P/Invoke and CIL

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P/Invoke

- P/Invoke = Platform Invoke
- Allows managed code to call unmanaged functions in COM objects, C/C++ DLLs, etc.
  - e.g. access to Win32 API
- To declare unmanaged functions
  - Use DllImport attribute and static extern

```
[DllImport("kernel32.dll")]
    static extern int GetProcessHeap()
```

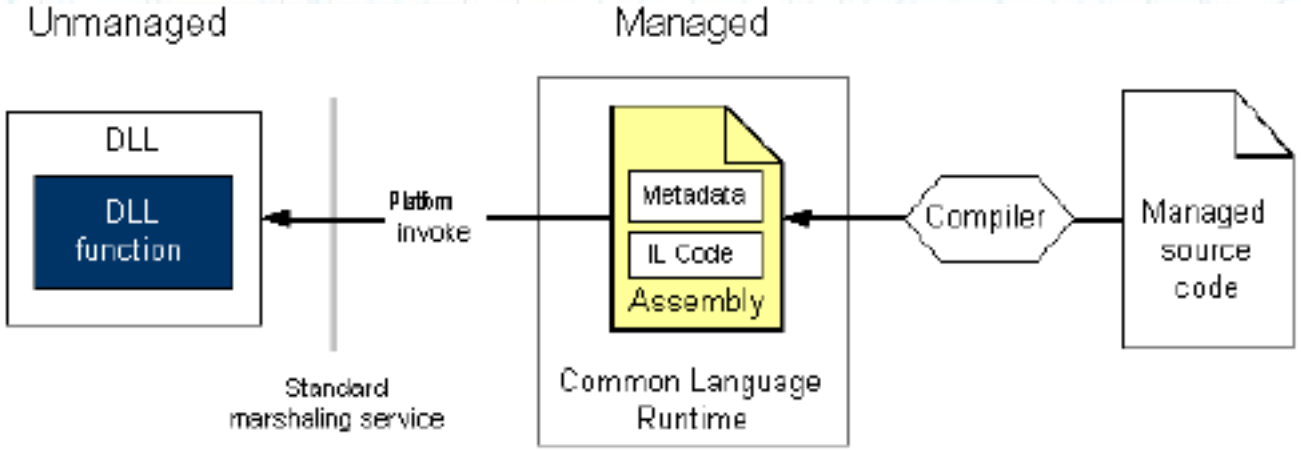
P/Invoke Example

```
using System.Runtime.InteropServices;
namespace HelloWorld {
    class MyClass {
        [DllImport("user32.dll", CharSet=CharSet.Ansi)]
        static extern int MessageBox(int hwnd,
                        string msg, string caption, int t);

        public static void Main() {
            MessageBox(0, "Hello World!", "Caption", 0);
        }
    }
}
```

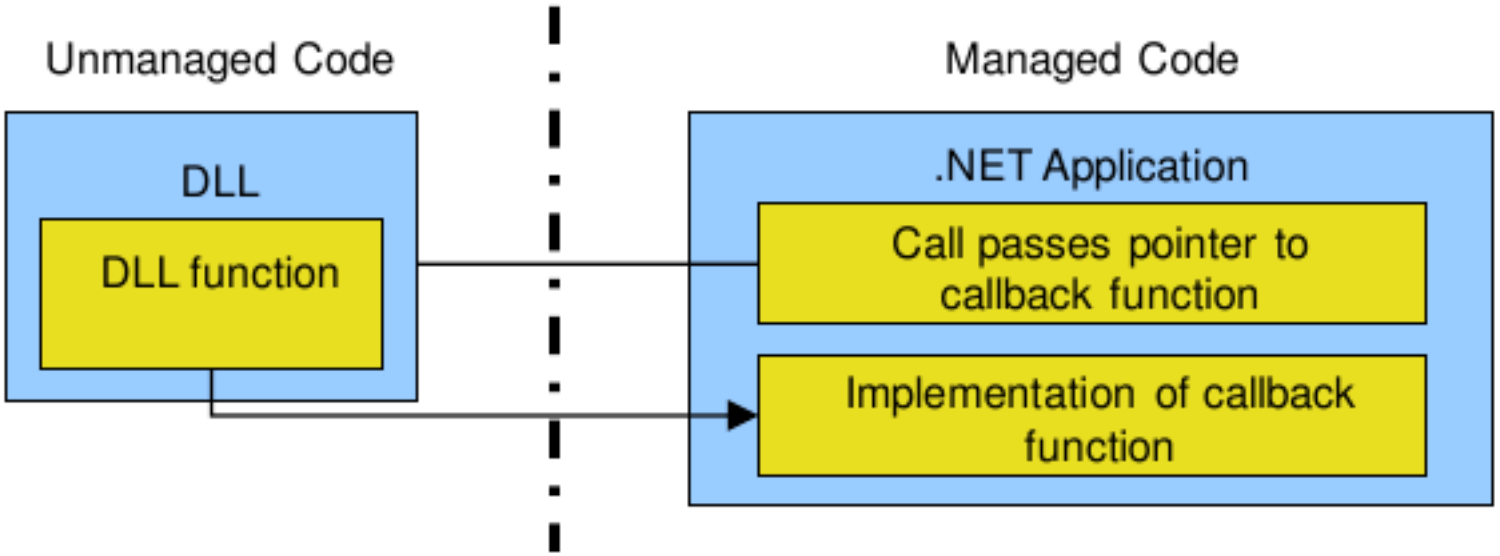
Steps in P/Invoke

- Locates implementing DLL
- Loads DLL into memory
- Finds function address
- Pushes args on stack, marshalling data
- Transfers control to unmanaged code



P/Invoke Callbacks

- Unmanaged code can call back to managed code
  - Unmanaged parameter is function pointer
  - In managed code, must supply parameter as delegate
  - P/Invoke creates callback thunk
    - Passes address of thunk as callback parameters



Callback Example

```
public class SampleClass {
   delegate bool CallBack(int hwnd, int lParam);

   [DllImport("user32.dll")]
   static extern int EnumWindows(CallBack x,
                                  int lParam);

   // report the window handle
   public bool Report(int hwnd, int lParam) {
      Console.Write("Window handle is " + hwnd);
      return true;
   }

   public static void Main() {
      CallBack myCallBack = new CallBack(Report);
      EnumWindows(myCallBack, 0);
   }
}
```

C++/CLI

- Write managed C++ code
  - Compile with /clr
  - Generates CIL from C++
  - new keywords
    - `__gc, __box, __typeof, __interface, __property`
- Very useful for native access to C++ libraries
  - Build a “managed wrapper”

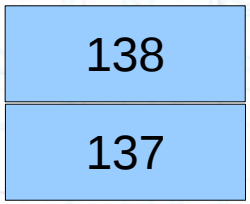
CIL

- Recall: two stage compilation
  - C# compiler: C# → CIL code
  - Just-in-time (JIT) compiler: CIL → native code
- Common Intermediate Language
  - Very close to C#
  - Define classes, structs, inheritance, methods
  - Assembly-like statements

CIL

- Stack language
  - Instead of registers, everything is from stack
  - Main operations take operands from stack
  - e.g.

```
int a = 137;
int b = 1;
int k = a + b;
```



Hello World Example

```
.assembly extern mscorlib {} //automatically added
.assembly hello {}
.class Program {
   .method static public void Main() cil managed {
        .entrypoint //designates this method as the entry pt
        .locals init (string name) //create a local var
        ldstr "World"  //load the string onto eval stack
        stloc.0 //store the string into the first local var
        ldstr "Hello, {0}!"
        ldloc name //load local var onto eval stack
        call void [mscorlib] System.Console::WriteLine(
   string, object) //call method with stack items as params
        ret
   }
}
```

Compile with
`ilasm /exe /debug hello.il`

CIL Directives

- `.assembly`
- `.class`
  - Define any type
  - Extends: extend some other type
    - If extend `System.ValueType`, then value type
- `.method, .field, .property, .event`
- `.locals`: names and types for local vars
- `.entrypoint`
- `.maxstack`

Load/Store Operations

- `ldloc/stloc`
  - Pushes contents of local var (or index) onto stack
  - Pops and stores in local var (or index)
- `ldc`
  - `ldc.i4 50000`
  - `ldc.i4 1`
  - `ldc.i4.ml`
- `ldnull`
- `ldfld/stfld`
  - `ldsfld int32 A::fielda`

Load/Store Example

```
.locals init ([1] int32 a, [0] int32 b)
ldc.i4.5
stloc.0 ldc.i4 10
stloc.1
ldloc a
call void [mscorlib]
  System.Console::WriteLine(int32)
ldloc b
call void [mscorlib]
  System.Console::WriteLine(int32)
```

CIL Operations

- Integer operations
  - `add, mul, sub, div, rem, neg`
- Boxing
  - Removes the value type from stack
  - Creates an object on the managed heap that boxes the value type
  - Places a reference to the newly created object back on the evaluation stack
- Data type conversions: `conv.*`

CIL Operations

- Construct objects
  - newobj instance void A::.ctor()
- Invoke functions
  - `call void [mscorlib] System.Console::WriteLine(string, object)`
  - `call instance int32 A::F()`
  - `callvirt instance int32 A::G()`

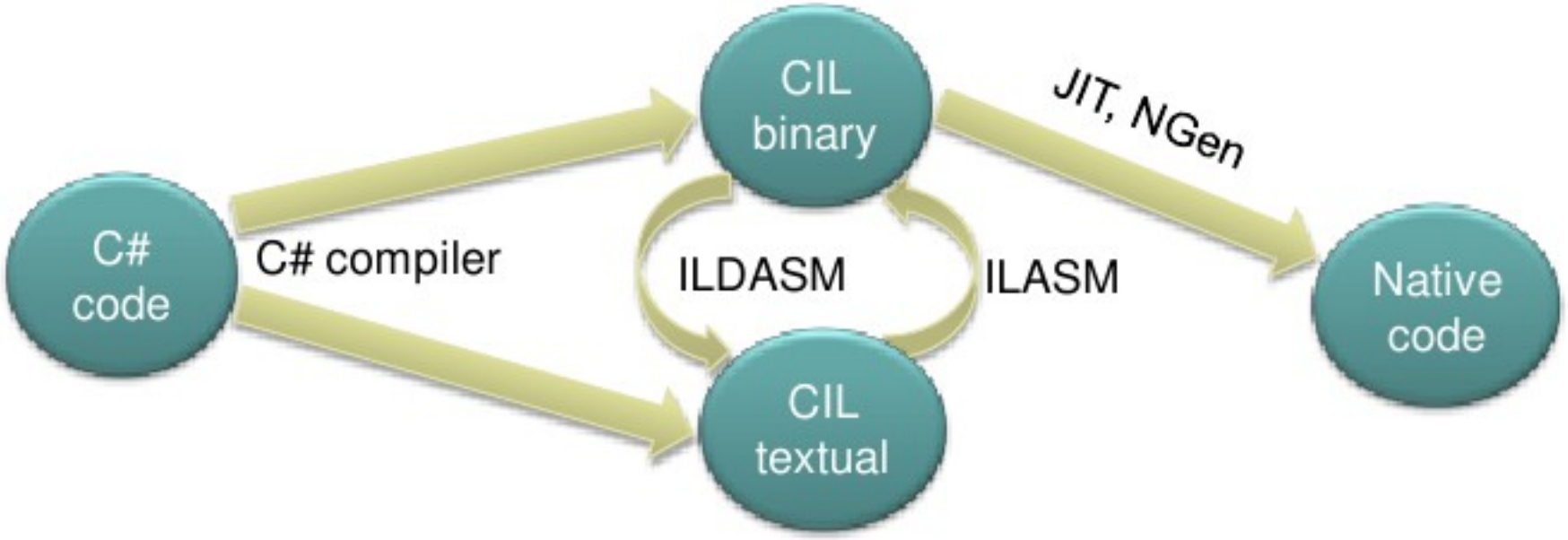
Control Flow Operations

- `ceq/cgt/clt`
  - Pop top two elements of stack
  - Check =, >, <
  - Push true or false onto stack
- `br/beq/bne/bgt/blt/brfalse/brtrue`
  - Do the comparison and jump
  - Use to implement structured control flow

Control Flow Example

```
            ldc.i4.3
            ldc.i4.1
            cgt
            brtrue greater
            ldstr "{0} is less than or equal {1}"
            br end
greater:    ldstr "{0} is greater than {1}"
end:        ldc.i4.3
            box int32
            ldc.i4.1
            box int32
            call void [mscorlib]
  System.Console::WriteLine(string, object, object)
```

CIL Tools



- Roundtripping
  - `ildasm /out=new_program.il program.exe`
  - Edit the CIL code in `new_program.il`
  - `ilasm newadd.il`