Supplement 3

Unsafe Code and Pointers in C#

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Objectives

After completing this unit you will be able to:

- **Describe the use of unsafe code in C#.**
- **Use the C# pointer type.**

Unsafe Code

- **The mainstream use of C# is to write *managed code*, which runs on the Common Language Runtime.**
- **As we shall see when we study the .NET Framework, it is quite possible for a C# program to call unmanaged code, such as a legacy COM component, which runs directly on the operating system.**
  - This facility is important, because a tremendous amount of legacy code exists, which is all unmanaged.
  - There is overhead in transitioning from a managed environment to an unmanaged one and back again.
- **C# provides another facility, called *unsafe code*, which allows you to bypass.NET memory management and get at memory directly, while still running on the CLR.**
  - In particular, in unsafe code you can work with **pointers**, which we will discuss later in this appendix.

Unsafe Blocks

- **The most circumspect use of unsafe code is within a block, which is specified using the C# keyword *unsafe*.**
- **The program *UnsafeBlock* illustrates using the *sizeof* operator to determine the size in bytes of various data types.**
  - You will get a compiler error if you try to use the **sizeof** operator outside of unsafe code.

```
// UnsafeBlock.cs
using System;
struct Account
{
   private int id;
   private decimal balance;
}

public class UnsafeBlock
{
   public static void Main()
   {
      unsafe
      {
         Console.WriteLine("size of int = {0}",
                           sizeof(int));
         Console.WriteLine("size of decimal = {0}",
                           sizeof(decimal));
         Console.WriteLine("size of Account = {0}",
                           sizeof(Account));
      }
   }
}
```

Unsafe Blocks (Cont'd)

- **To compile this program at the command line, open up a DOS window and navigate to the directory *C:\OIC\CSharp\Supp3\UnsafeBlock*.**
  - Recall that you can ensure proper environment variables are set by starting the command prompt from Start | All Programs | Microsoft Visual Studio 2012 | Visual Studio Tools | Developer Command Prompt for VS2012.
- **You can then enter the following command to compile using the */unsafe* compiler option:**

```
csc /unsafe UnsafeBlock.cs
```

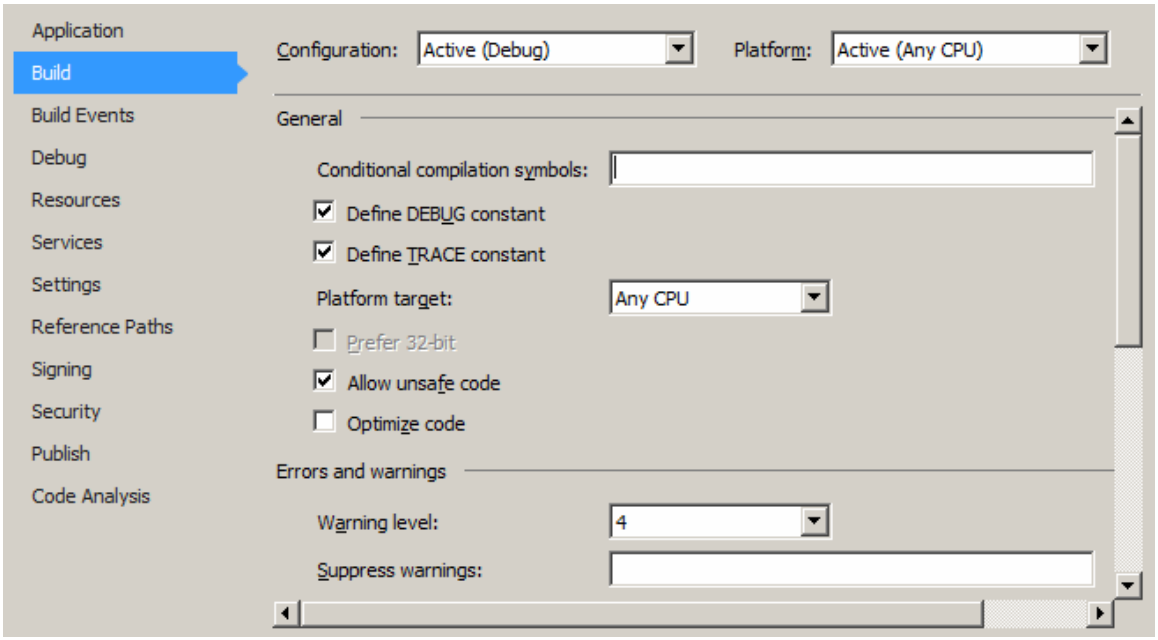
  - (You may ignore the warning messages, as our program does not attempt to use fields of **Account**. It only applies the **sizeof** operator.)
  - To run the program, type **unsafeblock** at the command line, obtaining the output shown below:

```
C:\OIC\CSharp\Supp3\UnsafeBlock>unsafeblock

size of int = 4
size of decimal = 16
size of Account = 20
```

Unsafe Option in Visual Studio

- **To set the unsafe option in Visual Studio, perform the following steps:**
  - Right-click over the project in the Solution Explorer, and choose Properties.
  - In the Property Pages window that comes up, click on Build.
  - In the General section, check Allow unsafe code.
  - You can now compile your project in unsafe mode.



Pointers

- **In Chapter 8 we saw that C# has three kinds of data types:**
  - Value types, which directly contain their data
  - Reference types, which refer to data contained somewhere else
  - Pointer types
- **Pointer types can only be used in unsafe code.**
  - A pointer is an **address** of an actual memory location.
  - A pointer variable is declared using an asterisk after the data type.
  - To refer to the data a pointer is pointing to, use the **dereferencing** operator, which is an asterisk before the variable.
  - To obtain a pointer from a memory location, apply the **address of** operator, which is an ampersand in front of the variable.
- **Here are some examples.**

```
int* p;     // p is a pointer to an int
int a = 5;  // a is an int, with 5 stored
p = &a;     // p now points to a
*p = 12;    // 12 is now stored in location pointed
            // to by p. So a now has 12 stored
```

Pointers (Cont'd)

- **Pointers were widely used in the C programming language, because functions in C only pass data by value.**
- **Thus, if you want a function to return data, you must pass a pointer rather than the data itself.**
- **The program *UnsafePointer* illustrates a *Swap* method, which is used to interchange two integer variables.**
  - Since the program is written in C#, we can pass data by reference.
  - We illustrate with two overloaded versions of the **Swap** method, one using **ref** parameters and the other using pointers.
  - Rather than using an **unsafe** block, this program uses **unsafe** methods, which are defined by including **unsafe** among the modifiers of the method.
  - Both the **Main** method and the one **Swap** method are unsafe.
- **Again you should compile the program using the unsafe option, either at the command line or in the Visual Studio project.**
  - The first swap interchanges the values. The second swap brings the values back to their original state.

Swapping Via Pointers

```
public static unsafe void Main()
{
    int x = 55;
    int y = 777;
    Show("Before swap", x, y);
    Swap(ref x, ref y);
    Show("After swap", x, y);
    Swap(&x, &y);
    Show("After unsafe swap", x, y);
}
private static void Show(string s, int x, int y)
{
    Console.WriteLine("{0}: x = {1}, y = {2}",
                      s, x, y);
}
private static void Swap(ref int x, ref int y)
{
    int temp = x;
    x = y;
    y = temp;
}
private static unsafe void Swap(int* px, int* py)
{
    int temp = *px;
    *px = *py;
    *py = temp;
}
```

- **Here is the output:**

```
Before swap: x = 55, y = 777
After swap: x = 777, y = 55
After unsafe swap: x = 55, y = 777
```

Fixed Memory

- **When working with pointers, there is a pitfall.**
  - Suppose you have obtained a pointer to a region of memory that contains data you are working on.
  - Since you have a pointer, you are accessing memory directly.
  - But suppose the garbage collector collects garbage and moves data about in memory.
- **Then your object may now reside at a different location, and your pointer may no longer be valid.**
- **To deal with such a situation, C# provides the keyword *fixed*, which declares that the memory in question is "pinned" and cannot be moved by the garbage collector.**
  - Note that you should use **fixed** only for temporary, local variables, and you should keep the scope as circumscribed as possible.
  - If too much memory is pinned, the CLR memory management system cannot manage memory efficiently.

Fixed Memory Illustration

- **The program *UnsafeAccount* illustrates working with *fixed* memory.**
  - This program declares an array of five **Account** objects, and then assigns them all the same value.
  - The attempt to determine the size of this array is commented out, because you cannot apply the **sizeof** operator to a managed type such as **Account[]**.
- **It also illustrates the arrow operator for dereferencing a field in a struct, when you have a pointer to the struct.**
  - For example, if **p** is a pointer to an instance of the struct **Account** shown below, the following code will assign values to the account object pointed to by p.

```
p->id = 101;          // assign the id field
p->balance = 50.00m;  // assign the balance field
```

  - The following code displays an account object.

```
private static unsafe void ShowAccount(
   Account* pAcc)
{
   Console.WriteLine("id = {0}, balance = {1:C}",
      pAcc->id, pAcc->balance);
}
```

Fixed Memory Illustration (Cont'd)

```
public static unsafe void Main()
{
   int id = 101;
   decimal balance = 50.55m;
   Account acc = new Account(id, balance);
   ShowAccount(&acc);
   Account[] array = new Account[5];
   // Console.WriteLine("size of Account[] = {0}",
   //    sizeof(Account[]));
   ShowArray(array);
   fixed (Account* pStart = array)
   {
      Account* pAcc = pStart;
      for (int i = 0; i< array.Length; i++)
         *pAcc++ = acc;
   }
   ShowArray(array);
}
private static unsafe void ShowAccount(
   Account* pAcc)
{
   Console.WriteLine("id = {0}, balance = {1:C}",
      pAcc->id, pAcc->balance);
}
private static void ShowAccount(Account acc)
{
   Console.WriteLine("id = {0}, balance = {1:C}",
      acc.id, acc.balance);
}
private static void ShowArray(Account[] array)
{
   for (int i = 0; i < 5; i++)
   {
      ShowAccount(array[i]);
   }
}
```

Summary

- **Unsafe code in C# allows you to bypass .NET memory management and get at memory directly.**
- **You may use unsafe code within a block with the C# keyword *unsafe*.**
- **The *unsafe* keyword can also be applied to a method.**
- **Code with either an unsafe block or an unsafe method must be compiled with the unsafe compiler option.**
- **You can use the C# pointer type in unsafe code.**
- **When working with pointers you may need to use the *fixed* keyword to pin memory, preventing it from being moved around by the garbage collector.**
- **Unsafe code should be used sparingly if at all!**