Practical C/C++ Programming Part 1

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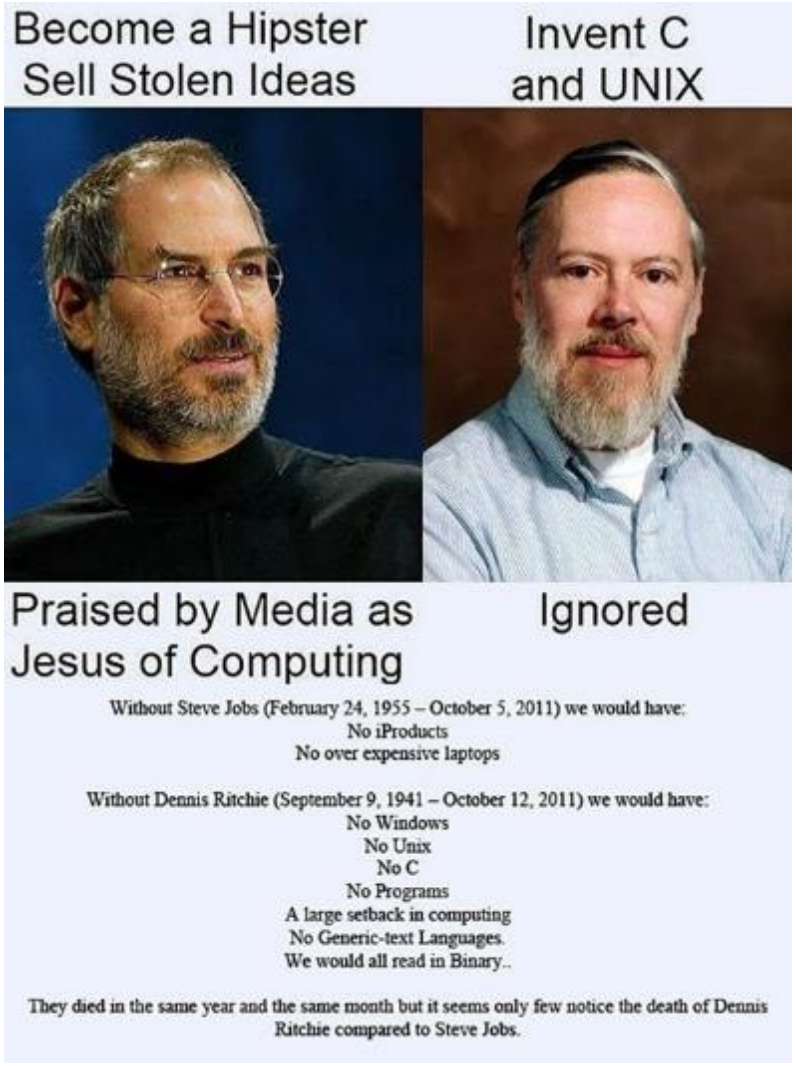
Things to be covered today

- You should be able to understand basic C/C++ after the training
- Use them for your research.

- Introduction to C and C++ language
- Basic syntax and grammar
- Variables and data types, operators
- Control Flow
- Functions
- Input/Output control

Who are they?


Become a Hipster
Sell Stolen Ideas
Invent C
and UNIX
Praised by Media as
Jesus of Computing
Ignored
Without Steve Jobs (February 24, 1955 – October 5, 2011) we would have:
No iProducts
No over expensive laptops
Without Dennis Ritchie (September 9, 1941 – October 12, 2011) we would have:
No Windows
No Unix
No C
No Programs
A large setback in computing
No Generic-text Languages.
We would all read in Binary..
They died in the same year and the same month but it seems only few notice the death of Dennis Ritchie compared to Steve Jobs.

C/C++ programming language overview

- C language
  - Developed by Dennis Ritchie starting in 1972 at Bell Labs
- C++ language
  - Developed by Bjarne Stroustrup starting in 1979 at Bell Labs
- C/C++ is most widely used programming languages of all time
- C/C++ compilers are available on most platforms, dominant on most science and engineering software packages
- Most of today's state-of-the-art OS and softwares have been implemented using C/C++. (Ref: https://www.mycplus.com/featured-articles/top-10-applications-written-in-c-cplusplus/)

C compiler overview

- What is a compiler?
  - A compiler is a computer program (or set of programs) that transforms ***source code*** written in a programming language (the source language) into another computer language (the target language, often having a binary form known as ***object code***).
- What does a compiler do?

  - ***In short, translate C/C++ source code to binary executable***
- List of common C compilers
  - GCC GNU Project (MinGW, Cygwin)
  - Intel Compiler
  - PGI Compiler
  - Microsoft/Borland Compilers
  - XL C (IBM)
  - Xcode

Writing your first C Program

- hello_world.c

```c
#include <stdio.h>

/* This is our first C program.
   for part 1 */
int main ( void ) {
   /* print a line to screen */
   printf( "Hello World!\n" );
   return 0;
}
```

Compile your first C program

- LONI and HPC users, start an interactive session:

```
# example on Philip
# ssh yourusername@philip.hpc.lsu.edu
# start an interactive job (session)
$ qsub -I -l nodes=1:ppn=8 -l walltime=02:00:00 -q workq -A
your_allocation
...start the interactive job...
$ cd
$ git clone https://github.com/lsuhpchelp/cprog1.git
$ cd cprog1/examples
$ gcc hello_world.c
```

- Execute the program by typing:

```
$ ./a.out
Hello World!
```

Structure of the hello_world.c file

- `#include` statements and preprocessor definitions
- Define `main()` function

```
int main(void)
{
    Function  body
    return 0;
}
```

The #include macro

- Header files: constants, functions, other declarations
- `#include <stdio.h>` – read the contents of the header file
- stdio.h- this is ***C Standard Input and Output Library*** definition (below are some ugly details):

```
#define FILE   struct __file
#define stdin   (__iob[0])
#define stdout   (__iob[1])
#define stderr   (__iob[2])
#define EOF   (-1)
#define fdev_set_udata(stream, u) do { (stream)->udata = u; } while(0)
#define fdev_get_udata(stream)   ((stream)->udata)
#define fdev_setup_stream(stream, put, get, rwflag)
...
```

Basic C syntax

- C is a ***case sensitive*** programming language: Var, var
- Each individual statement is ended with a semicolon ";".
- Except inside a character string, whitespace (tabs or spaces) is never significant.
- All C statements are defined in free format, i.e., with no specified layout or column assignment. The following program would produce exactly the same result as our earlier example:

```
#include <stdio.h>
int main()/*first program*/{printf("Hello World\n"); return 0;}
```

- Comments in C:

```
/*  this  is a single line comment */
/ * This is
    a multiline  comment * /
```

  - Always use proper comments in your code.
  - Comments are completely ignored by compiler (test/debug code)

Some more details on printf()

- `/* print formatted data to stdout (your screen) */`
  `int printf (const char * format, argument_list);`
- If format includes format specifiers (start with %), the additional arguments following format are formatted & replacing the specifiers.
- Format specifier prototype: `%[flags][width][.precision][length]specifier`
- Common format specifiers:

specifier	Output	Example
%f	decimal float	3.456
%7.5f	decimal float, 7 digit width, precision 5	8.52000
%d	decimal integer	180
%s	String of characters	“hello world”
%e	decimal float, scientific notation (mantissa/exponent)	3.141600e+05
\n	new line	
\t	tab	

Some more details on printf()

- An example showing the ***printf()*** usage

```
/* printf example showing different specifier usage */
#include <stdio.h>

int main()
{
   printf ("Characters: %c %c \n", 'a', 65);
   printf ("Decimals: %d %4d\n", 2014, 65);
   printf ("floats: %7.5f \t%f \t%e \n", 3.1416, 3.1416, 3.1416);
   printf ("%s \n", "hello world");
   return 0;
}
```

Practical C/C++ Programming 1

Variables and data types, operators

Data types in C

- Data types in C:
  - Basic types:
    - integers - ***char, int***, short, long.
    - floating point - Defined using float and double.
    - void - no value is available
  - Derived types - (a) Pointer types, (b) Array types
  - Custom types - structure/union/enum/class, will be detailed in Part 2
- For science and engineering, mostly used types:
  - integer
  - floating point
  - In C there is no logical type (available in C++ as `bool`)
    - **0** (zero) as false
    - non-zero as true

Integer Types: signed and unsigned

Type	Storage size	Value range
char	1 byte	-128 to 127 or 0 to 255
unsigned char	1 byte	0 to 255
signed char	1 byte	-128 to 127
int	2 or 4 bytes	-32,768 to 32,767 or -2,147,483,648 to 2,147,483,647
unsigned int	2 or 4 bytes	0 to 65,535 or 0 to 4,294,967,295
short	2 bytes	-32,768 to 32,767
unsigned short	2 bytes	0 to 65,535
long	4 bytes	-2,147,483,648 to 2,147,483,647
unsigned long	4 bytes	0 to 4,294,967,295

Floating Point Types

Type	Storage size	Value range	Precision
float	4 byte	1.2E-38 to 3.4E+38	6 decimal places
double	8 byte	2.3E-308 to 1.7E+308	15 decimal places
long double	10 byte	3.4E-4932 to 1.1E+4932	19 decimal places

void Types

Situation	Description
function returns as void	function with no return value
function arguments as void	function with no parameter
pointers to void	address of an object without type

Constants in C

- Constants refer to fixed values that the program may not alter during its execution
- Integer constant

```
275  /* integer */
215u /* unsigned int */
85   /* decimal */
31   /* int */
31u  /* unsigned int */
31l  /* long */
31ul /* unsigned long */
```

- floating point constant

```
3.1416
314159E-5  /* 3.14159 */
2.1E+5     /* 2.1x10^5*/
3.7E-2     /* 0.037   */
0.5E7      /* 5.0x10^6*/
-2.8E-2    /* -0.028  */
```

- character constant

```
'a' /* character 'a' */
'Z' /* character 'Z' */
\?  /*? character */
\\  /*\ character */
\n  /*Newline */
\r  /*Carriage return */
\t  /*Horizontal tab */
```

- string constant

```
/* normal string */
"hello, world"
/* multi-line string */
"c programming \
 language"
```

Define constants

- Two ways to define constants in C
  - Using `#define` preprocessor (defining a macro)
  - Using the `const` key word (new standard borrowed from C++)

```c
#include <stdio.h>
/* define LENGTH using the macro */
#define LENGTH 5
int main()
{
   /*define WIDTH using const */
   const int  WIDTH  = 3;
   const char NEWLINE = '\n';
   int area = LENGTH * WIDTH;

   printf("value of area : %d", area);
   printf("%c", NEWLINE);

   return 0;
}
```

Basic variable types

- A variable is a name given to a storage area.
- Each variable in C has a specific type, which determines the size and layout of the variable's memory;

Type	Description
`char`	A single character. (interchangeable with integer).
`int`	integer type.
`float`	A single-precision floating point value.
`double`	A double-precision floating point value.
`void`	Represents no type.

Define variables - variable names rules

- A variable name consists of any combination of alphabets, digits and underscores. Please avoid creating long, meaningless variable name.
- The first character of the variable name must either be alphabet or underscore. It should not start with the digit.
- No special symbols (including blanks or commas) other than underscore are allowed in the variable name.
- Examples:

```
int count;
float safety_factor;
double normal_force;
```

Define and initialize variables

- C is a strong type language, variables must be declared before use
- Syntax for defining variables:

  type list_of_variables_names;

- Examples of variables definition:

```
int    i, j, k;
char   item, name;
float  force, factor;
double value;
```

- Variables initialized via assignment operator at declaration :

```
int a = 31;
float phi = 31.2345835;
```

- Can declare/initialize multiple variables at once:

```
int a, b, c= 0, d= 51;
```

C reserved keywords

- C reserved words may not be used as constant or variable or any other identifier names.

auto	else	long	switch
break	enum	register	typedef
case	extern	return	union
char	float	short	unsigned
const	for	signed	void
continue	goto	sizeof	volatile
default	if	static	while
do	int	struct	_Packed
double			

Operators in C - 1

- Arithmetic Operators

```
+ , - ,* , /
%  /* mod */
++ /*increases integer value by one */
-- /*decrease integer value by one */
```

- Relational Operators

```
== /* equal */
!= /* not equal*/
>  /* greater than */
<  /* less than */
>= /* greater than or equal to*/
<= /* less than or equal to*/
```

- Bitwise Operators

```
&, |, ^, ~, <<, >>
```

Operators in C - 2

- Assignment Operators

```
=  /* simple assignment */
/* Reverse Polish Notation (RPN) */
+= /* C += A <=> C = C + A*/
-= /* C -= A <=> C = C - A*/
*= /* C *= A <=> C = C * A*/
/= /* C *= A <=> C = C * A*/
```

- Logical Operators

```
!  /* not */
&& /* and */
|| /* or  */
```

Operators in C -3

- Misc Operators

```
sizeof() /* Returns the size of an variable.    */
&        /* Returns the address of an variable. */
*        /* Pointer to a variable.              */
?=:      /* (ternary conditional operator),
      condition is true ? Then value X : Otherwise value Y*/
, /* comma separates expression and evaluates to the last */
```

Operators example

- Define variables x and y:

```
int x, y;
```

- Simple arithmetic:

```
x+y, x-y, x*y, x/y, x%y
```

- C statement examples:

```
x+y, x-y, x*y, x/y, x%y;
x++,x--;
y = x+5*x/(y-1);
x += y; /* x=x+y Reverse Polish notation (RPN) */
x -= y, x *= y; /* Comma operator */
x>0?y=x+1:y=x-1; /* ternary operator */
```

- Use parentheses to override order of evaluation

Type Conversion

- You can convert values from one type to another explicitly using the cast operator: `(type_name) expression`
  - `(float)3`
- Arithmetic Conversion: `int->float->double->long double`

```
#include <stdio.h>
main() {
   int a = 4, b = 3;
   float c;
   c =  a / b;
   /* make sure you are doing the right conversion */
   printf("c= %f\n", c );
   c =  b / a;
   printf("c= %f\n", c );
   c = (float)a / b;
   printf("c= %f\n", c );
}
```

char and int type in C

- In C `char` and `int` are interchangeable, C allows assign `char` to `int`, and vice versa (char_int.c):

```
#include <stdio.h>
/* interchangeability between char and int */
int main() {
    char a=120; /* ascii value for 'x' is 120 */
    int  b='y'; /* ascii value for 'y' is 121 */
    printf("%c,%c\n",a,b);
    printf("%d,%d\n",a,b);
    printf("a-b=%d\n",a-b);
    return 0;
}
```

- Memory layout of a and b:

a:	0	1	1	1	1	0	0	0
b:	0	1	1	1	1	0	0	1

Using variables and operators-Example

```c
#include <stdio.h>

int main() {
  int i = 3;
  int j = 4;
  int x, y;
  int kronecker_delta;
  float a = 4.5;
  double b = 5.25;
  double sum;

  x=1, y=2, x = (x, y);
  /* 1. calculate the kronecker_delta using ?= */
  kronecker_delta = (i==j)?1:0;
  /* 2. calculate the sum of a and b */
  sum = a+b;

  printf("x= %d, y= %d\n", x, y);
  printf("i/j= %d\n", i/j);
  printf("j/i= %d\n", j/i);
  printf("kronecker_delta= %d\n", kronecker_delta);
  printf("a+b= %f\n", sum);

  return 0;
}
```

Blocks and Compound Statements

- A simple statement ends in a semicolon ";":

```
area=2.0*pi*rad*rad;
```

- Use curly braces to combine simple statements into compound statement/block, no semicolon at end
- Variables can be defined inside block, example:

```
{
    double area;
    double rad=1.0;
    double pi=3.1415926;
    area=2.0*pi*rad*rad;
}
```

- Block can be empty {}
- Usage? See next few slides

Practical C/C++ Programming 1

Control Flow

Control flow

- Control flow
  - Conditional Statements (decision making/selection)
    - if...else if...else
    - switch
  - Loops
    - for
    - while
    - do while

The if...else if...else statement

- An if statement can be followed by an optional else if...else statement.
  - Evaluate condition
  - If true, evaluate inner statement
  - Otherwise, do nothing

```
if(boolean_expression 1) {
   /* executes when the boolean expression 1 is true */
}else if( boolean_expression 2){
   /* optional, executes when the boolean expression 2 is true */
}else if( boolean_expression 3){
   /* optional, executes when the boolean expression 3 is true */
}else{
   /* optional, executes when the none of the above condition is true
*/
}
```

The if statement example

```c
#include <stdio.h>

int main () {
   /* local variable definition */
   int a = 100;

   /* check the boolean condition */
   if( a == 10 ) {
       printf("Value of a is 10\n" );
   }
   else if( a == 20 ) {
       printf("Value of a is 20\n" );
   }
   else {
       /* if none of the conditions is true */
       printf("None of the values is matching\n" );
   }
   printf("Exact value of a is: %d\n", a );

   return 0;
}
```

The switch statement

- A switch statement allows a variable to be tested against a list of values. Each value is called a case.
- *Without break, the program continues to evaluate the next case*

```
switch(expression){
    case constant-expression  :
       statement(s);
       break; /* optional */
    case constant-expression  :
       statement(s);
       break; /* optional */
    /* you can have any number of case statements */
    default : /* Optional */
       statement(s);
}
```

The switch statement example

- What is the expected output of this code?

```
/* switch_statement_grade.c */
#include <stdio.h>
int main (){
    /* local variable definition */
    char grade = 'A';
    /* what is the expected output? */
    switch(grade) {
        case 'A' : printf("Excellent!\n" );
        case 'B' : printf("Well done\n" );
        case 'C' : printf("You passed\n" );
        case 'F' : printf("You failed\n" );
        default  : printf("Invalid grade\n" );
    }
    printf("Your grade is  %c\n", grade );
    return 0;
}
```

Nested conditional statements

- Conditional statements can be nested as they do not overlap:

```
if( boolean_expression 1) {
   if(boolean_expression 2) {
      /* Executes when the boolean expression 2 is true */
        /* nested switch statement */
        switch(expression){
        case constant-expression  :
           statement(s);
           break; /* optional */
        case constant-expression  :
           statement(s);
           break; /* optional */
        /* you can have any number of case statements */
        default : /* Optional */
           statement(s);
        }
   }
}
```

For loops

- For loops in C:
  - The init step is executed first and only once.
  - the condition is evaluated. If it is true, the body of the loop is executed. If it is false, the body of the loop does not execute, the loop exits.
  - the increment statement executes after the loop body.
  - The loop continues until the condition becomes false

```
for ( init; condition; increment ) {
   loop body;
}
```

while and do...while loops

- while loops are similar to for loops
- A while loop continues executing the code block as long as the condition in the while holds.

```
while(condition) {
    statement(s);
}
```

- do...while loop is guaranteed to execute at least one time.

```
do {
    statement(s);
} while(condition);
```

Simple loops using for, while, do while

```c
#include <stdio.h>

int main ()
{
   int i;
   /* for loop execution */
   for(i = 0; i < 5; i++ ) {
      printf("for loop i= %d\n", i);
   }
   i=0;
   /* while loop execution */
   while( i < 5 ) {
      printf("while loop i: %d\n", i);
      i+=1;
   }
   i=1;
   /* do-while loop execution */
   do {
       printf("do while loop i: %d\n", i);
       i=i+1;
   }while( i < 0 );

   return 0;
}
```

Nested loops in C

- All loops can be nested as long as they do not overlap:

```
/* nested for loops*/
for (init; condition; increment) {
   for (init; condition; increment) {
      statement(s);
   }
   statement(s);
}

/* nested while loops*/
while(condition) {
   while(condition) {
      statement(s);
   }
   statement(s);
}
```

```
/* nested do while loops*/
do {
   statement(s);
   do {
      statement(s);
   }while( condition );
}while( condition );

/* mixed type loops*/
while(condition) {
   for (init; condition; increment) {
      statement(s);
      do {
            statement(s);
      }while( condition );
   }
   statement(s);
}
```

Nested loops example

```c
#include <stdio.h>

int main()
{
    int i, j, k;
    printf("i j k\n");
    /* examples for nested for loops */
    for (i=0; i<2; i++)
        for(j=0; j<2; j++)
            for(k=0; k<2; k++)
                printf("%d %d %d\n", i, j, k);
    return 0;
}
```

Loop Control Statements

- Loop control statements change execution from its normal sequence:
  - ***break*** statement
    - terminates the ***entire loop*** or switch statement
  - ***continue*** statement
    - causes the loop to skip the remainder of the loop body for the ***current iteration***.
  - ***goto*** statement
    - **Avoid** using this in your program

Loop Control Example

```c
#include <stdio.h>

int main () {
   /* local variable definition */
   int a = 0;

   /* while loop execution */
   while( a < 10 ) {
      if( a > 5) {
         /* terminate the loop using break statement */
         break;
      }
      if (a==3) {
          a++;
          /* terminate the current iteration using continue statement */
          continue;
      }
      printf("value of a: %d\n", a);
      a++;
   }

   return 0;
}
```

Practical C/C++ Programming 1

Derived Data Types

Arrays in C

- Arrays are special variables which can hold more than one value using the same name with an index.
- Declaring Arrays: ***type arrayName[arraySize]***;

```
/* simply define the arrays */
double balance[10];
float atom[1000];
int index[5];
```

- C array starts its index from 0

index[5]

[0]	[1]	[2]	[3]	[4]
5	4	6	3	1

- Initialize the array with values:

```
/* initialize the array with values*/
int index[5]={5, 4, 6, 3, 1};
double value[]={5.3, 2.4, 0.6, 1.3, 1.9};
```

- Access array values via index:

```
/* access the array values*/
int current_index=index[i];
double current_value=value[current_cell_index];
```

Be careful in accessing C array

- C arrays are a sequence of elements with contiguous addresses.
- There is no bounds checking in C.
- Be careful when accessing your arrays
- Compiler will not give you error, you will have *undefined* runtime behavior:

```
#include <stdio.h>
int main() {
    int index[5]={5, 4, 6, 3, 1};
    int a=3;
    /* undefined behavior */
    printf("%d\n",index[5]);
}
```

Multidimensional Arrays

- General form of a multidimensional array declaration in C:

```
datatype name[size1][size2]...[sizeN];
```

- Declaring 2D and 3D arrays:

```
float array2d[4][5];
double array3d[2][3][4];
```

- Initialize multidimensional arrays

```
int a[3][4] = {/* 2D array is composed of 1D arrays*/
    {0, 1,  2,  3},   /*  initialize row 0 */
    {4, 5,  6,  7},   /*  initialize row 1 */
    {8, 9, 10, 11}};  /*  initialize row 2 */
```

	col 0	**col 1**	**col 2**	**col 3**
row 0	a[0][0]=0	a[0][1]=1	a[0][2]=2	a[0][3]=3
row 1	a[1][0]=4	a[1][1]=5	a[1][2]=6	a[1][3]=7
row 2	a[2][0]=8	a[2][1]=9	a[2][2]=10	a[2][3]=11

Something to remember for C arrays

- ***Row-major*** order and ***Column-major*** order describe methods for storing multidimensional arrays in ***linear memory***
- In C/C++ programming language, ***Row-major*** order is used.
- Consider the below array

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$$

- Declared in C as:

```
int A[2][3] = { {1, 2, 3}, {4, 5, 6} };
```

- In C the array is laid out contiguously in linear memory as:

1	2	3	4	5	6

- Fortran is Column-major order

Arrays-Example

```c
#include <stdio.h>
#define N 10

int main() {
  /* TODO: find the max, min, sum of the 10 values */
  double sum, max, min;
  int i=0;
  int a[N]={13, 14, 15, 16, 17, 16, 15, 14, 13, 11};

  sum=min=max=a[0];
  for (i=1;i<N;i++) {
    if (max<a[i]) max=a[i];
    if (min>a[i]) min=a[i];
    sum += a[i];
  }
  printf("The max value is: %f\n" max);
  printf("The min value is: %f\n", min);
  printf("The sum value is: %f\n", sum);
  return 0;
}
```

Strings in C

- Strings in C are a special type of array: ***array of characters*** terminated by a null character `'\0'`.

```
/* define a string */
char str[7]={'H','E','L','L','O','!','\0'};
char str1[]="HELLO!";
```

- Memory presentation of above defined string in C/C++:

str[]	[0]	[1]	[2]	[3]	[4]	[5]	[6]
	'H'	'E'	'L'	'L'	'O'	'!'	'\0'

- C uses built-in functions to manipulate strings:

```
/* C sample string functions */
strcpy(s1, s2); /* Copies string s2 into string s1.*/
strcat(s1, s2); /* Concatenates string s2 onto the end of string s1. */
strlen(s1);     /* Returns the length of string s1. */
strcmp(s1, s2); /* Returns 0 if s1 and s2 are the same; less than 0 if
s1<s2; greater than 0 if s1>s2. */
```

Strings-Example

```c
#include <stdio.h>
#include <string.h>
#define N 30

int main ()
{
   char str1[N] = "C program ";
   char str2[N] = "is great!";
   char str3[N];
   int  len;

   /* copy str1 into str3 */
   strcpy(str3, str1);
   printf("strcpy( str3, str1) :  %s\n", str3 );

   /* concatenates str1 and str2 */
   strcat( str1, str2);
   printf("strcat( str1, str2):   %s\n", str1 );

   /* total length of str1 after concatenation */
   len = strlen(str1);
   printf("strlen(str1) :  %d\n", len );

   return 0;
}
```

Structures

- User-defined type in C: ***struct***, union and enum
- A C ***struct*** is an aggregate of elements of (nearly) arbitrary types.
- Structures are the basic foundation for objects and classes in C++.
- Structures are used for:
  - Passing multiple arguments in and out of functions through a single parameter
  - Data structures such as linked lists, binary trees, graph, and more
- Syntax for defining structure:

```
/* syntax for defining structure */
struct [structure tag] /* tag is optional */
{
    member definition;
    member definition;
    ...
    member definition;
} [one or more structure variables];
```

How to use struct

- Example of defining a “Point” struct

```
/* define a structure “Point” */
struct Point {
    int index;
    char tag;
    double x;
    double y;
};
```

- Define the struct Point type variables:

```
/* define two struct Point variables */
struct Point p1, p2, p3;
```

- Here is how we access the struct Point type variables, using the “.”:

```
p1.index=0; /* access members of p1 with dot “.” operator */
p1.tag = 'a';
p1.x = 0.0;
p1.y = 0.0;
p3 = p1; /* assign struct variable p1 to variable p3 */
```

Using typedef to define new variables

- C provides a keyword called ***typedef*** to name a new variable type (note that typedef does not create new types).

```
typedef existing_type new_type_name;
```

- Use ***typedef*** with struct in the previous example:

```
typedef struct Point point;
typedef struct Point {/* alternative way to define Point*/
    int index;
    char tag;
    double x;
    double y;
} Point;
```

- ***typedef*** can also used to give alias to existing variable types:

```
typedef double real; /* typedef float real; easy switch between
precisions*/
```

- Use the newly defined type to define your variables, e.g.:

```
real x; /* x is actually double defined above */
Point p1, p2, p3; /* p1, p2 and p3 are struct Point */
```

Practical C/C++ Programming 1

Functions

Functions

- A function is a group of statements that together perform a task.
- Every C program has at least one function, which is ***main()***
- Functions receive either a fixed or variable amount of arguments.
- Functions can only return one value, or return no value (void).
- In C, arguments are ***passed by value*** to functions
- How to pass by reference?-***Pointers*** (we will detail it in Part 2)
- Functions are defined using the following syntax:

```
return_type function_name(type0 param0, type1 param1,...,typeN paramN)
{
   function body
}
```

- Function ***declaration***: declare function's name, return type, and parameters.
- Function ***definition***: provides the actual body of the function.

Function definition

- Return Type: Function's return type is the data type of the value the function returns. When there is no return value, return ***void***.
- Function Name: This is the actual name of the function.
- Parameter/argument list (optional): The parameter list refers to the type, order, and number of the parameters of a function. A function may contain no parameters.
- Function Body: The function body contains a collection of statements that define the function behavior.
- Example for function definition:

```
/* find the max between two numbers */
int find_max(int a, int b)
{
   /* function body */
   int t;
   if (a > b) t = a;
   else t = b;
   return t;
}
```

Functions-Example

```c
#include <stdio.h>

/* function declaration */
int max(int a, int b);

int main() {
   /* local variable definition */
   int a = 100, b = 200, ret;
    /* calling a function to get max value */
   ret = find_max(a, b);
   printf( "Max value is : %d\n", ret );
   return 0;
}

/* function returning the max between two numbers */
int find_max(int a, int b) {
   /* function body */
   int t;
   if (a > b) t = a;
   else t = b;
   /* rewrite the above using the ternary operator */
   /* t=(a>b)?a:b; */
   return t;
}
```

Practical C/C++ Programming 1

Input and Output

Input/Output

- Input means to feed data into program.
  - This can be given in the form from
    - screen (stdin)
    - ***file***
  - C uses ***built-in functions*** to read given input and direct it to the program
- Output means to display data to:
  - *file* (C treats all devices as files):
    - screen (stdout, stderr)
    - printer
    - ***file***
  - C uses a set of ***built-in functions*** to output the data on the computer screen as well as you can save that data in text or binary files.

C Input/Output built-in functions -1

- getchar() and putchar()

```
/*reads the next available character from screen and returns the
same character*/
int getchar(void);
/* puts the character "c" on the screen and returns the same
character. */
int putchar(int c);
```

- gets() and puts()

```
/* reads a line from stdin into the buffer pointed to by s until
either a terminating newline or EOF.*/
char *gets(char *s);
/* writes the string s and a trailing newline to stdout. */
int puts(const char *s);
```

C Input/Output built-in functions -2

- scanf() and printf()

```
/* reads input from the standard input stream stdin and scans that
input according to the format string. */
int scanf(const char *format, ...);
/* writes output to the standard output stream stdout and produces
output according to the format string. */
int printf(const char *format, ...);
```

- fscanf() and fprintf() - file operations, see next few slides

```
/* reads input from file fp and stores them according to the
format string. */
int fscanf(FILE * fp, const char * format, ... );
/* writes output to file fp according to the format string. */
int fprintf(FILE * fp, const char * format, ... );
```

C Input/Output example

```c
/* io_example */
#include <stdio.h>

int main() {
   char str[100];
   int i;
   float a;
   double b;
   printf( "Enter string i(int) a(float) b(double):\n");
   /*
   1. note the & sign (get the address of the variable) before i,a,b
   2. question, why there is no address sign before the str?
   3. note the %lf when reading double
   */
   scanf("%s %d %f %lf", str, &i, &a, &b);
   printf( "\nYou entered: %s, %d, %f, %lf\n", str, i, a, b);
   return 0;
}
```

File Input/Output

- Two types of files:
  - text file (ASCII) /*we will only talk about text file in this training*/
  - binary file
- Similar to standard I/O, C uses built-in functions for File I/O
- Opening a file

```
/* use fopen() function to create a new file or to open an
existing file,
   the call will initialize a FILE object */
FILE *fopen( const char * filename, const char * mode );
/* filename: string for the file name
   mode:     controls the file access mode */
```

- Closing a file:

```
/* closing a file, *NEVER* forget to close a file after
opening */
 int fclose( FILE *fp );
```

File Input/Output

- More on file access mode:

```
/* file access modes*/
“r”, “w”, “a”, “w+”, “r+”, “a+”
```

Mode	Description
r	Read only. The file pointer is placed at the beginning of the file.
w	Write only. The file pointer will be at the beginning of the file.
a	Append, The file pointer is at the end of the file if the file exists.
t	text mode
b	binary mode
+	read and write

File Input/Output Example

- The "***file_io.c***" example reads a series of vectors from "***vector.in***", calculates the length of each vector and then outputs the length results to a file named "***vector.out***"
- Compile your program with "**gcc file_io.c -lm**" with math library

```
...
/* open the "vector.in" in read mode */
   if ((fp=fopen("vector.in", "r"))==NULL) exit(1);
   fscanf(fp,"%d",&num_vec);
   if (num_vec>N) {
       fprintf(stderr, "out of bound error");
       exit(1);
   }
   for (i=0;i<num_vec;i++) {
       /* read the vectors */
       fscanf(fp,"%f %f %f",&vx,&vy,&vz);
       v_length[i]=sqrt(vx*vx+vy*vy+vz*vz);
   }
   fclose(fp);
...
```

Part 2 Outline (proposed)

- Pointers in C/C++
- User defined types
- C++ basics and Objected Oriented Programming concepts
- Standard Template Library (STL)

Exercise 0

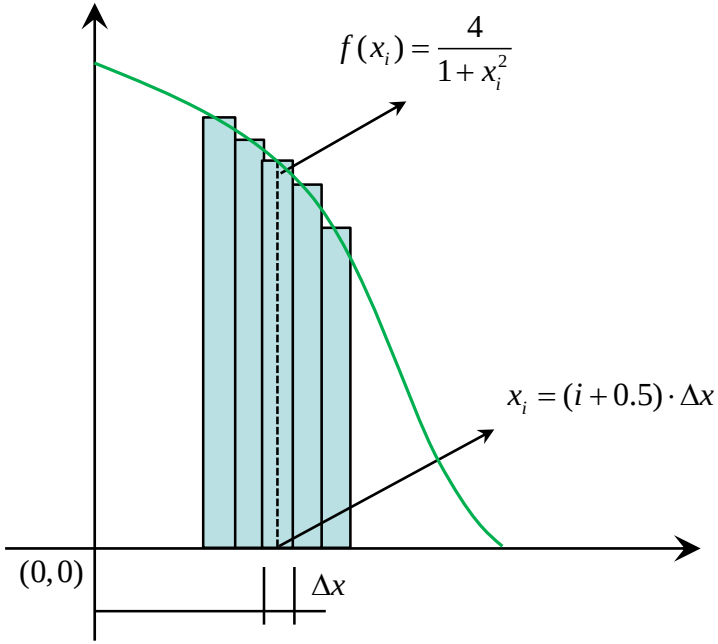
1. Complete the C code for π value evaluation. ***calc_pi.c***
2. Write a function to calculate π, then call this function from main()

Hint: We can use the following equation to calculate the value of pi:

$$\int_0^1 \frac{4}{1+x^2} dx = 4 \cdot \arctan(x)\Big|_0^1 = \pi$$

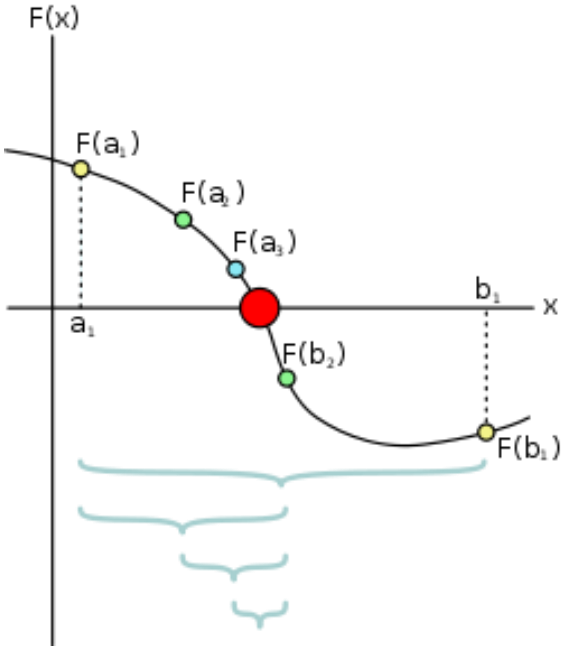
The numerical integration:

$$\pi \approx \sum_{i=1}^{N} \frac{4}{1+x_i^2} \Delta x$$



Exercise 1

- Finding the root of a polynomial equation using the bisection method, you can refer to the details from the wiki page:
  - http://en.wikipedia.org/wiki/Bisection_method
  - Create a function that calculates: $f(x) = x^3 - x - 2$
  - Find the solution for $x = [1.0, 2.0]$
- Source code: ***bisection.c***



Exercise 2

- Calculate the result of a constant times a vector plus a vector: where ***a*** is a constant, $\vec{x}$ and $\vec{y}$ are one dimensional vectors

$$\vec{y} \Leftarrow a\vec{x} + \vec{y}$$

Exercise 3

- 3. Complete the C code for matrix multiplication

$$A \cdot B = C$$

where:

$$a_{i,j} = i + j$$

$$b_{i,j} = i \cdot j$$

$$c_{i,j} = \sum_{k} a_{i,k} \cdot b_{k,j}$$