Storage Classes, Scope and Linkage

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Introduction

- ***Linkage, Scope, Storage Classes, and Specifiers***
  - The terms …
    - Linkage,
    - Scope,
    - Storage classes,
    - Storage class specifiers
  - Often used interchangeably yet really have distinct meanings.

Storage Classes, Scope and Linkage

- ***Linkage***
  - There are two types of linkage *internal* and *external*
  - When a variable or a function has
    - Internal linkage
      - It can be used only in the implementation file in which it has been defined….it cannot be shared by code in another implementation file
    - External linkage
      - Means that the variable or function can be shared with another implementation file.

Storage Classes, Scope and Linkage

- ***Scope***
  - Scope defines visibility….
    - Variables declared inside a function are only visible in that function their scope is the block of code of the function
    - Variables declared outside a function - an *external variable* visible to any function in the implementation file
      - *These external variables are commonly called global*
      - *variables*

Storage Classes, Scope and Linkage

- ***Storage Class***
  - Storage class describes where variables are stored
    - C++ has three storage classes…
      - ⇒ *automatic*
      - ⇒ *static*
      - ⇒ *freestore*

Storage Classes, Scope and Linkage

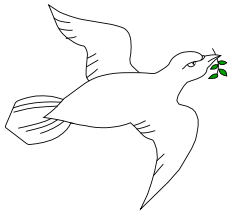
- ***Storage Class***
  - *Automatic Storage Class*
    - Variables with the *automatic* storage class are declared inside functions
    - They have internal linkage and block scope
    - These variables only useable in the implementation file where they are declared...
      - ...and further only within the block of code in which they are declared.

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Static Storage Class*
    - Variables with the *static* storage class are declared outside of any function
    - These are *external* variables…
      - External variables are created before any use of the variable
      - External variables always have external linkage
      - External variables have the scope of the implementation file

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Freestore Storage Class*
    - Variables with the *freestore* storage class are those the programmer creates:
      - These variables have the linkage and scope of the pointer containing the address of the variable in freestore.
      - These variables exist until specifically deleted

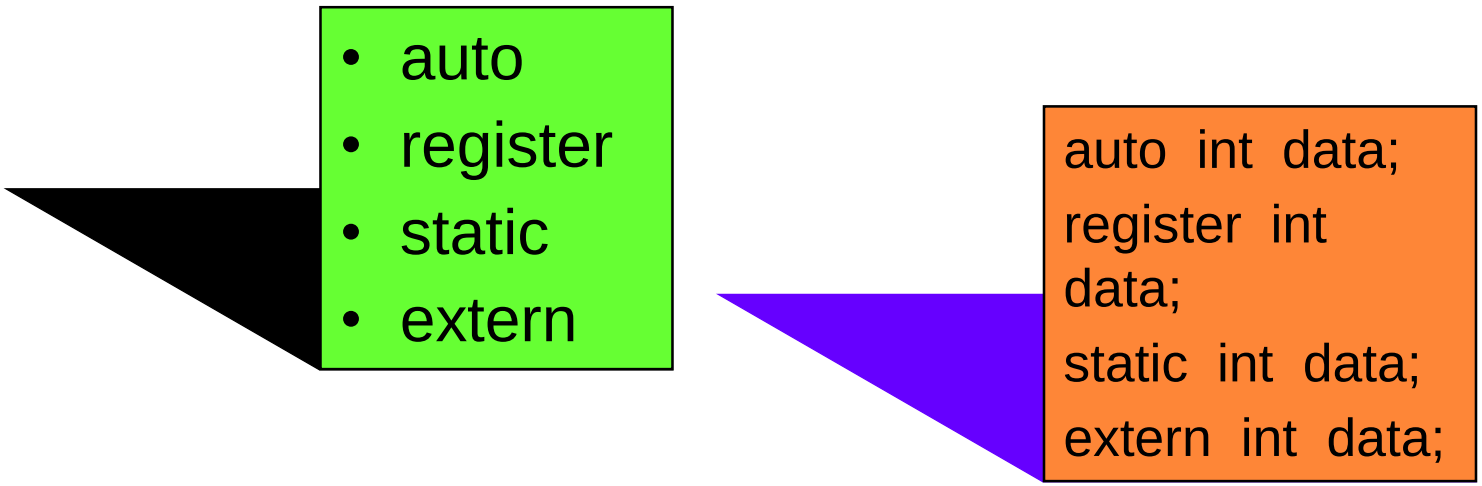


Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Storage Class Specifier*
    - Used to provide instructions to the compiler for modifying the
      - Storage class, linkage, or scope of a specific variable or function
    - Storage class specifiers apply only to the automatic and static storage classes.

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Storage Class Specifier*
    - Storage class specifiers are….



Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Auto Storage Class Specifier*
    - The *auto* storage class specifier
      - Used only with variables to specify the *automatic* storage class
      - *auto* storage class defines
        - The variable will be stored on the *stack*
        - The variable will be local to the function using it
        - The compiler will destroy it automatically when it is no longer needed

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Auto Storage Class Specifier*

```
auto  int  aValue;                  // Error. No auto variables
   outside a function

void FunctionA()
{
   auto  int  a;       // Ok. auto variables go on the stack
              int  b;     // Ok. auto is assumed
}
```

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Register Storage Class Specifier*
    - Instructs the compiler to keep a variable in a register within the processor if possible
    - With the variable in a processor register not in memory
      - Cannot take the address of a register variable
      - Cannot have a pointer to register variable
    - Register storage class is a *recommendation* to the compiler
    - Processing may be faster

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Register Storage Class Specifier*
    - Time to use this storage class is when a variable is going to be accessed frequently in a very short period.
    - Unless you are very aware of what you are doing, typically will never use register storage class.
    - ….Register variables are in a processor register
      - Cannot exist for the life of the program
      - Cannot declare a register variable outside a function.
    - *To do so requires the static storage class which would require the compiler to permanently reserve a processor register for the variable…since this is not possible, a register declaration outside a function is an error.*

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Static Storage Class Specifier*
    - The *static* storage class specifier can be used with
      - Automatic or static variables
      - Functions
    - Confusion arises because…
      - Name of a storage class is *static* and
      - Name of the storage class specifier is also *static*

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Using the Static Storage Class Specifier*
    - Using the static storage class specifier on a variable that normally would be automatic makes the variable static.
    - Can use the static storage class specifier with variables declared inside functions.
    - When the function is called the first time….
      - Variable is created and initialized to zero
      - Remains in existence for the remainder of the program
      - Scope of the variable remains unchanged
      - Can be used only in the block that declared it

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Static Storage Class Specifier*

```
void CountIt()
{
        int  count = 0;              // auto variable created on each
        CountIt call
        ++count;
}
```

```
void CountIt()
{
        static int  count = 0; // variable created on first CountIt
        call
        ++count;
}
```

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Static Storage Class Specifier*
    - Static storage class specifier changes the linkage of static variables to internal linkage
    - Such change can *only* occur with variables declared outside functions
    - The scope of the variable remains unchanged
    - The variable can be used by any function in the implementation file
    - Internal linkage prevents functions in other implementation files from accessing the variable

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Static Storage Class Specifier*

Note: **This use of the static storage class specifier is in C++ for backwards compatibility with C programs.**

In C++, we would use a namespace to restrict access to a variable to the implementation file.

Namespaces are not covered in this course.

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Static Storage Class Specifier*
    - Using the static storage class specifier with a function limits the scope of the function to the implementation file containing the function
      - Only other functions in the same implementation file can call it
      - It is not possible to call a static function from another implementation file

```
static void functionA()
{
        // some processing
}
```

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Extern Storage Class*
    - The *extern* storage class specifier informs the compiler that the variable is not defined in the current implementation file
    - The compiler will not check to see if it is actually declared
    - When this implementation file is compiled
      - It will have an unresolved external reference
      - Reference will be left to the linker to resolve
      - The location where the variable is defined is not specified

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Extern Storage Class*
    - Using the *extern* storage class specifier prevents the compiler from stopping build by generating an unresolved external reference error.

```
void countIt()
{
      extern  int  count;  // count is declared outside
      this file
      ++count;
}
```

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Extern Storage Class*
    - The extern storage class specifier with a function works the same as with a variable
    - Specifies the function is defined outside the current implementation file

```
extern void countIt();      // function not defined in this file
```

Storage Classes, Scope and Linkage

- ***Storage Class***
  - *Extern Storage Class*

***Note*:** **Do not confuse the *extern* storage class specifier with *external* variables.**

External variables are variables declared outside any function.

Storage Classes, Scope and Linkage

- ***Storage Class - Summary***

Specifier	*Storage Class*	*Linkage*	*Scope*
auto	automatic	internal	declaring block
register	automatic	internal	declaring block
--------	automatic	internal	declaring block
--------	static	external	global
static	static	internal	file or declaring blo
extern	static	external	global or declaring block

Storage Classes, Scope and Linkage

- ***Const Revisited***
  - A global variable may be *const*:
    - const double PI = 3.14159;
  - Because a *const* variable must be initialized when it is created….
  - …. PI is initialized to 3.14159 when created
  - If we want to share this *const* variable from another implementation file we would write
    - extern const int PI;
  - When the compiler compiles this file what value is assigned to PI?

Storage Classes, Scope and Linkage

- ***Const Revisited***
  - Answer is unknown ….. because PI is *extern*,
  - The declaration violates the *const* rule of initializing a variable with the constant value when it is created…as a result, the above line of code will generate an error.
  - To use
    - const double PI = 3.14159;
  - In each implementation file we must declare it in each implementation file….that is *const* global variables have *internal*, or local, linkage
- They behave as static variables

Storage Classes, Scope and Linkage

- ***Functions Revisited***
  - **Where C++ Finds Functions???**
    - When we make a function call, C++ locates the function according to this decision logic
      - If the function is static
        - Will use the function in the implementation file
      - If the function is not static
        - Will use the function from another object file
      - If the function can't be found in the object file
        - Library definition will be used

Storage Classes, Scope and Linkage

- ***Functions Revisited***
  - When user specified function prototype matches the function prototype of a library function
  - …The user function will be selected over the library function

Storage Classes, Scope and Linkage

- ***Summary***
  - In this lesson we've studied
    - How to use multiple implementation files
    - How to use storage classes correctly
    - How share variables among implementation files

THANK YOU!

Any Questions Please?