Characters Lesson Outline

Numeric Encoding of Non-numeric Data #1

In Programming Project #4, we ***encoded*** (represented) entree options using **integer** values.

For example:

1. burger
2. chicken sandwich
3. fish sandwich

If we wanted, we could add other entree options.

For example:

4. vegan burger
5. chicken nuggets

Numeric Encoding of Non-numeric Data #2

1. burger
2. chicken sandwich
3. fish sandwich
4. vegan burger
5. chicken nuggets

...

The numbers in these cases have no standard meaning with respect to the items that they encode; they've been chosen essentially at random.

Numeric Encoding of Non-numeric Data #3

1. burger
2. chicken sandwich
3. fish sandwich
4. vegan burger
5. chicken nuggets

…

So, we see that we can encode ***qualitative*** (non-numeric) values
with ***quantitative*** (numeric) values,
using **arbitrary** but **fixed** and **distinct** numeric values
to encode a set of qualities.

That is, the code values can be any `int` values, but:

- they can't change at runtime;
- the same `int` value can't be used to encode two different things.

Representing Characters

What's the most important set of non-numeric values in computing?

It's the one that allows the computer to communicate with us in a way that makes sense to actual real live human beings: **natural language**.

The most efficient way for computers to communicate in a natural language is by **writing**.

Writing is based on **characters**.

Characters are **non-numeric**.

So, we want a way to **encode** characters numerically.

How Characters Are Represented #1

Here’s a code you might have used to play secret code games when you were a kid:

'A' = 1, 'B' = 2, 'C' = 3, 'D' = 4, . . ., 'Z' = 26

Now that you’ve grown up and taken CS1313, you realize that the numbers that you choose can be **arbitrary**, as long as they’re **fixed** and **distinct**.

So you could just as easily choose:
'A' = 65, 'B' = 66, 'C' = 67, 'D' = 68, . . ., 'Z' = 90

This is a perfectly reasonable encoding, if the only characters that you care about are upper case letters.

What about lower case?

How Characters Are Represented #2

'A' = 65, 'B' = 66, 'C' = 67, 'D' = 68, . . ., 'Z' = 90

What about lower case?

Well, you could add, for example:

'a' = 97, 'b' = 98, 'c' = 99, 'd' = 100, . . ., 'z' = 122

(Arbitrary, fixed, distinct.)

Are these the only characters that you need?

Representing Digits

Another kind of very important character is a digit.

Here’s a possible encoding of the decimal digits:

'0' = 48, '1' = 49, '2' = 50, '3' = 51, . . ., '9' = 57

Notice that there’s an important distinction between
  the character to be represented,
  which happens to be a digit,
  and the numeric encoding,
  whose value **DOESN’T** have to have anything to do with the value of the digit being encoded.

(Arbitrary, fixed, distinct.)

Representing Punctuation

In addition to the upper case letters, the lower case letters and the digits, we also need to encode special characters such as punctuation.

This is starting to get pretty complicated, so maybe it'd help to have a standardized system.

ASCII

The ***American Standard Code for Information Interchange*** (ASCII)* is a standardized system for encoding characters numerically.

It has several categories of characters:

- letters:
  - upper case ('A' = 65 through 'Z' = 90);
  - lower case ('a' = 97 through 'z' = 122);
- digits ('0' = 48 through '9' = 57);
- punctuation
  - space = ' ' 32 through slash ' / ' = 47;
  - Colon ' : ' = 58 through at sign ' @ ' = 64;
  - open square bracket '[' = 91 through backquote ' ` ' = 96;
  - open curly brace '{' = 123 through tilde ' ~ ' = 126;
- ***control characters***, encoded as 0 through 31; also **DEL** (encoded as 127).

* http://www.asciitable.com/

ASCII Table #1

Code	Char	Kbd	Name	Code	Char	Kbd	Name
0	NUL		Null	16	DLE	Ctrl-P	Data Line Escape
1	SOH	Ctrl-A	Start of Heading	17	DC1	Ctrl-Q	Device Control 1
2	STX	Ctrl-B	Start of Text	18	DC2	Ctrl-R	Device Control 2
3	ETX	Ctrl-C	End of Text	19	DC3	Ctrl-S	Device Control 3
4	EOT	Ctrl-D	End of Transmission	20	DC4	Ctrl-T	Device Control 4
5	ENQ	Ctrl-E	Enquiry	21	NAK	Ctrl-U	Negative Acknowledge
6	ACK	Ctrl-F	Acknowledge	22	SYN	Ctrl-V	Synchronous File
7	BEL	Ctrl-G	Ring Bell	23	ETB	Ctrl-W	End Transmission Block
8	BS	Ctrl-H	Backspace	24	CAN	Ctrl-X	Cancel
9	HT	Ctrl-I	Horizontal Tab	25	EM	Ctrl-Y	End of Medium
10	LF	Ctrl-J	Line Feed	26	SUB	Ctrl-Z	Substitute
11	VT	Ctrl-K	Vertical Tab	27	ESC	Ctrl-Shift-K	Escape
12	FF	Ctrl-L	Form Feed	28	FS	Ctrl-Shift-L	File Separator
13	CR	Ctrl-M	Carriage Return	29	GS	Ctrl-Shift-M	Group Separator
14	SO	Ctrl-N	Shift Out	30	RS	Ctrl-Shift-N	Record Separator
15	SI	Ctrl-O	Shift In	31	US	Ctrl-Shift-O	Unit Separator

ASCII Table #2

Code	Char	Name	Code	Char	Name
32		Blank space	48	0	
33	!	Exclamation point (or “bang”)	49	1	
34	"	Double quote	50	2	
35	#	Pound (or hash)	51	3	
36	$	Dollar sign (or “buck”)	52	4	
37	%	Percent	53	5	
38	&	Ampersand (or “and”)	54	6	
39	'	Single quote	55	7	
40	(	Open parenthesis	56	8	
41	)	Close parenthesis	57	9	
42	*	Asterisk (or “star”)	58	:	Colon
43	+	Plus	59	;	Semicolon
44	,	Comma	60	<	Less than
45	-	Hyphen	61	=	Equals Sign
46	.	Period (or “dot”)	62	>	Greater than
47	/	Slash	63	?	Question mark

ASCII Table #3

Code	Char	Name	Code	Char	Name
64	@	At	80	P	
65	A		81	Q	
66	B		82	R	
67	C		83	S	
68	D		84	T	
69	E		85	U	
70	F		86	V	
71	G		87	W	
72	H		88	X	
73	I		89	Y	
74	J		90	Z	
75	K		91	[	Open square bracket
76	L		92	\	Backslash (or "bash")
77	M		93	]	Close square bracket
78	N		94	^	Caret (or "fang")
79	O		95	_	Underscore

ASCII Table #4

Code	Char	Name	Code	Char	Name
96	`	Accent grave	112	p	
97	a		113	q	
98	b		114	r	
99	c		115	s	
100	d		116	t	
101	e		117	u	
102	f		118	v	
103	g		119	w	
104	h		120	x	
105	i		121	y	
106	j		122	z	
107	k		123	{	Open curly brace
108	l		124			Vertical bar (or "bar")
109	m		125	}	Close curly brace
110	n		126	~	Tilde
111	o		127	DEL	Delete

ASCII Confirmation Program #1

```
#include <stdio.h>

int main ()
{ /* main */
    const int first_printable_character_code =  32;
    const int last_printable_character_code  = 126;
    const int program_success_code           =   0;
    int index;

    for (index = first_printable_character_code;
         index <= last_printable_character_code;
         index++) {
        printf("ASCII Code #%3d is: %c\n",
            index, index);
    } /* for index */
    return program_success_code;
} /* main */
```

ASCII Confirmation Program #2

```
% gcc -o asciitest asciitest.c
% asciitest
ASCII Code # 32 is:
ASCII Code # 33 is: !
ASCII Code # 34 is: "
ASCII Code # 35 is: #
ASCII Code # 36 is: $
ASCII Code # 37 is: %
ASCII Code # 38 is: &
ASCII Code # 39 is: '
ASCII Code # 40 is: (
ASCII Code # 41 is: )
ASCII Code # 42 is: *
ASCII Code # 43 is: +
ASCII Code # 44 is: ,
ASCII Code # 45 is: -
ASCII Code # 46 is: .
ASCII Code # 47 is: /
```

```
ASCII Code # 48 is: 0
ASCII Code # 49 is: 1
ASCII Code # 50 is: 2
ASCII Code # 51 is: 3
ASCII Code # 52 is: 4
ASCII Code # 53 is: 5
ASCII Code # 54 is: 6
ASCII Code # 55 is: 7
ASCII Code # 56 is: 8
ASCII Code # 57 is: 9
ASCII Code # 58 is: :
ASCII Code # 59 is: ;
ASCII Code # 60 is: <
ASCII Code # 61 is: =
ASCII Code # 62 is: >
ASCII Code # 63 is: ?
```

ASCII Confirmation Program #3

```
ASCII Code # 64 is: @
ASCII Code # 65 is: A
ASCII Code # 66 is: B
ASCII Code # 67 is: C
ASCII Code # 68 is: D
ASCII Code # 69 is: E
ASCII Code # 70 is: F
ASCII Code # 71 is: G
ASCII Code # 72 is: H
ASCII Code # 73 is: I
ASCII Code # 74 is: J
ASCII Code # 75 is: K
ASCII Code # 76 is: L
ASCII Code # 77 is: M
ASCII Code # 78 is: N
ASCII Code # 79 is: O
```

```
ASCII Code # 80 is: P
ASCII Code # 81 is: Q
ASCII Code # 82 is: R
ASCII Code # 83 is: S
ASCII Code # 84 is: T
ASCII Code # 85 is: U
ASCII Code # 86 is: V
ASCII Code # 87 is: W
ASCII Code # 88 is: X
ASCII Code # 89 is: Y
ASCII Code # 90 is: Z
ASCII Code # 91 is: [
ASCII Code # 92 is: \
ASCII Code # 93 is: ]
ASCII Code # 94 is: ^
ASCII Code # 95 is: _
```

ASCII Confirmation Program #4

```
ASCII Code # 96 is: `
ASCII Code # 97 is: a
ASCII Code # 98 is: b
ASCII Code # 99 is: c
ASCII Code #100 is: d
ASCII Code #101 is: e
ASCII Code #102 is: f
ASCII Code #103 is: g
ASCII Code #104 is: h
ASCII Code #105 is: i
ASCII Code #106 is: j
ASCII Code #107 is: k
ASCII Code #108 is: l
ASCII Code #109 is: m
ASCII Code #110 is: n
ASCII Code #111 is: o
ASCII Code #112 is: p
ASCII Code #113 is: q
ASCII Code #114 is: r
ASCII Code #115 is: s
ASCII Code #116 is: t
ASCII Code #117 is: u
ASCII Code #118 is: v
ASCII Code #119 is: w
ASCII Code #120 is: x
ASCII Code #121 is: y
ASCII Code #122 is: z
ASCII Code #123 is: {
ASCII Code #124 is: |
ASCII Code #125 is: }
ASCII Code #126 is: ~
```

A `char` is an `int` #1

```
#include <stdio.h>

int main ()
{ /* main */
    const int  first_printable_character_code =  32;
    const int  last_printable_character_code  = 126;
    const int  program_success_code           =   0;
    int  index;

    for (index = first_printable_character_code;
         index <= last_printable_character_code;
         index++) {
        printf("ASCII Code #%3d is: %c\n",
            index, index);
    } /* for index */
    return program_success_code;
} /* main */
```

Notice that the variable named `index` is declared as an `int`, but in the `printf` statement, `index` can be used not only as an `int` but also as a `char`. The reverse is also true.

A `char` is an `int` #2

```
#include <stdio.h>

int main ()
{ /* main */
    const int  program_success_code            =   0;
    const char first_printable_character_code =  32;
    const char last_printable_character_code  = 126;
    char index;

    for (index = first_printable_character_code;
         index <= last_printable_character_code;
         index++) {
        printf("ASCII Code #%3d is: %c\n",
            index, index);
    } /* for index */
    return program_success_code;
} /* main */
```

Notice that the variable named `index` is declared as a `char`, but in the `printf` statement, `index` can be used not only as a `char` but also as an `int`. The reverse is also true.

Declaring `char` Scalar Variables #1

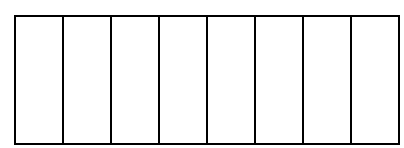
Here's a declaration of a `char` scalar variable:

```
char first_initial;
```

This declaration tells the compiler to grab a group of bytes, name them `first_initial`, and think of them as storing a `char`.

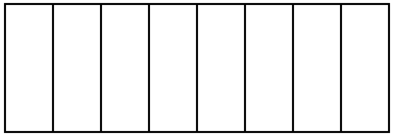
How many bytes in a `char` scalar?

Each `char` scalar takes one byte:

`first_initial :` 

Declaring `char` Scalar Variables #2

```
char first_initial;
```

first_initial : 

<u>REMEMBER</u>: A `char` is just like an `int`, except that it uses fewer bytes: typically, a `char` is 1 byte and an `int` is 4 bytes.

So, we can use `char` variables and constants in exactly the same ways that we use `int` variables and constants.

char Like int Example

```
% cat charadd.c
#include <stdio.h>

int main ()
{ /* main */
    const int program_success_code = 0;
    int addend, augend;
    char sum;

    printf("What are the addend and augend?\n");
    scanf("%d %d", &addend, &augend);
    sum = addend + augend;
    printf("The sum is %d.\n", sum);
    return program_success_code;
} /* main */
% gcc -o charadd charadd.c
% charadd
What are the addend and augend?
1 4
The sum is 5.
```

`char` Scalar Literal Constants

A ***character scalar literal constant*** is a single `char` enclosed in single quotes:

`'H'`

Note that

`'''`

is illegal.

However, you can also represent an individual `char` literal using the ***octal*** (base 8) code that represents it.

For example, the apostrophe character corresponds to ASCII code 39 decimal, which converts to 47 octal. (We'll learn about octal – base 8 – soon.)

So we can represent the apostrophe character like so:

`'\047'`

char Scalar Literal Constant Example

```
% cat apostrophe.c
#include <stdio.h>

int main ()
{ /* main */
    const int program_success_code = 0;
    printf("Apostrophe: %c\n", '\047');
    return program_success_code;
} /* main */
% gcc -o apostrophe apostrophe.c
% apostrophe
Apostrophe: '
```

Using `char` Scalar Variables

In C, we can use `char` scalar variables in many of the same ways that we use `int` scalar variables. As we saw, for example, we can declare them:

```
char first_initial;
```

We can also assign `char` scalar values to `char` scalar variables, by enclosing them in single quotes:

```
first_initial = 'H';
```

We can output `char` scalar values from `char` scalar variables, like so:

```
printf("My first initial is %c.\n",
    first_initial);
```

Using `char` Scalar Variables Example

```
% cat charscalar.c
#include <stdio.h>

int main ()
{ /* main */
    const char computers_favorite_character = 'q';
    const int  program_success_code         = 0;
    char users_favorite_character;

    printf("What is your favorite character?\n");
    scanf("%c", &users_favorite_character);
    printf("Your favorite character is '%c'.\n",
        users_favorite_character);
    printf("My favorite character is '%c'.\n",
        computers_favorite_character);
    return program_success_code;
} /* main */
% gcc -o charscalar charscalar.c
% charscalar
What is your favorite character?
Z
Your favorite character is 'Z'.
My favorite character is 'q'.
```

`char` Arrays #1

In C, you can have an array of type `char`, just as you can have arrays of numeric types:

```
char my_name[12];
```

We can fill this `char` array with characters and be able to print them out.

`char` Arrays #2

```
my_name[ 0] = 'H';
my_name[ 1] = 'e';
my_name[ 2] = 'n';
my_name[ 3] = 'r';
my_name[ 4] = 'y';
my_name[ 5] = ' ';
my_name[ 6] = 'N';
my_name[ 7] = 'e';
my_name[ 8] = 'e';
my_name[ 9] = 'm';
my_name[10] = 'a';
my_name[11] = 'n';
```

Is this a good solution?

Character Array Example #1

```
#include <stdio.h>
int main ()
{ /* main */
    const int my_name_length = 12;
    char my_name[my_name_length];
    int  index;
    my_name[ 0] = 'H';
    my_name[ 1] = 'e';
    my_name[ 2] = 'n';
    my_name[ 3] = 'r';
    my_name[ 4] = 'y';
    my_name[ 5] = ' ';
    my_name[ 6] = 'N';
    my_name[ 7] = 'e';
    my_name[ 8] = 'e';
    my_name[ 9] = 'm';
    my_name[10] = 'a';
    my_name[11] = 'n';
    printf("My name is ");
    for (index = 0; index < my_name_length; index++) {
        printf("%c", my_name[index]);
    } /* for index */
    printf(".\n");
    return 0;
} /* main */
```

Character Array Example #2

```
% gcc -o chararray chararray.c
% chararray
My name is Henry Neeman.
```

This is an improvement, but it's still not an efficient way to assign a sequence of characters to a variable.

What we want is a kind of `char` variable whose use will be convenient for inputting, outputting and using sequences of characters.