Data Types in C

Goals of C

Designers wanted C to:

- Support system programming
- Be low-level
- Be portable
- Be easy for people to handle

But also:

- Support application programming
- Be easy for computers to handle

- Conflicting goals on multiple dimensions!
- Result: different design decisions than Java

Primitive Data Types

- integer data types
- floating-point data types
- pointer data types
- no character data type (use small integer types instead)
- no character string data type (use arrays of small ints instead)
- no logical or boolean data types (use integers instead)

For "under the hood" details, stay tuned for "number systems" lecture next week

Integer Data Types

Integer types of various sizes: signed char, short, int, long

- char is 1 byte
- Number of bits per byte is unspecified!
  (but in the 21st century, pretty safe to assume it’s 8)
- Sizes of other integer types not fully specified but constrained:
  - int was intended to be “natural word size”
  - \( 2 \leq \text{sizeof}(\text{short}) \leq \text{sizeof}(\text{int}) \leq \text{sizeof}(\text{long}) \)

On ArmLab:

- Natural word size: 8 bytes (“64-bit machine”)
- char: 1 byte
- short: 2 bytes
- int: 4 bytes (compatibility with widespread 32-bit code)
- long: 8 bytes

What decisions did the designers of Java make?

Integer Literals

- Decimal: 123
- Octal: 0173 = 123
- Hexadecimal: 0x7B = 123
- Use “L” suffix to indicate long literal
- No suffix to indicate short literal; instead must use cast

Examples

- int: 123, 0173, 0x7B
- long: 123L, 0173L, 0x7BL
- short: (short)123, (short)0173, (short)0x7B

Unsigned Integer Data Types

unsigned types: unsigned char, unsigned short, unsigned int, and unsigned long

- Holds only non-negative integers
- Conversion rules for mixed-type expressions
  (Generally, mixing signed and unsigned converts to unsigned)
- See King book Section 7.4 for details

For "under the hood" details, stay tuned for "number systems" lecture next week
Unsigned Integer Literals

Default is signed
• Use "U" suffix to indicate unsigned literal

Examples
• unsigned int
  • 123, 0173, 0x7B
  • unsigned short
  • (unsigned short)123, (unsigned short)0173, (unsigned short)0x7B

"Character" Data Type

The C char type
• char is designed to hold an ASCII character
  • And should be used when you’re dealing with characters: character-manipulation functions we’ve seen (such as toupper) take and return char
  • char might be signed (-128..127) or unsigned (0..255)
  • But since 0 ≤ ASCII ≤ 127 it doesn’t really matter
  • If you want a 1-byte type for calculation, you might (should?) specify signed char or unsigned char

Character Literals

Single quote syntax: ‘a’
Use backslash (the escape character) to express special characters
• Examples (with numeric equivalents in ASCII):

<table>
<thead>
<tr>
<th>Character</th>
<th>ASCII Value</th>
<th>Hexadecimal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘a’</td>
<td>97</td>
<td>0x61</td>
</tr>
<tr>
<td>‘b’</td>
<td>98</td>
<td>0x62</td>
</tr>
<tr>
<td>‘A’</td>
<td>65</td>
<td>0x41</td>
</tr>
<tr>
<td>‘B’</td>
<td>66</td>
<td>0x42</td>
</tr>
<tr>
<td>‘\’</td>
<td>92</td>
<td>0x5C</td>
</tr>
<tr>
<td>‘\n’</td>
<td>10</td>
<td>0x0A</td>
</tr>
<tr>
<td>‘\t’</td>
<td>9</td>
<td>0x09</td>
</tr>
</tbody>
</table>

Strings and String Literals

Issue: How should C represent strings and string literals?
Rationale:
• Natural to represent a string as a sequence of contiguous chars
  • How to know where char sequence ends?
  • Store length together with char sequence?
  • Store special "sentinel" char after char sequence?

Decisions
• Adopt a convention
  • String is a sequence of contiguous chars
  • String is terminated with null char (‘\0’)
  • Use double-quote syntax (e.g., "hello") to represent a string literal
  • Provide no other language features for handling strings
  • Delegate string handling to standard library functions

Examples
• ‘a’ is a char literal
• “about” is a string literal
• “a” is a string literal

Arrays of characters

```c
char s[10] = {'H','e','l','l','o',0};
(char, equivalently)
char *p = s+2;
printf("Je%s!", p);
```
Unicode
Back in 1970s, English was the only language in the world (citation needed), so we all used this alphabet:

ASCII: American Standard Code for Information Interchange

In the 21st century, it turns out that there are other people and languages out there, so we need:

Modern Unicode
When Java was designed, Unicode fit into 16 bits, so char in Java was 16 bits long. Then this happened:

ASCII and UTF-8
Lots of characters in today’s Unicode
- 100,000+ defined, capacity for > 1 million

Can’t modify size of char in C

Solution: variable-length encoding (UTF-8)
- Standard ASCII characters use 1 byte
- Most Latin-based alphabets use 2 bytes
- Chinese, Japanese, Korean characters use 3 bytes
- Historic scripts, mathematical symbols, and emoji use 4 bytes
- This won’t be on the exam!

Logical Data Types
No separate logical or Boolean data type

Represent logical data using type char or int
- Or any integer type
- Or any primitive type!

Conventions:
- Statements (if, while, etc.) use 0 ⇒ FALSE, ≠0 ⇒ TRUE
- Relational operators (<, >, etc.) and logical operators (!, &&, ||) produce the result 0 or 1

Logical Data Type Shortcuts
Using integers to represent logical data permits shortcuts

It also permits some really bad code...

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iClicker Question
Q: What is i set to in the following code?

\[ i = (1 != 2) + (3 > 4); \]

A. 0
B. 1
C. 2
D. 3
E. 4
Logical Data Type Dangers

The lack of a logical data type hampers compiler's ability to detect some errors

```
int i;
i = 0;
if (i = 5)
    statement1;
```

What happens in Java?

What happens in C?

Floating-Point Data Types

C specifies:
- Three floating-point data types: float, double, and long double
  - Sizes unspecified, but constrained:
    - sizeof(float) ≤ sizeof(double) ≤ sizeof(long double)

On ArmLab (and on pretty much any 21st-century computer using the IEEE standard)
- float: 4 bytes
- double: 8 bytes
- long double: 16 bytes

On ArmLab (but varying a lot across architectures)

Floating-Point Literals

How to write a floating-point number?
- Either fixed-point or "scientific" notation
- Any literal that contains decimal point or "E" is floating-point
- The default floating-point type is double
- Append "F" to indicate float
- Append "L" to indicate long double

Examples
- double: 123.456, 1.23456E4
- float: 123.456F, 1E-2F, 1.23456E4F
- long double: 123.456L, 1E-2L, 1.23456E4L

Data Types Summary: C vs. Java

Java only
- boolean, byte

C only
- unsigned char, unsigned short, unsigned int, unsigned long, long double

Sizes
- Java: Sizes of all types are specified, and portable
- C: Sizes of all types except char are system-dependent

Type char
- Java: char is 2 bytes (to hold all 1995-era Unicode values)
- C: char is 1 byte