fib-re.c` `fib-array.c` `fib-iter.c`

Greatest Common Divisor

- $a > b \implies \gcd(a, b) = \gcd(a - b, b)$
- $a < b \implies \gcd(a, b) = \gcd(a, b - a)$

gcd-euclid-re.c gcd-euclid-iter.c

Greatest Common Divisor

$$\gcd(a, b) = \gcd(b, a \% b)$$

gcd-euclidean-re.c gcd-euclidean-iter.c

Binary Search

---

bsearch-re.c

Recursion; Data Types

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Nov. 22, 2021

Review

Recursion

A function that calls itself.

Recursion

Thinking Recursively

Overview

Recursion (More Examples)

Data Types

`static`

"Talk is Cheap. Show me the Code."

Binary Search

bsearch-re.c

Merge Sort

merge-sort.c

Data Types

The type of a variable determines

- the set of *values* it may take on and
- what *operations* can be performed on them.

```
int   double   char
```

Integral Types

Signed (有符号数)

- short int
- int
- long
- long long

Unsigned (无符号数)

- bool (stdbool.h)
- unsigned short int
- unsigned int
- unsigned long
- unsigned long long

char (unsigned/signed)

Overflow (溢出)

- 有符号整数运算中发生溢出, 程序的行为是未定义的。
- 无符号整数运算中发生溢出, 程序的行为是有定义的。

Integral Promotion (整型提升)

- 定义初始化
- 赋值操作
- 参数传递
- 函数返回值

Integral Promotion (整型提升)

"Arithmetic operators do not accept types smaller than `int` as arguments, and integral promotions are automatically applied."

Floating-point Numbers

- `float y = 5.0F`
    - %f
    - %f
- `double x = 5.0`
    - %lf
    - %f
- `long double z = 5.0L`
    - %Lf
    - %Lf

Floating-point Numbers

Floating-point Arithmetic

"Floating-point Arithmetic is Hard."

Floating-point Arithmetic

`float.h` (Section 23.1)

Floating-point Arithmetic

- Overflow (上溢)
- Underflow (下溢)
- Significance Loss (精度丢失)
    - `significance.c`

Floating-point Arithmetic

"Many applications don't need floating-point arithmetic at all."

Use `math.h` (Section 23.3) whenever possible.

C 语言安全编码标准

整型数安全编码标准 (INT)

- 使用正确的整数类型
- 确保无符号整数运算不产生回绕
- 确保有符号整数运算不造成溢出
- 确保除法与余数运算不造成除0错误
- 确保整数转换不会造成数据丢失或者错误解释

浮点数安全编码标准 **(FLP)**

- 不要使用浮点数变量作为循环计数器
- 避免或者检测数学函数中的定义域与值域错误
- 确保浮点数转换在新类型的范围中

References

Pointers

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Nov. 29, 2021

Overview

Pointers and Arrays Pointers and C Strings

Overview

Pointers

"A pointer is a *variable* that
contains the *address* of a variable."

"Talk is Cheap. Show me the Code."

Variables Revisited

```
int radius = 10;
```

- `radius` refers to a *location* (`&radius`) in memory.

`&`: Address-of Operator ("取地址"运算符)

```
printf("%p\n", &radius);
```

Pointers

```
int *ptr_radius = &radius;
```

- The type of `ptr_radius` is "pointer to int".

Variables Revisited

```
double circumference = 2 * 3.14 * radius;

radius = 20;
```

A variable behaves as an *lvalue* or a *rvalue.*
左值　右值

Pointers

```
int *ptr_radius = &radius;
```

- `*ptr_radius` behaves just like `radius` does.
    - *: Indirection/Dereferencing ("间接寻址/解引用"运算符)

```
double circumference = 2 * 3.14 * (*ptr_radius);
*ptr_radius = 20;
```

Pointers

```
int *ptr_radius = &radius;
```

- `ptr_radius` is also a variable.

Swap Numbers

selection-sort.c

Min and Max

Compute both the min and the max
of an array of integers.

min-max.c

scanf.c

Dynamic Memory Management

```
int *numbers = malloc(len * sizeof *numbers);
```

void *malloc(size_t size);

void free(void *ptr);

selection-sort.c

Dynamic Memory Management

---

stdlib.h ~~malloc.h~~

Pointers and Arrays

- The name of an array is a synonym for the address of its first element.
- `numbers[i]` `*(numbers + i)` ~~`i[numbers]`~~
- `&numbers[i]` `numbers + i`
- But an array name is not a variable.
  - ~~`numbers++`~~

Pointers and C Strings

```
char msg[20] = "Hello World!";
char *msg = "Hello World!";
```

strlen.c

strlen strlen_s

Pointers and C Strings

strcmp.c

strcmp

strncmp

Pointers and C Strings

strcpy.c

strcpy strcpy_s

strncpy strncpy_s

Return Pointers from Functions

Do not return pointers to

`local` variables in functions!!!

References

Chapter 14: `string.h`

Pointer Arrays

selection-sort-strings.c

Pointers (More)

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Dec. 06, 2021

Review

Pointers and Arrays Pointers and C Strings

Overview

`string.h`
Pointer Arrays Pointers and 2D Arrays
Function Pointers

"Talk is Cheap. Show me the Code."

Pointers; Structures

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Dec. 13, 2021

Review

`string.h`

Pointer Arrays Pointers and 2D Arrays

Overview

Program Arguments Function Pointer

`struct` `union` `enum`

"Talk is Cheap. Show me the Code."

Linked Lists

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Dec. 20, 2021

Review and Overview

Program Arguments Function Pointer

`struct` `union` `enum`

Overview: Linked Lists

"Talk is Cheap. Show me the Code."

struct

musician.c

Linked Lists

Singly Linked List

Doubly Linked List

Linked Lists

Circular Linked List

Josephus Problem

终结章