VL03 Scalar Data Types

6. December

Scalar Data Types

- Integer
- Double
- Character, String
- Regular Expressions

Integer

> Any of the natural numbers, the negatives of these numbers, or zero.
>
> — The Merriam Webster Dictionary

- Ranges
  - Signed: $-(2^{n-1})$ to $(2^{n-1} - 1)$
  - Unsigned: 0 to $(2^{n} - 1)$
- Fast hexadecimal ⇒ binary conversions because $\log_2(16) = 4$
- Fast operations: Comparison, Negation, Addition, Multiplication

Table 1. int32_t examples, the prefix 0x denotes a hexadecimal value

Real Value	Memory Value
0x0	0x0
0x1	0x1

Real Value	Memory Value
-0x1	0xFFFFFFFF
-0x10	0xFFFFFFF0
-0x100	0xFFFFFF00
-0x1000	0xFFFFF000
-0x10000	0xFFFF0000
-0x100000	0xFFF00000
-0x1000000	0xFF000000
-0x10000000	0xF0000000
-0x80000000	0x80000000
0x7FFFFFFF	0x7FFFFFFF

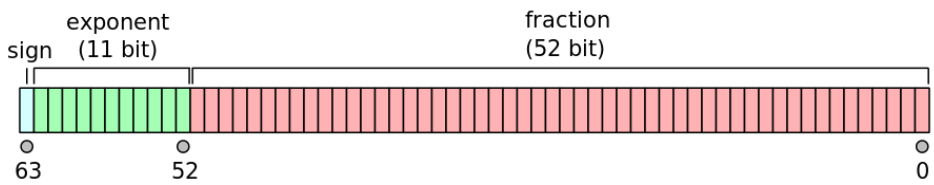
This representation mechanism is called **Two's Complement**. Sum of a positive number and its negative counterpart gives 2^n (except zero, n is number of bits). The conversion between negative and positive (multiplication with -1) can be done very fast as bit negation (ones' complement) and

increase by 1.

Double

IEEE-754 Standard for Floating-Point Arithmetic

```
 Specifies interchange and
arithmetic formats and methods
for binary and decimal floating-
point arithmetic in computer
programming environments.
IEEE = Institute of Electrical
and Electronics Engineers
```



Representation

There are some reserved values for signed zero, infinity, and NaN (not a number). For non-reserved values, numeric representation can be obtained with the following formula:

$$(-1)^{\text{sign}}(1.b_{51}b_{50}\ldots b_0)_2 \times 2^{e-1023}$$

```c
#include <stdio.h>

int main()
{
    double a;
    double b;

    a = 1;
    b = a + 1;
    if(a == b) {
        printf("this would be
weird\n");
    }

    a = 10000000000000000.0;
    b = a + 1;
    if(a == b) {
        printf("yes, this is
perfectly normal\n");
    }
}
```

See https://en.wikipedia.org/wiki/Double-precision_floating-point_format for detailed

information.

Character, String

A string is often implemented as an array of bytes that stores a sequence of characters, using some character encoding. String may also denote more general arrays or other sequence (or list) data types and structures.

ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

Figure 1. American Standard Code for Information Interchange

Character Encoding

```
string name = "Antonín Dvořák";
//name.Length == 14
```

Abbreviations

```
UCS = Universal Coded Character
Set; UTF = UCS Transformation
Format
```

UTF-8

UTF-8 encoded string occupies 17 bytes.

```
00000000: 41 6e 74 6f 6e c3 ad
6e 20 44 76 6f c5 99 c3 a1
Anton..n Dvo....
00000010: 6b
k
```

UTF-32

UTF-32 encoded string occupies 56 bytes.

```
00000000: 00 00 00 41 00 00 00
6e 00 00 00 74 00 00 00 6f
...A...n...t...o
00000010: 00 00 00 6e 00 00 00
ed 00 00 00 6e 00 00 00 20
...n.......n...
00000020: 00 00 00 44 00 00 00
76 00 00 00 6f 00 00 01 59
...D...v...o...Y
00000030: 00 00 00 e1 00 00 00
6b
.......k...
```

- UTF-32 uses fixed four bytes
- UTF-8 uses a byte at the minimum in encoding the characters
- UTF-8 encoded file tends to be smaller
- UTF-8 is compatible with ASCII

Consider problems like sorting, error detection, length determination, and conversions between distinct encodings.

Regular Expressions

A regular expression, regex or regexp is a string that defines a search pattern. Such patterns can be used for match or replace operations on strings. The control syntax uses a limited set of characters:
`*{}[]()^$.|*+?-` The implementations can vary, look at *Regular expressions in Java*, etc.

Boolean "or"

```
A vertical bar separates
alternatives. apple|orange
```

Grouping

```
Parentheses are used to define
the scope and precedence of the
operators.
For example, gray|grey and
gr(a|e)y are equivalent patterns
which both describe
the set of "gray" or "grey".
Grouping is also used to specify
```

```
and extract
specific data within the regex
match.
```

Quantification

```
A quantifier how often the
previous element must precede to
match.
```

- `?` optional occurrence, colou?r matches both "color" and "colour", also used for greediness control
- `*` zero or more occurrence; ab*c matches "ac", "abc", "abbc", "abbbc", and so on.
- `+` at least one occurrence; ab+c matches "abc", "abbc", "abbbc", and so on, but not "ac".
- `{n}` The preceding item is matched exactly `n` times.
- `{min,}` The preceding item is matched at least `min` times.

- `{min,max}` The preceding item is matched at least `min` times, but less than `max` times.

Wildcards

- `^` beginning of a line (also used as a negation, see below)
- `$` end of line
- `.` match any character
- `[]` determines a group of characters, `-` interval, `^` is negation
  - `[a-z]` match any character between **a** and **z**
  - `[0123456789]` or `[0-9]` match any decimal digit
  - `[^A-Z]` match all characters except all between **A** and **Z**

Implementation

```
The environment (programming
language, text editor) usually
defines some
```

```
specific abbreviations or
macros.
```

- `\d` decimal digit
- `\w`, `\W` word character, non-word character
- `\s`, `\S` space character, non-space character
- `\b`, `\<`, `\>` word boundary, beginning/end of a word

Working with meta-characters

```
Meta-characters need to be
escaped if they should be
matched.
```

Regex `\\d` matches string `\d`, regex `\*\+\+\?` matches string `*++?`

Regex Examples

Notation: example regular expressions are enclosed between two slashes /regex/.

```
/[a-z0-9_-]{3,16}/
# match a username
/[a-z0-9_-]{6,18}/
# match a password
/0x?([a-f0-9]+)/
# match a hexadecimal number
/(\d\d):(\d\d):(\d\d)/
# match a date in hh:mm:ss
format

# match a web address
/(https?:\/\/)?([\da-z\.-]+)
\.([a-z\.]{2,6})([\/\w
\.-]*)*\/?/
```

Experiment with your own regular expressions at https://regexr.com/

Exercise

Consider a string containing multiple space separated expressions. An expression is either a single word or a compound expression consisting of multiple words between double quotes.

Example input:

```
apple orange banana "honey pie"
sun "high noon"
```

Example output:

```
all expressions: 6
compound expressions: 2
```