Data III & Integers I
CSE 351 Autumn 2023

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Relevant Course Information

❖ hw3 due Friday, hw4 due Monday

❖ Lab 1a released
   ▪ Some later functions require *bit shifting*, covered in Lesson 5
   ▪ Workflow:
     1) Edit pointer.c
     2) Run the Makefile (make clean followed by make) and check for compiler errors & warnings
     3) Run ptest (./*ptest) and check for correct behavior
     4) Run rule/syntax checker (python3 d1c.py) and check output
   ▪ Due Monday 10/9, will overlap a bit with Lab 1b
     • We grade just your last submission
     • Don’t wait until the last minute to submit – need to check autograder output
Lab Synthesis Questions

❖ All subsequent labs (after Lab 0) have a “synthesis question” portion
   ▪ Can be found on the lab specs and are intended to be done after you finish the lab
   ▪ You will type up your responses in a .txt file for submission on Gradescope
   ▪ These will be graded “by hand” (read by TAs)

❖ Intended to check your understand of what you should have learned from the lab
   ▪ Also great practice for short answer questions on the exams
Data III & Integers I
Lesson Summary (1/2)

- Bit-level operators allow for fine-grained manipulations of data
  - Bitwise AND (&), OR (|), and NOT (~) different than logical AND (&&), OR (||), and NOT (!)
  - Especially useful with bitmasks – chosen bit vectors used with & | ^

- Choice of **encoding scheme** is important
  - Tradeoffs based on size requirements and desired operations

- Integers represented using unsigned and two’s complement representations
  - Limited by fixed bit width, satisfy desirable arithmetic properties
Lesson Summary (2/2)

❖ Terminology:
- Bitwise operators (&, |, ^, ~), Logical operators (&&, ||, !)
- Short-circuit evaluation
- Unsigned integers, Signed integers (Two’s Complement)

❖ Learning Objectives:
- Compute the effects of bit shifting, bitwise, logical, and arithmetic operations on integers.
- Analyze the benefits and drawbacks of different integer representations (Unsigned, Sign and Magnitude, Two’s Complement) and custom encoding schemes.

❖ What lingering questions do you have from the lesson?
Integer Hardware

- In practice, all modern systems use **unsigned** and **two’s complement** encoding schemes for integers
  - Sign and magnitude for integers is a historical artifact, but useful context for design decision and for floating point (next lesson)
  - Much of the same hardware can be used for both encoding schemes (e.g., addition, subtraction)

- Fun fact: Java was designed to only support **signed** data types
  - *Assumed easier for beginners to understand* than having unsigned as well (i.e., eliminate potential sources of error)
  - Unsigned operation support provided with Unsigned Integer API (starting with Java SE 8 in 2014)
Discussion Question

❖ Discuss the following question(s) in groups of 3-4 students
  ▪ I will call on a few groups afterwards so please be prepared to share out
  ▪ Be respectful of others’ opinions and experiences

❖ Thinking about the (implicit and explicit) design decisions for Two’s Complement, what are some of the advantages and disadvantages of choosing to:
  ▪ Represent consecutive (i.e., no gaps) integers
    example, if only representing even integers, what should happen when we compute 6/2 ?
  ▪ Represent the same number of positives and negatives
    the bias should make sense in the context of our application
    arithmetic might get weird again...
  ▪ Positive number encodings match unsigned
    no need to convert anything when changing interpretations
Data III & Integers I –
Practice
Group Work Time

❖ During this time, you are encouraged to work on the following:
   1) If desired, continue your discussion
   2) Work on the lesson problems (solutions at the end of class)
   3) Work on the homework problems

❖ Resources:
   ▪ You can revisit the lesson material
   ▪ Work together in groups and help each other out
   ▪ Course staff will circle around to provide support
Practice Questions (1/2)

❖ Compute the result of the following expressions for char `c = \text{0x81};`

\[
\begin{align*}
\text{c} \land \text{c} &= \text{0x00} \\
\text{c} \land \text{0xA9} &= \text{0x28} \\
\text{c} \lor \text{0x80} &= \text{0x81} \\
\neg \text{c} &= \text{0x01}
\end{align*}
\]

❖ Compute the value of signed char `sc = \text{0xF0};` (Two’s Complement)

\[
\begin{align*}
\neg \text{sc} + 1 &= \text{0b0000 1111} + 1 \\
&= \text{0b0001 0000} \\
&= -2^9 + 2^6 + 2^5 + 2^4 \\
&= -16
\end{align*}
\]
Practice Questions (2/2)

❖ Take the 4-bit number encoding \( x = 0b1011 \)

❖ Which of the following numbers is NOT a valid interpretation of \( x \) using any of the number representation schemes discussed today?

- Unsigned, Sign and Magnitude, Two’s Complement

A. -4
B. -5
C. 11
D. -3
E. We’re lost...

**Unsigned Calculation:**
\[
\text{unsigned: } 8 + 2 + 1 = 11
\]

**Sign and Magnitude Calculation:**
\[
\text{sign + mag: } 1011 \rightarrow -(2+1) = -3
\]

**Two’s Complement Calculation:**
\[
\text{two’s: } -8 + 2 + 1 = -5
\]
\[
-x = 0b010011 = 5 \rightarrow x = -5
\]