CS 460

Programming Languages

Fall 2021

Dr. Watts

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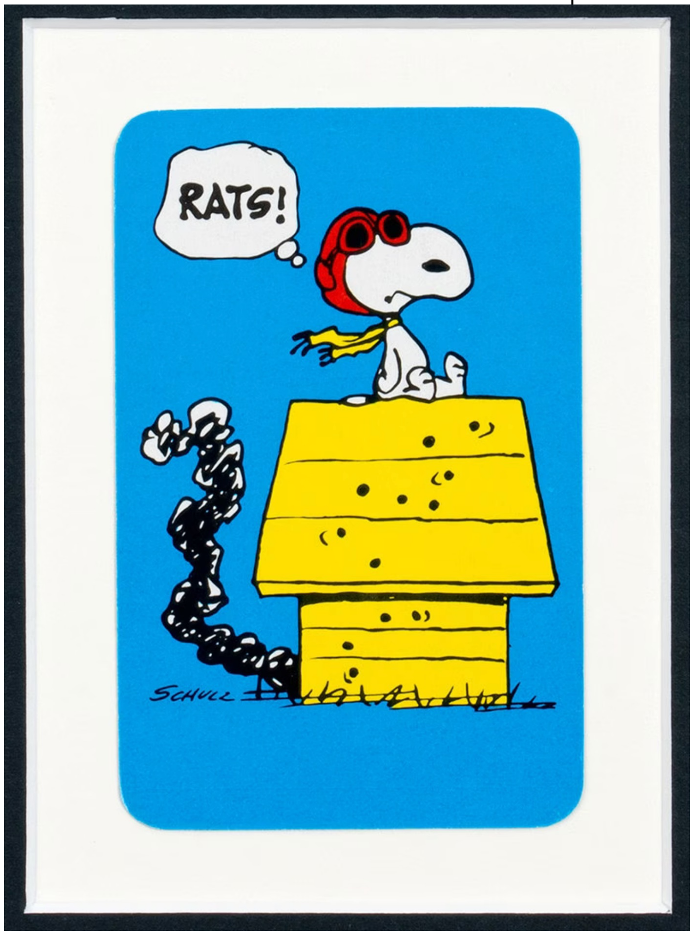
Exercise 2

- Will be revisiting this as Exercise 5
- Issues
  - Testing
  - C++ input protocols
- Preliminary Exercise
  - Will be posted soon – not due for quite a while.



Project 1

- Questions? (By email or on paper)

Project 1

- Regarding the white leading whitespaces in the .lst files before the line number. Does our output .lst file have to match the format exactly? Did you use \t to tab it or what width is that set to?
- .lst files do not need to match.
- .p1 files need to match. (White space not important.)

Project 1

- How should the .lst and and.p1 files look for an input such as:

  .-123.43 12/.5 ./

```
Input file: ha.pl460
   1: .-123.43 12/.5 ./
Error at 1,1: Unexpected '.' found
Error at 1,12: Unexpected '12/' found
Error at 1,16: Unexpected '.' found
3 errors found in input file
```

```
ERROR_T         .
NUMLIT_T        -123.43
ERROR_T         12/
NUMLIT_T        .5
ERROR_T         .
DIV_T           /
EOF_T
```

IEEE Single Precision (float 32)

- The IEEE single precision floating point standard representation requires a 32 bit word, which may be represented as numbered from 0 to 31, left to right. The first bit is the sign bit, S, the next eight bits are the exponent bits, 'E', and the final 23 bits are the fraction 'F':

```
S EEEEEEEE FFFFFFFFFFFFFFFFFFFFFFF
0 1      8 9                    31
```

- The value V represented by the word may be determined as follows:
  - If E=255 and F is nonzero, then V=NaN ("Not a number")
  - If E=255 and F is zero and S is 1, then V=-Infinity
  - If E=255 and F is zero and S is 0, then V=Infinity
  - If 0<E<255 then V=(-1)**S * 2 ** (E-127) * (1.F) where "1.F" is intended to represent the binary number created by prefixing F with an implicit leading 1 and a binary point.
  - If E=0 and F is nonzero, then V=(-1)**S * 2 ** (-126) * (0.F) These are "unnormalized" values.
  - If E=0 and F is zero and S is 1, then V=-0
  - If E=0 and F is zero and S is 0, then V=0
- In particular,
  - `0 00000000 00000000000000000000000 = 0`
  - `1 00000000 00000000000000000000000 = -0`
  - `0 11111111 00000000000000000000000 = Infinity`
  - `1 11111111 00000000000000000000000 = -Infinity`
  - `0 11111111 00000100000000000000000 = NaN`
  - `1 11111111 00100010001001010101010 = NaN`
  - `0 10000000 00000000000000000000000 = +1 * 2**(128-127) * 1.0 = 2`
  - `0 10000001 10100000000000000000000 = +1 * 2**(129-127) * 1.101 = 6.5`
  - `1 10000001 10100000000000000000000 = -1 * 2**(129-127) * 1.101 = -6.5`
  - `0 00000001 00000000000000000000000 = +1 * 2**(1-127) * 1.0 = 2**(-126)`
  - `0 00000000 10000000000000000000000 = +1 * 2**(-126) * 0.1 = 2**(-127)`
  - `0 00000000 00000000000000000000001 = +1 * 2**(-126) * 0.00000000000000000000001 = 2**(-149) (Smallest positive value)`

IEEE Double Precision (float64)

- The IEEE double precision floating point standard representation requires a 64 bit word, which may be represented as numbered from 0 to 63, left to right. The first bit is the sign bit, S, the next eleven bits are the exponent bits, 'E', and the final 52 bits are the fraction 'F':

```
S EEEEEEEEEEE FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
0 1        11 12                                                63
```

- The value V represented by the word may be determined as follows:
- If E=2047 and F is nonzero, then V=NaN ("Not a number")
- If E=2047 and F is zero and S is 1, then V=-Infinity
- If E=2047 and F is zero and S is 0, then V=Infinity
- If 0<E<2047 then V=(-1)**S * 2 ** (E-1023) * (1.F) where "1.F" is intended to represent the binary number created by prefixing F with an implicit leading 1 and a binary point.
- If E=0 and F is nonzero, then V=(-1)**S * 2 ** (-1022) * (0.F) These are "unnormalized" values.
- If E=0 and F is zero and S is 1, then V=-0
- If E=0 and F is zero and S is 0, then V=0

IEEE Quadruple Precision (float128)

- 1 bit sign
- 15 bit exponent
- 112 bit fraction

Half Precision (float16)

- Half precision floating point representation requires a 16 bit word, which may be represented as numbered from 0 to 15, left to right. The first bit is the sign bit, S, the next five bits are the exponent bits, 'E', and the final 10 bits are the fraction 'F':

```
S EEEEE FFFFFFFFFF
0 1   5 6        15
```

- The value V represented by the word may be determined as follows
- Sign
  - Sign = 0 is positive
  - Sign = 1 is negative
- Exponent
  - Biased (15)
  - 00000 – 11111
- Fraction

Half Precision Example 1

- Example: 125.25
  - Whole number 125_{10} == $?_2$
  - Fraction $.25_{10}$ == $?_2$

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value																

Half Precision Example 2

- Example: 123000.0
  - Whole number $123000_{10} == ?_2$
  - Fraction $.0_{10} == ?_2$

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value																

Half Precision Example 3

- Example: 0.21875
  - Whole number 0_{10} == $?_2$
  - Fraction $.21875_{10}$ == $?_2$

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value																

Half Precision Example 4

- Example: 5.20
  - Whole number 5_{10} == $?_2$
  - Fraction $.20_{10}$ == $?_2$

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value																

Half Precision Example 5

- Example: 12.20
  - Whole number $12_{10} == ?_2$
  - Fraction $.20_{10} == ?_2$

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value																

Half Precision Example 6

- Example: 25.20
  - Whole number $25_{10} == ?_2$
  - Fraction $.20_{10} == ?_2$

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value																

Half Precision Example 7

- Example: 37.20
  - Whole number $37_{10} == ?_2$
  - Fraction $.20_{10} == ?_2$

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value																

Let's go the other way!

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0

Let’s go the other way!

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit value	1	1	0	1	1	1	0	0	1	1	0	0	1	1	0	1

Some Half-precision values

Binary	Hex	Value	Notes
0 00000 0000000000	0000	0	
0 00000 0000000001	0001	$2^{-14} \times (0 + \frac{1}{1024}) \approx 0.000000059604645$	smallest positive subnormal number
0 00000 1111111111	03ff	$2^{-14} \times (0 + \frac{1023}{1024}) \approx 0.000060975552$	largest subnormal number
0 00001 0000000000	0400	$2^{-14} \times (1 + \frac{0}{1024}) \approx 0.00006103515625$	smallest positive normal number
0 01101 0101010101	3555	$2^{-2} \times (1 + \frac{341}{1024}) \approx 0.33325195$	nearest value to 1/3
0 01110 1111111111	3bff	$2^{-1} \times (1 + \frac{1023}{1024}) \approx 0.99951172$	largest number less than one
0 01111 0000000000	3c00	$2^{0} \times (1 + \frac{0}{1024}) = 1$	one
0 01111 0000000001	3c01	$2^{0} \times (1 + \frac{1}{1024}) \approx 1.00097656$	smallest number larger than one
0 11110 1111111111	7bff	$2^{15} \times (1 + \frac{1023}{1024}) = 65504$	largest normal number
0 11111 0000000000	7c00	∞	infinity
1 00000 0000000000	8000	-0	
1 10000 0000000000	c000	-2	
1 11111 0000000000	fc00	$-\infty$	negative infinity

```
#include <iostream>
#include <iomanip>
#include <cmath>
using namespace std;

int main ()
{
        float value = 0;
        do
        {
                cout << "Please enter a floating point value (0 to quit): ";
                cin >> value;
                cout << "  value: " << fixed << showpoint << setprecision (30)
                     << value << endl;
                float rounded = (round (value * 100)) / 100.0;
                cout << "rounded: " << fixed << showpoint << setprecision (30)
                     << rounded << endl;
        } while (value != 0);
        return 0;
}
```

Other Numeric Types

- Arbitrary precision
- Fraction type
- User defined types

String types

- C style strings
- C++ strings

Composite Data Types

- Array
- Struct
- Class
- Union

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