Data Types

ESC108A Elements of Computer Science and Engineering

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Objectives

- At the end of this lecture, student will be able to
  - Explain data representation and limitations for Integer, floating point and Character data types
  - Explain user defined data types

Contents

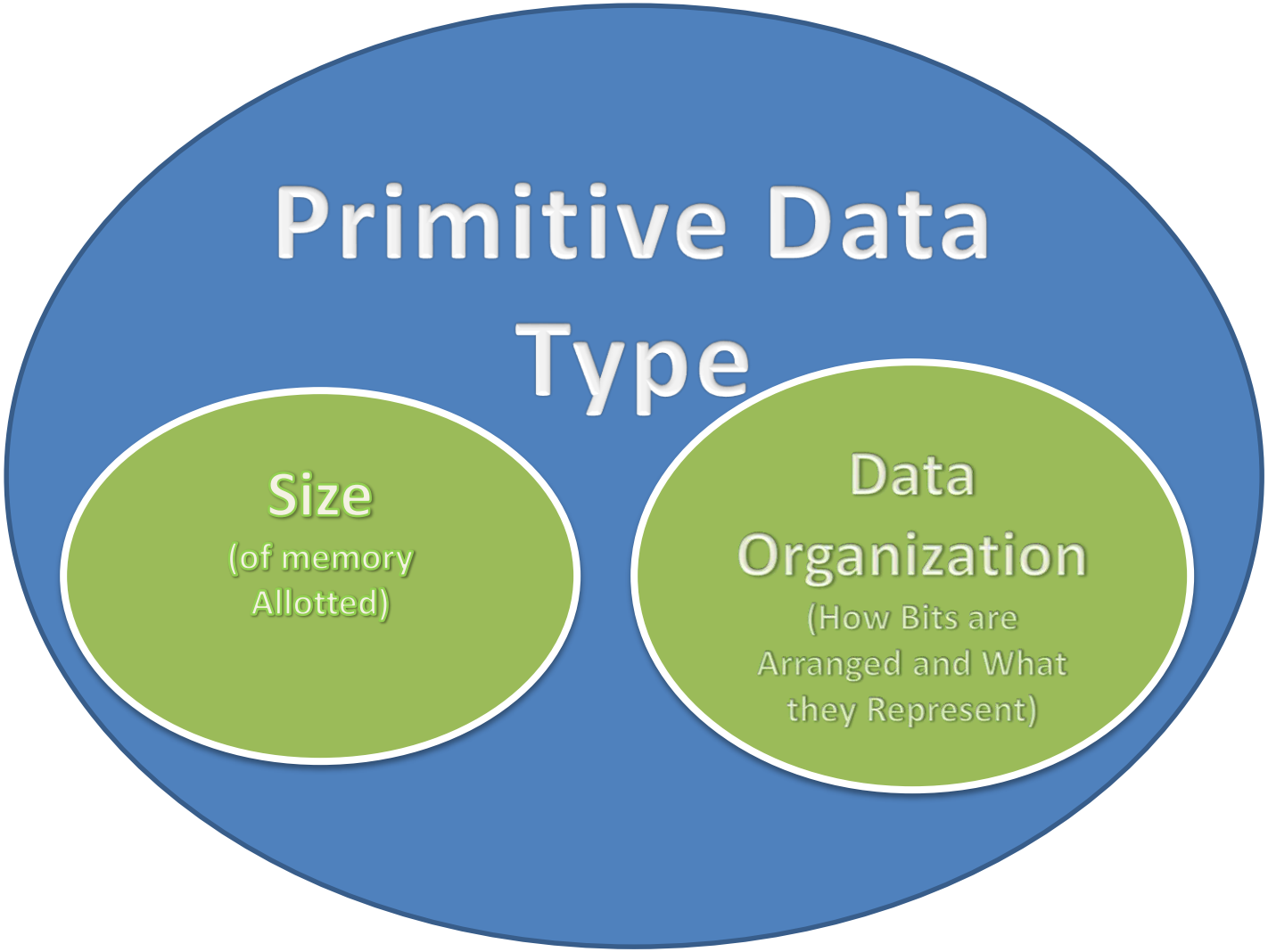
- Integer Data Type
- Floating Point Data Type
- Character Data Type

Data Types

- Data types indicate the type of data that a variable can hold

- In C, data types are categorized into
  - Built-in data types/Primitive data types
  - Derived data types
  - User-defined data types

Primitive Data Type



Mathematical Numbers

- Mathematics
  - Integers
    - -∞, …. -2, -1, 0, +1, +2, … + ∞
  - Real Numbers
    - Integers, Fraction and square roots
    - -∞, …. -2,…,-1,…,-1/2, 0, …,+1,…, +2, … + ∞

Data Types for Numbers

- Computers - Integers
  - Every data type has a fixed size based on the processor
  - A processor can process a ***'word'*** at a time
  - The size of an integer is equal to word size of the system
  - In *'64-bit' processor*, *64 bits* or *8 bytes* is the word size

- Computers – Real Numbers (Floating Point)
  - Fixed size and hence limited range
  - Representation of all real numbers in decimal form
    - Example: 1.414, 3.12

Integer Data Type Declarations

- They’re messages to the compiler

- For example the definition int i;

  tells the compiler the type of variable i and instructs the compiler to reserve space in memory for the variable

Integer Data Type Declarations contd.

- Declaration

  int <variable list>;

- Example
  - int a; /*Single variable declaration*/
  - int a,b,c; /*Multiple variables*/
  - int a = 5; /*Single variable with initialisation, giving initial value to variable*/
  - int a = b = c = 5; /*multiple assignment statement*/

Integers – Variables and Constants

int a = 5;

- 5 is an Integer constant
- a is an Integer variable

#define SIDES 4

- 4 is an Integer constant
- SIDES is a Symbolic constant

Integer Data Type

- We can represent $(10)_{10}$ as $(1010)_2$
- How do we represent $(-10)_{10}$?

Signed Integers

- Assume MSB represents sign – Call it sign bit

  0 means '+' and 1 means '-'
- Remaining numbers represent the actual number in binary form
- Results in +0 and -0

- For example, in an 8-bit system
  - 1000 0000 = $-(0)_2$
  - 0000 0000 = $+(0)_2$

Unsigned Integers

- Whole numbers

  0 to INT_MAX (Infinity in mathematics)
- No need for sign bit
- Equivalent binary form
- Declaration

  unsigned int <variable list>;
- Example
  - unsigned int a, b, c; /*Multiple variables*/
  - unsigned int a; /*Single variable*/
  - unsigned int a = 5; /*Single variable with initialisation*/

Range of Integers

- Range of Integers
  - Signed : -2^{n-1} to $2^{n-1}-1$
  - Unsigned : 0 to $2^{n}-1$
    - Where ‘n’ is word size in bits

- If n is 8 bits:
  - Signed : - 128 to +127
  - Unsigned : 0 to +127
- What if n is
  - 16 bits
  - 64 bits

Long and Short Modifiers

- Long
  - When applied to int, it doubles the length in bits of the base type that it modifies
  - If an **int** is of 16-bits, then **long int** is of 32-bits
  - When applied to double, it roughly doubles the precision

- Short
  - Makes the size of an int half

Floating Point Data Type

- Think of how money is represented 300.50 (Three hundred Rupees and fifty Paisa)
- Consider
    - 3.1413
    - 2.0
    - 12.18
    - 122.1
  - These are numbers where the decimal point moves or ‘floats’

- Such a representation of real numbers is called *floating point number system*

Floating Point Data Type contd.

- Consider
  - $3.1413 = 31413.0 \times 10^{-4}$
  - $2.0 = 2.0 \times 10^{0}$
  - $12.18 = 1218.0 \times 10^{-2}$
  - $122.1 = 1221.0 \times 10^{-1}$
- This representation is known as *scientific notation*
  - The fixed number is called 'Mantissa' and the power of 10 as 'Exponent'
- Floating point numbers are represented in computers as one memory area having 2 numbers: the exponent and mantissa

Floating Point Data Type contd.

- Both mantissa and exponent are represented in
  - Binary form if positive
  - 2's complement notation if negative
- Hence both numbers have a sign bit

- How many bits are allotted is left to the designer of the compiler
  - Range cannot be estimated
- Some compilers implement a standard form of representation known as IEEE-754

Double

- Used to indicate a double precision floating-point number
- Used when more accuracy in required in representing a floating-point number

- Equivalent to float
  - but the number of significant digits stored after the decimal point is double that of the float

Floating Point Data Type - Declaration

- Declaration
  - float a;
  - float b = 5.0f;
  - float a = 5.1f, b = 2.2f;
  - double a;
  - double b = 5.0;
  - double a = 5.1, b = 2.2;

- Constants
  - 2.0f is a float constant
  - 2.0 is a double constant

Character Data Type

- Character data types store numbers representing characters
- These numbers are given by ANSI and called ASCII codes

  'A' has the ASCII value 65

- Character is an Integer data type with fixed size of 1 byte

- All operators that Integers can be used with can also be used with character operators

Character Constants

- A single character enclosed in a pair of apostrophes
- Signed (-128 to +127) or unsigned(0 to 255)
- Example

```
char c = 'A' ; //notice the single quotes
int x=10+'A' //arithmetic operations can be done
printf("character is %c and its ASCII value is %d\n",c,c);
printf("Result is %d\n",x);
```

- Output will be

```
character is A and its ASCII value is 65
Result  is  75
```

Type-cast

- (type) is known as type cast or cast operator
  - Its use indicates that the programmer explicitly is converting value between incompatible types
- Beware
  - Do not convert between variables of data types with greater storage space and lesser storage space
  - Use cast operator if you know what you are doing
- Example:

  int b = 10; char a = **(char)** b;
  - a is a char variable and b is an int variable
  - 10 is an integer constant

Type-cast

- Use cast operator to convert from float to integer
  - int a = (int) 10.5f;

- Beware
  - Integer only expressions return integer values
  - An expression must have at least one floating point variable or constant to yield a floating point result

Summary

- Data types specify the size, representation and organisation of data in the computer's memory
- Primitive Data types are the basic data types that are provided by the programming language
- Three primitive data types are
  - Integer
  - Float
  - Character

Further Reading

Kernighan, B. W. and Richie, D. (1992) *The C Programming Language.* 2nd ed., New Delhi:PHI.