OUTLINE

- Review
- Functions
- Pointers
  - Function calls
  - Array Pointers
  - Pointer Arrays
- Data Structures and dynamic Memory
- Function Pointers
  - quicksort example

FUNCTIONS

- Functions enable grouping of commonly used code into a reusable and compact unit.
- In programs containing many functions main should be implemented as a group of calls to functions undertaking the bulk of the work
- Become familiar with rich collections of functions in the ANSI C standard library
- Using functions from ANSI standard library increases portability

STANDARD LIBRARY FUNCTIONS

Header	Description
<stdio.h>	Functions for standard input and output
<float.h>	Floating point size limits
<limits.h>	Contains integral size limits of system
<stdlib.h>	Functions for converting numbers to text and text to numbers, memory allocation, random numbers, other utility functions
<math.h>	Math library functions
<string.h>	String processing functions
<stddef.h>	Common definitions of types used by C

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FUNCTIONS AVAILABLE WITH THE LIBRARY MATH.H

Function	Returns
sqrt(x)	Square root
exp(x)	Exponential function
log(x)	Natural logarithm (base e)
log10(x)	Logarithm (base 10)
fabs(x)	Absolute value
pow(x,y)	X raised to the power of y
sin(x)	Trignometric sine (x in radians)
cos(x)	Trignometric cosine (x in radians)
tan(x)	Trignometric tangent (x in radians)
atan(x)	Arctangent of x (returned value is in radians)

USING FUNCTIONS

- Include the header file for the required library using the preprocessor directive
  - #include <libraryname.h>
  - Note no semi colon after this
- Variables defined in functions are local variables
- Functions have a list of parameters
  - Means of communicating information between functions
- Functions can return values
- printf and scanf good examples of function calls
- Use the –lm option to compile an application using math library functions e.g.
  - pgcc myprog.c –o myprog -lm

USER DEFINED FUNCTIONS

- Format of a function definition

```
Return-value-type function-name(parameter-list)
{
        declarations

        statements
}
```

A return value of type void indicates a function does not Return a value.

FUNCTIONS: RETURN

- Return control to point from which function called
- 3 Ways to return
  - Function does not return a result (void) control is returned when function right brace } is reached.
  - Execute the statement
    - return;
  - If the statement returns a value the following statement must be executed
    - return expression;

FUNCTION PROTOTYPES

- Tells compiler
  - type of data returned by function
  - Number and types of parameters received by a function
- Enable compiler to validate function calls
- Function prototype for a RollDice function
  - int RollDice(int iPlayer);
  - Terminated with ;
  - Placed after pre-processor declarations and before function definitions

USING FUNCTIONS

- Declare function using prototype
- Define source code for function
- Call the function
- See program functions.c for an example of function declaration, definition, usage

HEADER FILES

- Standard libraries have header files containing function prototypes for all functions in that library
- Programmer can create custom header files
  - Should end in .h e.g. myfunctionlib.h
- Programmer function prototypes declared using the pre processor directive
  - #include “myfunctionlib.h”

Demonstration

- Build and run the example function1.c
  - •Add more calls to the blorf() function in the main pprogram
- Build and run function2.c
  - •Note this avoids the use of the function prototype
  - •Move the soup function after the main function compile and run what happens?
  - •Add a prototype and build and run again

POINTERS AND ARRAYS

- Pointers are a powerful feature of C which have remained from times when low level assembly language programming was more popular.
- Used for managing
  - Arrays
  - Strings
  - Structures
  - Complex data types e.g. stacks, linked lists, queues, trees

VARIABLE DECLARATION

- A variable is an area of memory that has been given a name.
- The variable declaration
  - float f1;
  - is command to allocate an area of memory for a float variable type with the name f1.
- The statement
  - f1=3.141
  - is a command to assign the value 3.141 to the area of memory named f1.

WHAT IS A POINTER

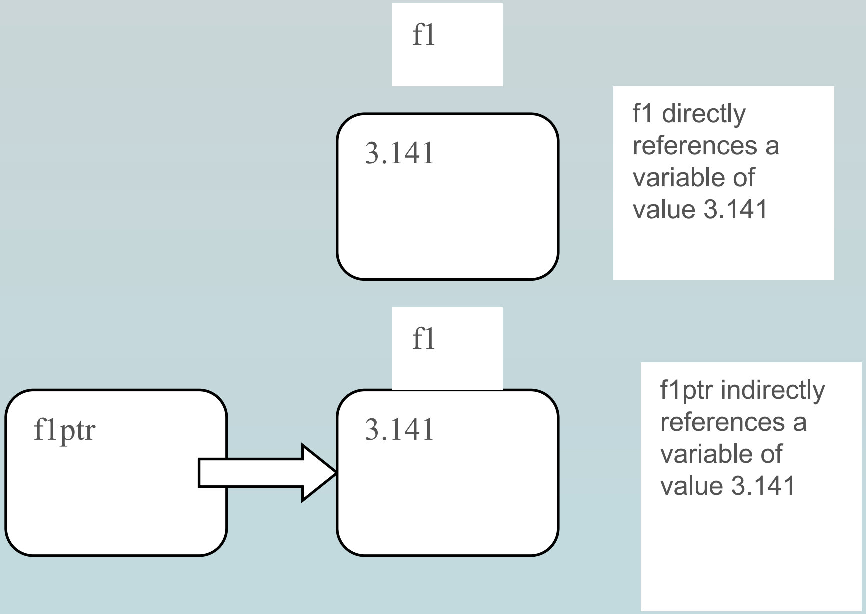
- **Pointers are variables that contain memory addresses as their values.**
- Pointer declared using the indirection or de-referencing operator *.
- Example
  - float *f1ptr;
- f1ptr is pointer variable and it is the memory location of a float variable

POINTER EXAMPLE

- The redirection operator returns the address of a variable
- & applied to f1 returns the address of f1

```
float f1;
float *f1ptr;  /* Declare a pointer variable to an integer*/
f1=3.141;
f1ptr=&f1; /*f1ptr is set to the address of f1*/
```

Pointer Variables



USING THE * AND & OPERATORS:

```
int some_var;   /*1*/
int *ptr_to_some_var; /*2*/
ptr_to_some_var = &some_var; /*3*/
printf ("%d\n\n", *ptr_to_some_var); /*4*/
```

- /*1*/ Declare an integer
- /*2*/ Declare a pointer
- /*3*/ Assign a value to the pointer variable
- /*4*/ Use the pointer in a function (dereference the value)
- Compile and run the example pointers.c

FUNCTION CALLS

- Call by value
  - Copy of variable passed to function
  - If that variable is modified within the function then upon return from the function since only the copy has been modified, the actual variable is not modified
- Call by reference
  - Pass the address of a variable (i.e. a pointer) to a function
  - The variable pointed to can be modified within that function

CALL BY VALUE EXAMPLE

- finval=FuncByValue(finval);
- The FuncFyValue function

```
float FuncByValue(float fval)
{
        return fval*fval;
}
```

CALL BY REFERENCE EXAMPLE

- FuncByReference(&finref), Use & to pass the address of a variable to the function;
- The FuncByReference function
- Value of the referenced variable passed to the function is modified after returning from the function.

```
void  FuncByReference(float *fvalptr)
{
        *fvalptr = *fvalptr * *fvalptr;
}
```

ARRAYS

- Initialisation
- int iarray[5]={1,2,3,4,5};
- Or… initialise elements individually
- Note first element is referenced using 0
  - iarray[0]=1;
  - ……..
  - iarray[4]=5;

FURTHER EXAMPLES OF FUNCTION CALLS

- Putting it all together
  - Function calls
  - Simple array examples
- Numerical Method Examples
  - Numerical differentiation
  - Numerical Integration

MULTIDIMENSIONAL ARRAY

- The declaration for a multi dimensional array is made as follows:
  - *Type variable[size1][size2];*
- To access or assign an element to an element of a multidimensional array we use the statement:
  - *variable[index1][index2]=avalue;*

MATRIX INITIALISATION EXAMPLE

- Alternatively the bracket initialisation method can be used, for example the integer matrix[2][4] can be initialised as follows:

```
int matrix[2][4]
{
 {1,2,3,4},
 {10,20,30,40}
};
```

ARRAYS ARE POINTERS

- The array variable is a pointer whose value is the address of the first element of the array.
- For a one dimensional array access a value using the following pointer notation:

  *int ielement= *(iarray+1);*

- This assignment increments the array pointer to the second element in the array (the first element is always index 0)
- uses the * operator to dereference the pointer

POINTER ARRAYS

- A string is a pointer to an array of characters
- An array of strings is an array of pointers
- Multidimensional array is essentially an array of pointer arrays.

MEMORY LEAKS

- TAKE VERY SPECIAL CARE IN USE OF POINTERS AND MANAGEMENT OF ARRAYS
- A common problem when using arrays is that the program might run off the end of the array particularly when using pointer arithmetic.
- When passing an array to a function it is good practice to pass the size of that array making the function more general.

DATA TYPES AND STRUCTURES

- Features for representing data and aggregations of different data types.
  - structures,
  - type definitions,
  - enumerations and
  - unions.

DATA STRUCTURES

- Arrays and structures are similar
  - pointers to an area of memory that
  - aggregates a collection of data.
- Array
  - All of the elements are of the same type and are numbered.
- Structure
  - Each element or field has its own name and data type.

FORMAT OF A DATA STRUCTURE

```
struct structure-name {
        field-type field-name; /*description*/
        field-type field-name; /*description*/
        …….
}  variable-name;
```

DECLARING STRUCTURES AND ACCESSING FIELDS

- *struct structure-name variable-name;*
- A pointer to a structure
  - *struct structure-name *ptr-variable-name;*
- Accessing a field in a structure
  - *variable-name.field-name*
- For a pointer to a structure a field is accessed using the indirection operator ->
  - *ptr-variable-name->field-name*

STRUCTURE EXAMPLE

```
struct node {
        char *name;
        char *processor;
        int  num_procs;
        };
```

DECLARING AND INITIALISING STRUCTURES

```
struct node n1;
struct node *n1ptr;

n1.name="Titania";
n1.processor ="Ultra Sparc III Cu";
n1.num_procs = 80;
n1ptr = &n1;
```

ACCESSING STRUCTURE DATA

- Direct access

```
printf("The node %s has %d %s processors\n",
    n1.name, n1.num_procs, n1.processor);
```

- Access using a pointer

```
printf("The node %s has %d %s processors\n",
    n1ptr->name, n1ptr->num_procs, n1ptr->processor);
```

- Dereferencing a pointer

```
printf("The node %s has %d %s processors\n",
    (*n1ptr).name, (*n1ptr).num_procs, (*n1ptr).processor);
```

TYPE DEFINITIONS

- *typedef float vec[3];*
- Defines an array of 3 float variables a particle position may then be defined using:
- *vec particlepos;*
- Defined structure types
- *typedef struct structure-name mystruct;*
- *mystruct mystructvar;*

ENUMERATIONS

- enum enum-name {tag-1, tag-2, ….} variable-name;
- enum months {JAN=1, FEB, MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,NOV,DEC};
- Same as
  int JAN=1;

  int FEB=2;

  ..

  int DEC=12;

USING AN ENUMERATION

```
enum months month;

for(month=JAN; month<=DEC;
  month++)

     statement;
```

DECLARING AND USING AN ENUMERATION

```
int main ()
{
  enum compass_direction {
            north,
            east,
            south,
            west
};
enum compass_direction my_direction;
my_direction = west;
return 0;
 }
```

DYNAMIC MEMORY ALLOCATION

- Allocate Memory
  - malloc
  - calloc
- Free memory
  - Free
- Size of memory used by variabletype
  - sizeof

USING MALLOC

```
struct node *newPtr;

newPtr = (struct node *)malloc(sizeof(struct node));
```

- The *(struct node *)* before the malloc statement
  - used to recast the pointer returned by malloc from (void *) to (struct node *).

FREE ME!

- *free(newPtr);*

RESERVING MEMORY FOR AN ARRAY

```
int n=10;

struct node *newPtr;

newPtr = (struct node *)calloc(n, sizeof(struct node));
```

Avoid memory leaks Free the memory!

```
free(newPtr);
```

POINTERS TO FUNCTIONS

- Pointer to function
  - Address of the function in memory
  - Starting address of the code
- Quick sort function has prototype (see 2 slides later)
  - **int (*fncompare*)(const void *, const void *)**
  - fncompare is function pointer
  - Tells quicksort to expect pointer to a function receiving 2 pointers to void
- Note without the brackets around *fncompare the declaration becomes a declaration of a function

DECLARATION OF FUNCTION USING A POINTER TO A FUNCTION

- Declare mysortfunc as
  - mysortfunc(int *data, int size, int (*compare)(void * , void *))
- Call mysortfunc in the following way
  - mysortfunc(data,size,ascending)
  - mysortfunc(data,size,descending)
- Ascending and descending are functions declared as
  - Int ascending(void *a, void *b)
  - Int descending(void *a, void *b)

ARRAY OF POINTERS TO FUNCTIONS

- Declare functions
  - void function1(int);
  - void function2(int);
  - void function3(int);

- void (*f[3])(int)={function1,function2, function3};
- Called as follows
  - (*f[choice])(myintergerinput);
  - Choice and myintegerinput are both integers

APPLICATION OF FUNCTION POINTERS

- Numerical recipes
  - E.g. function which is dependent on a differential which has yet to be defined
- Quick sort function see next slides
- Make C object oriented
  - Include pointers to data methods in struct data types…. See later!

USING THE QUICK SORT FUNCTION

- Implementation of quick sort algorithm
- Qsort function in <stdlib.h>
- Features
  - Pointer to void *
  - Pointer to a function

SYNTAX FOR QSORT FUNCTION

- implementation of the quicksort algorithm to sort the *num* elements of an array pointed by *base*
  - each element has the specified *width* in bytes
  - method used to compare each pair of elements is provided by the caller to this function with *fncompare* parameter (a function called one or more times during the sort process).
- **void qsort (void * *base*, size_t *num*, size_t *width*, int (**fncompare*)(const void *, const void *));**

EXAMPLE USING QSORT

```
/* qsort example */
#include <stdio.h>
#include <stdlib.h>
 int values[] = { 40, 10, 100, 90, 20, 25 };
int compare (const void * a, const void * b)
{ return ( *(int*)a - *(int*)b ); }
int main ()
{
        int * pItem;
        int n;
        qsort (values, 6, sizeof(int), compare);
        for (n=0; n<6; n++)
        {
           printf ("%d ",values[n]);
         }
        return 0;
 }
```

EXAMPLES

- Compile and run the following programs
  - Program array.c initialising and using arrays with pointers
  - Program bubblesort.c is a bubble sort example, using call by reference to manipulate data passed into a function
  - Program arrayref.c uses pointer notation to manipulate arrays
  - Modify the bubblesort program to use the qsort routine

PRACTICAL EXAMPLES

- Compile and run the following programs
  - Numerical Differentiation
    - 2 and four point methods
  - Numerical Integration
    - Trapezium method
    - Simpsons rule (includes lagrange interpolation function)