CSC215
Lecture

Variables, Types and Expressions

Outline

- Variables
- Datatypes
  - Basic data types
  - Derived data types
  - User-defined data types
- Expressions
  - Operators: arithmetic, relational, logical, assignment, inc-/dec- rement, bitwise
  - Evaluation
- Formatted input/output

Variables

- Named values
  - Naming rules:
    - Made up of letters, digits and the underscore character ‘_’
    - Must not begin with a digit
    - Must not be a special keyword

`auto`	`break`	`case`	`char`	`const`	`continue`
`default`	`do`	`double`	`else`	`enum`	`extern`
`float`	`for`	`goto`	`if`	`int`	`long`
`register`	`return`	`short`	`signed`	`sizeof`	`static`
`struct`	`switch`	`typedef`	`union`	`unsigned`	`void`
`volatile`	`while`				

- Variable declaration:
  - Must declare variables before use
  - Variable declaration: `int n; float phi;`
    - int - integer data type
    - float - floating-point data type
  - Many other types
- Variable initialization:
  - Uninitialized variable assumes a default value
  - Variables initialized via assignment operator: `n = 3;`
  - Can also be initialized at declaration: `float phi = 1.6180339887;`
  - Can declare/initialize multiple variables at once: `int a, b, c = 0, d = 4;`

Basic Data Types

❑ Data type determines the variable’s domain and applicable operations

❑ Four types: **char** **int** **float** **double**

❑ Modifiers: signed unsigned short long

❑ Combinations:

	Type	**Bits**	**Range**
Char	[signed] char	8	-128 .. 127
	unsigned char	8	0 .. 259
int	[signed] int	16 (at least)	-2^{15} .. $2^{15}-1$
	unsigned int	16 (at least)	0 .. $2^{16}-1$
	[signed] short [int]	16	-2^{15} .. $2^{15}-1$
	unsigned short [int]	16	0 .. $2^{16}-1$
	[signed] long [int]	32 (at least)	-2^{31} .. $2^{31}-1$
	unsigned long [int]	32 (at least)	0 .. $2^{32}-1$
float	float	32	1.2E-38 .. 3.4E+38 (6 dig-prec)
double	double	64	2.3E-308 .. 1.7E+308 (15 dig-prec)
	long double	80 (at least)	3.4E-4932 .. 1.1E+4932 (19 dig-prec)

❑ What about boolean? strings?

Boolean?

- ❑ No special boolean type
- ❑ Evaluating boolean and logical expressions:
  - results in integer 1 if the logic is true
  - results in 0 if the logic is false
- ❑ Interpretation of integer as boolean:
  - 0 is perceived as false
  - any non-zero value is perceived as true

Strings ?

- Strings stored as character array
- Null-terminated (last character in array is ’\0’: null character)

```
char course[7] = {'C', 'S', 'C', '2', '1', '5', '\0'};
char course[] = {'C', 'S', 'C', '2', '1', '5', '\0'};
```

- Not written explicitly in string literals

```
char course[7] = "CSC215";
char course[] = "CSC215";
```

- Special characters specified using \ (escape character):
    - **`\\`** – backslash
    - **`\'`** – apostrophe
    - **`\"`** – quotation mark
    - **`\b`**, **`\t`**, **`\r`**, **`\n`** – backspace, tab, carriage return, linefeed
    - **`\o`**`oo`, **`\x`**`hh` – octal and hexadecimal ASCII character codes, e.g. \x41 – `'A'`, \060 – `'0'`

Initialization of Variables

- ❑ Local variables:
  - ○ declared inside a function
  - ○ are not initialized by default
- ❑ Global variables:
  - ○ declared outside of functions
    - ■ On top of the program
  - ○ are initialized by default:

Type	**Default value**
int	0
char	'\0'
float	0
double	0
pointer	null
Derived types	apply recursively

Constants

- The previous examples can be rewritten as:

  ```
  int main(void) /* entry point */ {
    const char msg [ ] = "Hello World!";
    /* write message to console */
    puts(msg);
  }
  ```

- **const** keyword: qualifies variable as constant
- **char**: data type representing a single character; written in quotes: ’a’, ’3’, ’n’
- const char msg[]: a constant array of characters

Expressions

- Expression:
  - a sequence of characters and symbols that can be evaluated to a single data item.
  - consists of: literals, variables, subexpressions, interconnected by one or more *operators*

- Operator:
  - Can be unary, binary, and ternary
  - Categories:
    - Arithmetic: `+x, -x, x+y , x-y , x*y , x/y , x%y`
    - Relational `x==y, x!=y, x<y, x<=y, x>y, x>=y`
    - Logical `x&&y, x||y, !x`
    - Bitwise `x&y, x|y, x^y, x<<y, x>>y, ~x`
    - Assignment `x=y, x+=y, x-=y, x*=y, x/=y, x%=y`
      `x<<=y, x>>=y, x&=y, x|=y, x^=y`
    - inc-/dec- rement `++x, x++, --x, x--`
    - Conditional `x?y:z`
    - More: `*x, &x, (type)x, sizeof(x), sizeof(<type>)`

Arithmetic Operators

- 2 Unary operators: + −
- 5 Binary operators: + − * / %
  - If both operands are of type int, the result is of type int
- Example:

```
int main() {
  int a = 9, b = 4, c;
  c = a+b;
  printf("a+b = %d \n",c);
  c = a-b;
  printf("a-b = %d \n",c);
  c = a*b;
  printf("a*b = %d \n",c);
  c=a/b;
  printf("a/b = %d \n",c);
  c=a%b;
  printf("Remainder when a divided by b = %d \n",c);
  return 0;
}
```

Relational Operators

- 6 Binary operators: == != > >= < <=
- Checks the relationship between two operands:
  - if the relation is true, it yieldss 1
  - if the relation is false, it yields value 0
- Example:

```
int main(){
  int a = 5, b = 5, c = 10;
  printf("%d == %d = %d \n", a, b, a == b); /* true */
  printf("%d == %d = %d \n", a, c, a == c); /* false */
  printf("%d > %d = %d \n", a, b, a > b); /*false */
  printf("%d > %d = %d \n", a, c, a > c); /*false */
  printf("%d < %d = %d \n", a, b, a < b); /*false */
  printf("%d < %d = %d \n", a, c, a < c); /*true */
  printf("%d != %d = %d \n", a, b, a != b); /*false */
  printf("%d != %d = %d \n", a, c, a != c); /*true */
  printf("%d >= %d = %d \n", a, b, a >= b); /*true */
  printf("%d >= %d = %d \n", a, c, a >= c); /*false */
  printf("%d <= %d = %d \n", a, b, a <= b); /*true */
  printf("%d <= %d = %d \n", a, c, a <= c); /*true */
  return 0;
}
```

Logical Operators

- 1 Unary operator: `!` and 2 binary operators: `&&` `||`
- Example:

```
int main(){
  int a = 5, b = 5, c = 10, result;
  result = (a = b) && (c > b);
  printf("(a = b) && (c > b) equals to %d \n", result);
  result = (a = b) && (c < b);
  printf("(a = b) && (c < b) equals to %d \n", result);
  result = (a = b) || (c < b);
  printf("(a = b) || (c < b) equals to %d \n", result);
  result = (a != b) || (c < b);
  printf("(a != b) || (c < b) equals to %d \n", result);
  result = !(a != b);
  printf("!(a == b) equals to %d \n", result);
  result = !(a == b);
  printf("!(a == b) equals to %d \n", result);
  return 0;
}
```

Bitwise Operators

- ❏ 1 Unary operator ~ and 5 binary operators & | ^ << >>
- ❏ Examples:

```
int main(){
  int a = 12;
  int b = 25;
  printf("complement=%d\n",~35);
  printf("complement=%d\n",~-12);
  printf("Output = %d", a&b);
  printf("Output = %d", a|b);
  printf("Output = %d", a^b);

  int num=212;
  printf("Right shift by 3: %d\n", num>>3);
  printf("Left shift by 5: %d\n", num<<5);
  return 0;
}
```

```
 35 00000000 00100011  ~
-36 11111111 11011100
```

```
-12 11111111 11110100  ~
 11 00000000 00001011
```

```
 12 00000000 00001100
 25 00000000 00011001
    -----------------  &
  8 00000000 00001000
```

```
 12 00000000 00001100
 25 00000000 00011001
    -----------------  |
 29 00000000 00011101
```

```
 12 00000000 00001100
 25 00000000 00011001
    -----------------  ^
 21 00000000 00010101
```

```
212 00000000 11010100
 26 00000000 00011010 ↠
```

```
 212 00000000 11010100
6784 00011010 10000000 ↞
```

Assignment Operators

- ❑ 11 Binary operators: = += -= *= /= %= &= |= ^= <<= >>=
- ❑ Example:

```
int main(){
  int a = 5, c;
  c = a;
  printf("c = %d \n", c);
  c += a; /* c = c+a */
  printf("c = %d \n", c);
  c -= a; /* c = c-a */
  printf("c = %d \n", c);
  c *= a; /* c = c*a */
  printf("c = %d \n", c);
  c /= a; /* c = c/a */
  printf("c = %d \n", c);
  c %= a; /* c = c%a */
  printf("c = %d \n", c);
  return 0;
}
```

Increment/Decrement operators

- 2 Binary operators: ++ --
- Example:

```
int main(){
  int a = 10, b = 100;
  float c = 10.5, d = 100.5;
  printf("++a = %d \n", ++a); /* 11 */
  printf("b++ = %d \n", b++); /* 100 */
  printf("c-- = %f \n", c--); /* 10,500000 */
  printf("--d = %f \n", --d); /* 99.500000 */
  return 0;
}
```

Ternary Conditional Operator

- Syntax: `<conditionalExpression> ? <expression1> : <expression2>`
- The conditional operator works as follows:
    - <conditionalExpression> is evaluated first to non-zero (1) or false (0).
    - if <conditionalExpression> is true, <expression1> is evaluated
    - if <conditionalExpression> is false, <expression2> is evaluated.
- Example:

```
int main(){
  char February;
  int days;
  printf("If this year is leap year, enter 1. If not enter any integer: ");
  scanf("%c",&February);
  /* If test condition (February == 'l') is true, days equal to 29. */
  /* If test condition (February =='l') is false, days equal to 28. */
  days = (February == '1') ? 29 : 28;
  printf("Number of days in February = %d",days);
  return 0;
}
```

More Operators

- sizeof: unary operator returns data (constant, variable, array, structure...)
- Example:

```
int main(){
  int a, e[10];
  float b;
  double c;
  char d;
  printf("Size of int=%lu bytes\n",sizeof(a));
  printf("Size of float=%lu bytes\n",sizeof(b));
  printf("Size of double=%lu bytes\n",sizeof(c));
  printf("Size of char=%lu byte\n",sizeof(d));
  printf("Size of integer type array having 10 elements = %lu bytes\n", sizeof(e));
  return 0;
}
```

Evaluating Expressions

- Expression: A sequence of characters and symbols that can be evaluated to a single data item.
- Expression evaluation:
  - Order of operations:
    Use parenthesis to override order of evaluation
  - Example: Assume x = 2.0 and y = 6.0.
    Evaluate the statement:
    float z = x+3*x/(y-4);
    1. Evaluate expression in parentheses
       → float z = x+3*x/2.0;
    2. Evaluate multiplies and divides, from left-to-right
       → float z = x+6.0/2.0; → float z = x+3.0;
    3. Evaluate addition float:
       → float z = 5.0;
    4. Perform initialization with assignment Now, z = 5.0.
  - How do I insert parentheses to get z = 4.0?

Operator	Associativity
<function>(), [ ], ->, .	left to right
!, ~, ++, --, +, -, *, (<type>), sizeof	right to left
*, /, %	left to right
+, - (unary)	left to right
<<, >>	left to right
<, <=, >, >=	left to right
==, !=	left to right
&	left to right
^	left to right
|	left to right
&&	left to right
||	left to right
? :	left to right
= += -= *= /= %= &= ^= |= <<= >>=	right to left
,	lrft to right

Formatted Input and Output

❑ Function `printf`

```
printf(control_string, arg1, arg2, …);
```

- control_string is the control string or conversion specification consists of % followed by a specifier

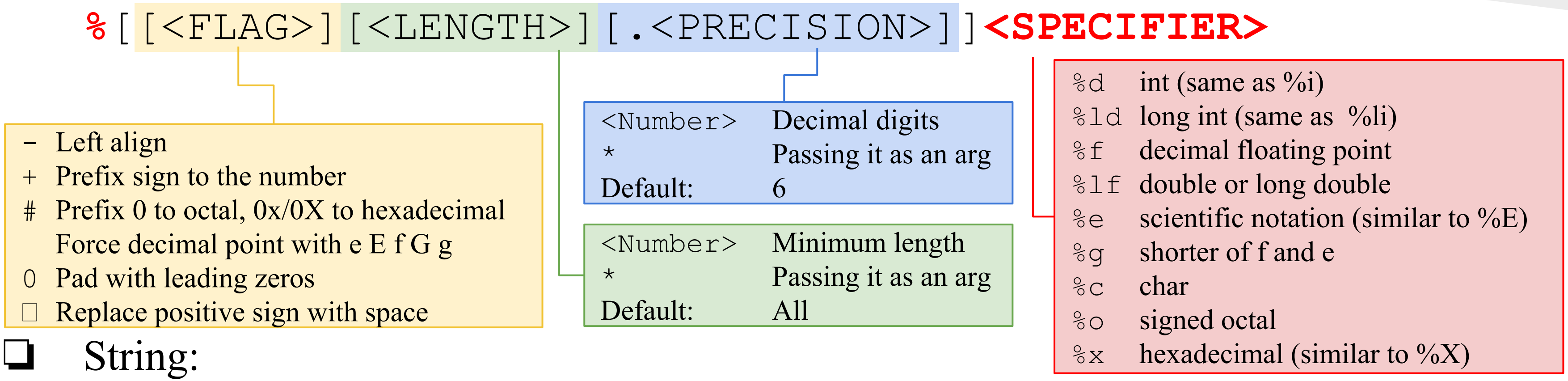
  ```
  %[flags][width][.precision][length]specifier
  ```

- Specifiers (place holders):
  - %d - int (same as %i)
  - %ld - long int (same as %li)
  - %f - decimal floating point
  - %lf - double or long double
  - %e - scientific notation (similar to %E)
  - %c - char
  - %s - string
  - %o - signed octal
  - %x - hexadecimal (similar to %X)
  - %p - pointer
  - %%- %
- Optional width, length precision and flags

Flags	: -	+	#	0
Width	: *	number		
Length	: h	l	L	
Precision	: .*	.number		

Formatted Input and Output

- Numeric:



`%[[<FLAG>][<LENGTH>][.<PRECISION>]]<SPECIFIER>`

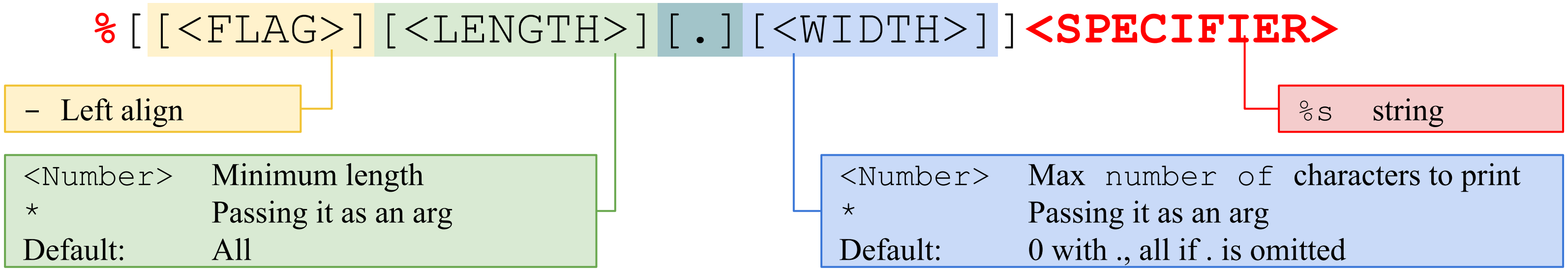
-	Left align
+	Prefix sign to the number
#	Prefix 0 to octal, 0x/0X to hexadecimal Force decimal point with e E f G g
0	Pad with leading zeros
□	Replace positive sign with space

`<Number>`	Minimum length
`*`	Passing it as an arg
Default:	All

`<Number>`	Decimal digits
`*`	Passing it as an arg
Default:	6

`%d`	int (same as %i)
`%ld`	long int (same as %li)
`%f`	decimal floating point
`%lf`	double or long double
`%e`	scientific notation (similar to %E)
`%g`	shorter of f and e
`%c`	char
`%o`	signed octal
`%x`	hexadecimal (similar to %X)

- String:



`%[[<FLAG>][<LENGTH>][.][<WIDTH>]]<SPECIFIER>`

-	Left align

`<Number>`	Minimum length
`*`	Passing it as an arg
Default:	All

`<Number>`	Max `number of` characters to print
`*`	Passing it as an arg
Default:	0 with ., all if . is omitted

`%s`	string

Formatted Input and Output

❑ Function scanf

`scanf(control_string, arg1, arg2, …);`

- Control_string governs the conversion, formatting, and printing of the arguments
- Each of the arguments must be a pointer to the variable in which the result is stored
- So: `scanf("%d", &var);` is a correct one, while `scanf("%d", var);` is not correct
- Place holders:
  - %d - int (same as %i)
  - %ld - long int (same as %li)
  - %f - float
  - %lf - double
  - %c - char
  - %s - string
  - %x - hexadecimal

Macros

- ❑ Preprocessor macros begin with # character
  - ○ `#define msg "Hello World"`
    defines msg as “Hello World” throughout source file
- ❑ #define can take arguments and be treated like a function
  #define add3(x,y,z) ((x)+(y)+(z))
  - ○ parentheses ensure order of operations
  - ○ compiler performs inline replacement; not suitable for recursion
- ❑ #if, #ifdef, #ifndef, #else, #elif , #endif conditional preprocessor macros
  - ○ can control which lines are compiled
  - ○ evaluated before code itself is compiled, so conditions must be preprocessor defines or literals
  - ○ the gcc option -Dname=value sets a preprocessor define that can be used
  - ○ Used in header files to ensure declarations happen only once
- ❑ Conditional preprocessor macros:
  - ○ #pragma preprocessor directive
  - ○ #error, #warning trigger a custom compiler error/warning
  - ○ #undef msg remove the definition of msg at compile time