Introduction to .NET

What is .NET?

- Introduced in 2002, Microsoft's architecture for applications in the Internet age
  - Increased robustness over classic Windows apps
  - New programming platform
  - Built for the web
- .NET is a platform that runs on the operating system
- Split with Windows RT (will discuss later)

.NET

- Sits on top on the OS (currently all the Windows; Linux/Unix subset also available – Mono Project)
- Provides language interoperability across platforms
- Strong emphasis on Web connectivity, using XML web services to connect and share data between smart client devices, servers, and developers/users
  - Later versions (current 4.5) added WPF, LINQ, Parallel extensions, Metro support
- Platform/language independent

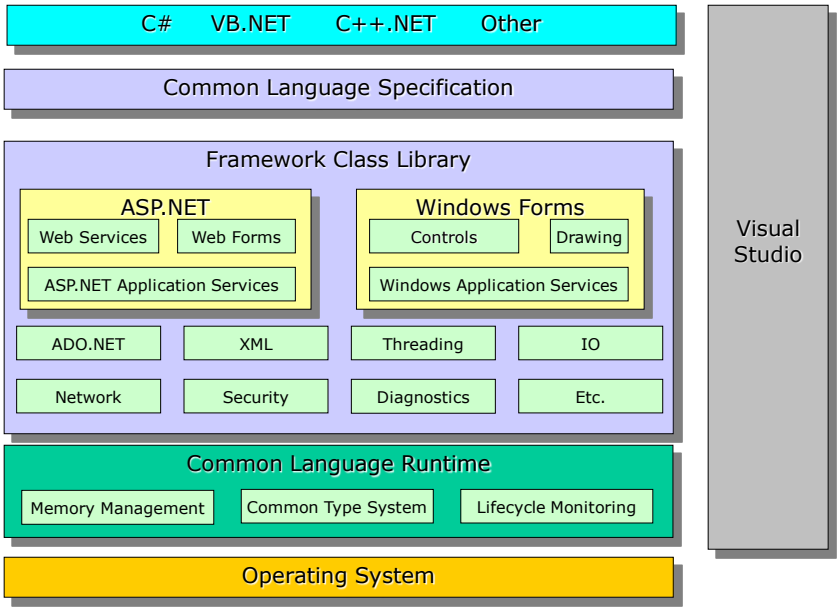
History

- Development began in 1998
- Beta 1 released Oct, 2000
- Beta 2 released July, 2001
- Finalized in Dec, shipping in Feb 2002
- Vista shipped with .NET Framework 3.0 (Runtime)

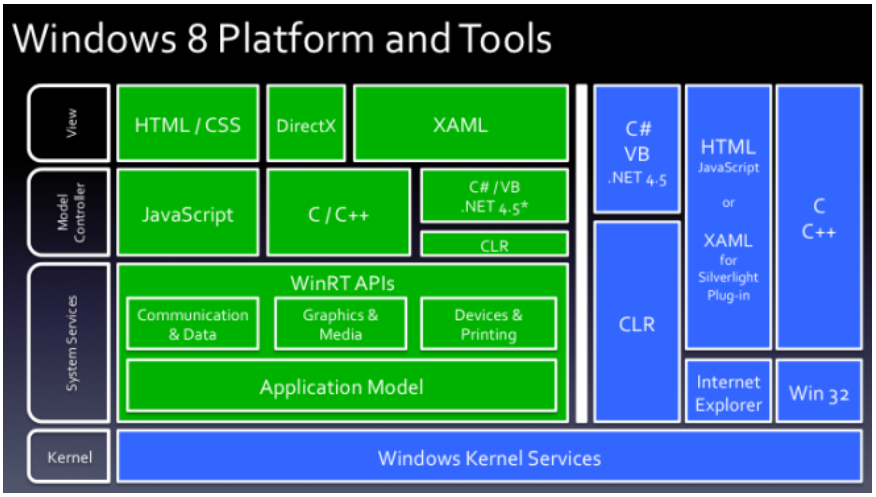
.NET Overview

- Three main elements:
  - The Framework (CLR, FCL, ASP, WinForms)
  - The Products (Windows, Visual Studio, Office)
  - The Services (My Services)
- Framework Goals
  - Improved reliability and integrated security.
  - Simplified development and deployment.
  - Unified API, multi-language support.
- XML is the .NET “Meta-Language”.
- All MS server products now .NET-enabled.

.NET Framework



.NET 4.5 on Windows 8



Green = Metro, Blue = Desktop

http://dougseven.com/2011/09/15/a-bad-picture-is-worth-a-thousand-long-discussions/

Common Language Runtime

- A runtime provides services to executing programs
  - Standard C library, MFC, VB Runtime, JVM
- CLR provided by .NET manages the execution of code and provides useful services
  - Memory management, type system, etc.
  - Services exposed through programming languages
    - C# exposes more features of the CLR than other languages (e.g. VB.NET)

.NET Framework Class Library

- Framework – you can call it and it can call you
- Large class library
  - Over 9000 classes in .NET 4
  - Major components
    - Base Class: Networking, security, I/O, files, etc.
    - Data and XML Classes
    - Web Services/UI
    - Windows UI

Framework Libraries

- Web Services
  - Expose application functionalities across the Internet, in the same way as a class expose services to other classes.
  - Each Web service can function as an independent entity, and can cooperate with one another.
  - Data described by XML.
- ASP.NET
  - Replacement for the Active Server Technology.
  - Web Forms provide an easy way to write interactive Web applications, much in the same way as “normal” Windows applications.

Framework Libraries

- Provides facilities to generate Windows GUI-based client applications easily
- Form-oriented
- Standard GUI components
  - buttons, textboxes, menus, scrollbars, etc.
- Event-handling

Common Language Specification

- CLS is a set of rules that specifies features that all languages should support
  - Goal: have the .NET framework support multiple languages
  - CLS is an agreement among language designers and class library designers about the features and usage conventions that can be relied upon
    - Example: public names should not rely on case for uniqueness since some languages are not case sensitive
    - This does not mean all languages are not case sensitive above the CLR!

Some .NET Languages

- C#
- COBOL
- Eiffel
- Fortran
- Mercury
- Pascal
- Python
- Ruby
- SML

Perl
Smalltalk
VB.NET
VC++
F#
Scheme
….

More are under development

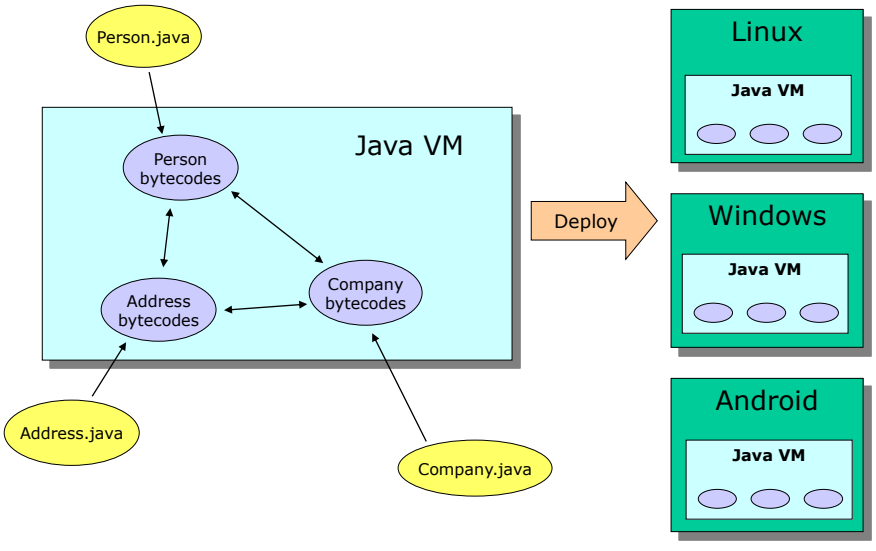
VB.NET and C#

- VB.NET introduces long sought-after features:
  - Inheritance
  - Parameterized Class Constructors
  - Function Overloading
  - Multi-Threading
  - Structured Error Handling
  - Creating NT Services
- VB.NET not backward compatible with VB6.
- C#
  - Flagship, modern, object-oriented language
  - Similar to C++/Java
  - Considered the most powerful language of .NET

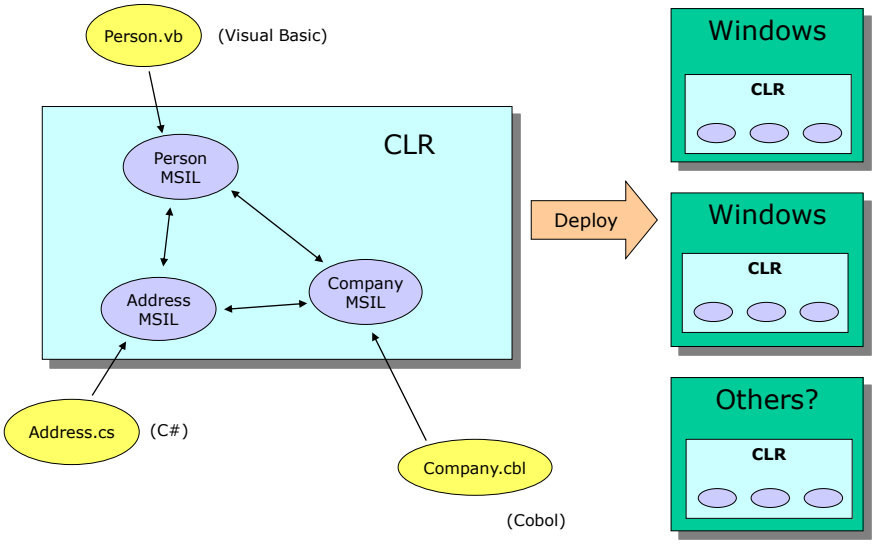
.NET vs. J2EE

- Both are similar in many ways:
  - Server- and client-side model for building enterprise applications.
  - Virtual machine designed to inspect, load, and execute programs in a controlled environment.
  - APIs for creating both fat- and thin-client models.
  - APIs for foundation services (data access, directory, remote object calls, sockets, forms).
  - Development environment for dynamic web pages.
- J2 Enterprise Edition
  - Language-Dependent & Platform-Independent
- .NET
  - Language-Independent & Platform Dependent (for the most part)

J2EE: Language-Specific, Platform- Independent



.NET: Language-Independent, (Mostly) Platform- Specific



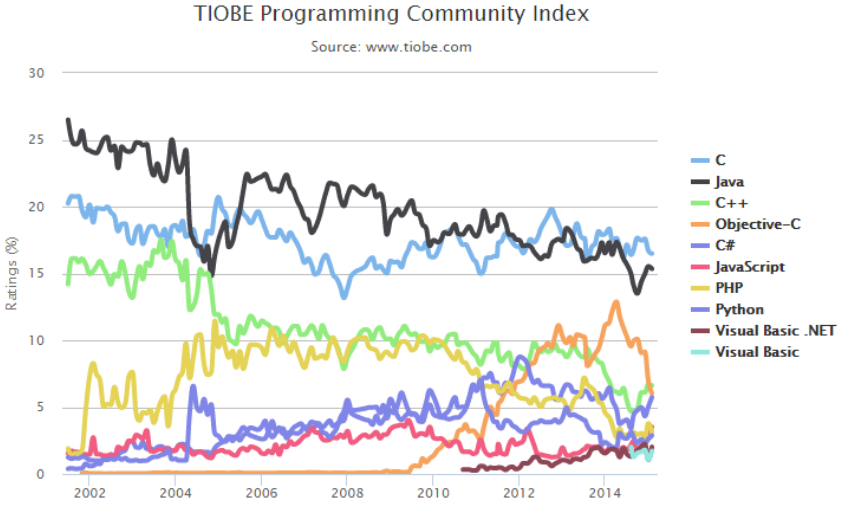
J2EE

- The core (JVM and standard class libraries) are mature.
- 3-4 million Java programmers.
- J2EE implementations are not entirely cross-platform.
- Java's true potential is realized only when all (or most) development is done in Java.
- Changing the Java language specification has an enormous impact on the entire platform.

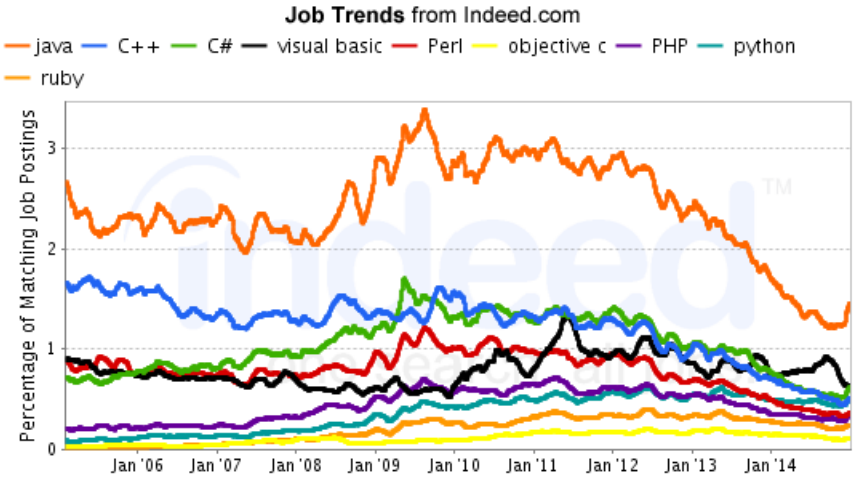
.NET

- .NET built into Windows; running an executable invokes the CLR automatically instead of explicitly invoking the JVM
- .NET added improvements such as native XML support, new features to CLR; spurred Java 8
- About 3 million C++ developers, 3-8 million VB developers, around 1 million C# developers
- Today, most development and deployment is Windows

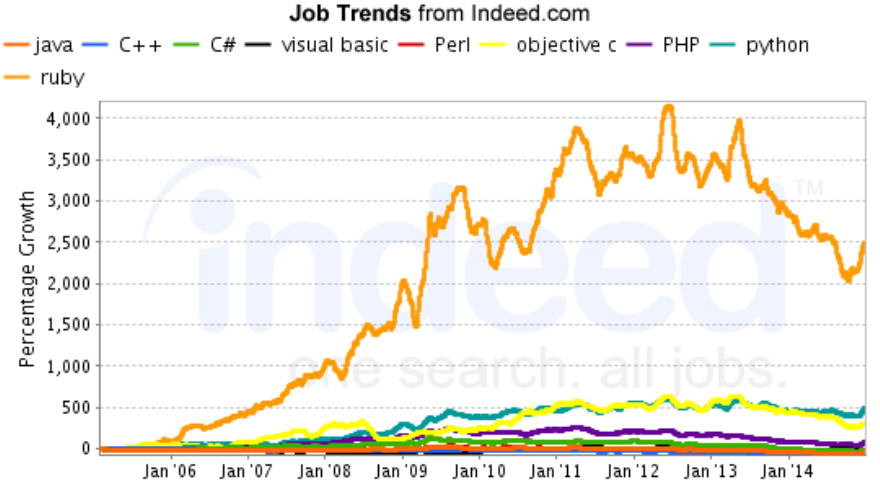
TIOBE Index, Feb 2015



PL Job Trends - % Postings



Relative Job Growth



Do you have to use Windows?

- Open source implementations of .NET
- Today there exists Xamarin's Mono, ~~Corel's Rotor~~ and the Free Software Foundation's Portable .NET projects
- Rotor: the Shared Source Common Language Infrastructure (SSCLI)
  - Started as "Project 7" with Academic Microsoft Research
  - With universities and programming language researchers, developed several languages for the CLR
- Mono
  - Implementation of ECMA C# and CLI for Linux
  - http://www.mono-project.com

Mono

- http://www.mono-project.com/Main_Page
- Mono provides the necessary software to develop and run .NET client and server applications on Linux, Solaris, Mac OS X, Windows, and Unix.
- Sponsored by Xamarin
- Mono allows your existing binaries to run on Linux with copy-deployment.
- Mono API coverage is limited to portions of .NET 4 and parts of .NET 4.5

Mono

- Core: mscorlib, System, System.Security and System.XML assemblies.
  - ADO.NET: System.Data and various other database providers.
  - ASP.NET: WebForms and Web Services are supported. Work on WSE1/WSE2 has also started.
  - Compilers: C#, VB.NET and various command line tools that are part of the SDK.
  - Open Source, Unix and Gnome specific libraries.
- Other components like Windows.Forms, Directory.Services, Enterprise Services and JScript are partially covered
- Some other smaller and less used components do not have yet a Mono equivalent

Common Language Runtime

- The CLR is at the core of the .NET platform - the execution engine
- The CLR provides a “Managed Execution Environment”. Manages the execution of code and provides services that make development easier (like the JVM)
- Code that relies on COM and the Win32 API is “Un-Managed Code” (e.g. built with Visual Studio 6.0, VB6)
- Code developed for a compiler that targets this platform is referred to as “Managed Code” (e.g. code developed in VB.NET … C# allows Managed and Unmanaged)

Simple Application Deployment

- Unlike COM, no “plumbing” code needed to connect separate components
  - Components can be developed in different programming languages
- Thousands of classes to reuse
- Automatic garbage collection
- Memory is managed
  - Common bugs like memory leaks, buffer overruns are not possible (if using 100% managed code)

Multiple Languages

- Common Type System makes interoperability seamless between languages
- Class in one language can inherit from a class in another language
- Exceptions can be thrown across languages
- Makes it easier to learn a new .NET language since the same tools and classes are in place
- Can debug across languages

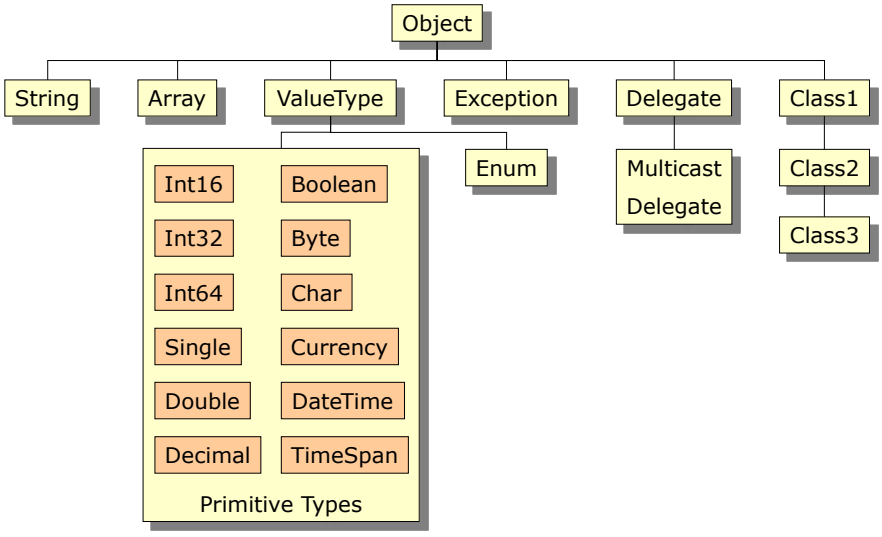
The Common Type System

- At the core of the Framework is a universal type system called the .NET Common Type System (CTS).
- Everything is an object - but efficient
  - Boxing and Unboxing
- All types fall into two categories - Value types and Reference types.
  - Value types contain actual data (cannot be null). Stored on the stack. Always initialized.
  - Three kinds of value types: Primitives, structures, and enumerations.
- Language compilers map keywords to the primitive types. For example, a C# "int" is mapped to System.Int32.

The Common Type System

- Reference types are type-safe object pointers. Allocated in the "managed heap"
- Four kinds of reference types: Classes, arrays, delegates, and interfaces.
  - When instances of value types go out of scope, they are instantly destroyed and memory is reclaimed.
  - When instances of reference types go out of scope, they are garbage collected.
- Boxing = converting an instance of a value type to a reference type. Usually done implicitly through parameter passing or variable assignments.
- UnBoxing = casting a reference type back into a value type variable.

The Common Type System



MSIL and JIT Compilation

- Source code is compiled into MSIL (Microsoft Intermediate Language). Similar to Java bytecodes - CPU-independent instructions
- MSIL allows for runtime type-safety and security, as well as portable execution platforms.
- The MSIL architecture results in apps that run in one address space - thus much less OS overhead.
- Compilers also produce “metadata” or glue that binds the code with debuggers, browsers, etc.
  - Definitions of each type in your code.
  - Signatures of each type’s members.
  - Members that your code references.
  - Other runtime data for the CLR.

MSIL and JIT Compilation

- Metadata in the load file along with the MSIL enables code to be self-describing - no need for separate type libraries, IDL, or registry entries.
- When code is executed by the CLR, a JIT compilation step occurs.
  - Code is compiled method-by-method to native machine code as methods are invoked
  - Results in performance slowdown when a program is first executed, but can be efficient for code that is never executed
  - Subsequent invocations reuse compiled code, so no slowdown

Delegates

- A new concept that is central to the programming model of the CLR.
- Delegates are like function pointers, but are actually type-safe, secure, managed CLR objects.
- The CLR guarantees that a delegate points to a valid method.
- You get the benefits of function pointers without the dangers.
- Each delegate is based on a single method signature.
- Commonly used for callbacks.
- Delegates are basis of event handlers.

Packaging: Modules, Types, Assemblies, and the Manifest

- A “module” refers to a managed binary, such as an EXE or DLL.
- Modules contain definitions of managed types, such as classes, interfaces, structures, and enumerations.
- An assembly can be defined as one or more modules that make up a unit of functionality. Assemblies also can “contain” other files that make up an application, such as bitmaps and resource files.
- An assembly is the the fundamental unit of deployment, version control, activation scoping, and security permissions.

Packaging: Modules, Types, Assemblies, and the Manifest

- An assembly is a set of boundaries:
  - A security boundary - the unit to which permissions are requested and granted.
  - A type boundary - the scope of an assembly uniquely qualifies the types contained within.
  - A reference scope boundary - specifies the types that are exposed outside the assembly.
  - A version boundary - all types in an assembly are versioned together as a unit.
    - Avoid multiple version problem for DLL’s

Packaging: Modules, Types, Assemblies, and the Manifest

- An assembly contains a "manifest", which is a catalog of component metadata containing:
  - Assembly name.
  - Version (major, minor, revision, build).
  - Assembly file list - all files "contained" in the assembly.
  - Type references - mapping the managed types included in the assembly with the files that contain them.
  - Scope - private or shared.
  - Referenced assemblies.
- In many cases, an assembly consists of a single EXE or DLL - containing the module's MSIL, the component metadata, and the assembly manifest. In other cases, the assembly may consist of many DLLs, with the manifest in its own file.
- No MSIL code can ever be executed unless there is a manifest associated with it.

Differences from JVM (prior to 1.5)

- 220 instructions in the CLR's instruction set
- JVM provides no way of encoding type-unsafe features of typical programming languages, such as pointers
  - E.g., JVM has no way to access the address of local variables for use in things like a Swap method, passing primitive variables by reference
- Arithmetic
  - Separate instructions for adding to generate overflow vs. no overflow
  - JVM never generates overflow on integer types

Differences from JVM (prior to 1.5)

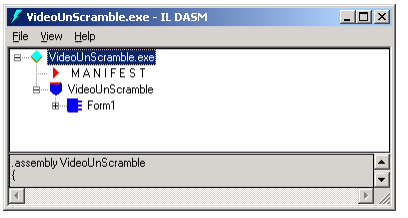
- Branches
  - Limited to 64K in JVM
- Structures and Unions
  - No support for these in JVM
  - Union supports Variant Records
    - When a field in the structure is selected from multiple possible types e.g., Struct.X could be an int or a boolean
- Automatic Boxing and Unboxing

Differences from JVM (prior to 1.5)

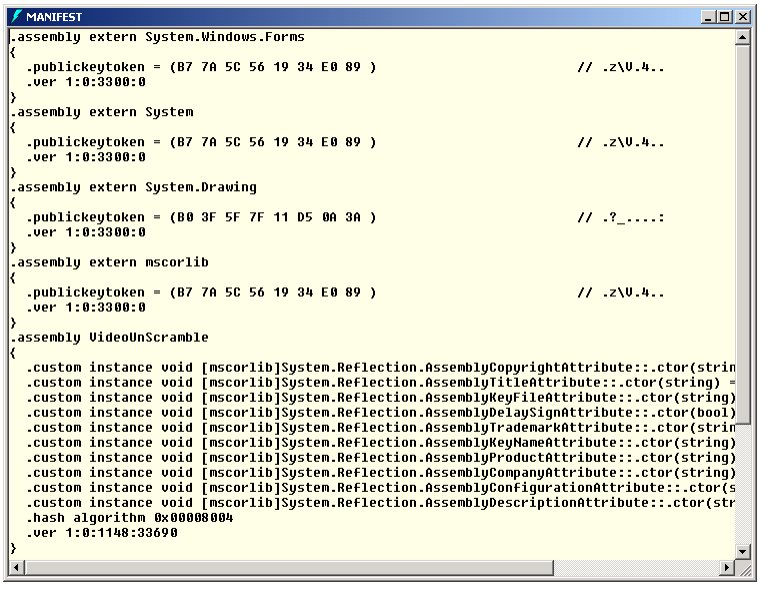
- Support for Tail Recursion
  - Discards previous stack frame, so tail recursion can result in an infinite loop instead of stack overflow
  - Faster as well (for non-infinite loop)
- Supports “unmanaged” code
  - Java has JNI, Java Native (code) Interface, as a way to do the same thing but not as directly

ILDASM

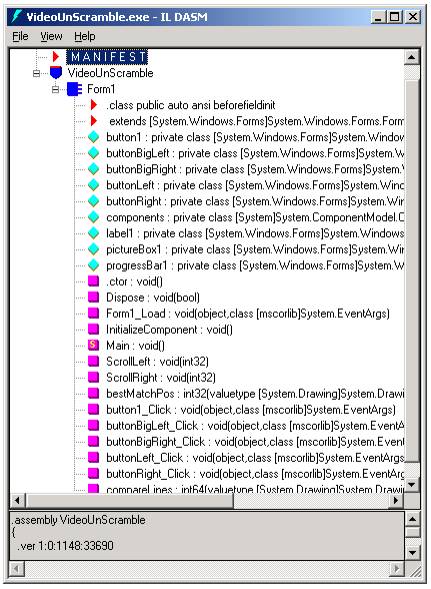
- Can examine assemblies, assembly code with the ILDASM tool
- Here is ILDASM run on VideoUnScramble.exe



Assembly Manifest



Assembly Components



MSIL Sample Code

```
    IL_006e:  ldloc.s    V_4
    IL_0070:  ldloc.1
    IL_0071:  ldelema    [System.Drawing]System.Drawing.Color
    IL_0076:  ldloc.0
    IL_0077:  ldloc.1
    IL_0078:  ldarg.1
    IL_0079:  sub
    IL_007a:  ldloc.2
    IL_007b:  callvirt   instance valuetype [System.Drawing]System.Drawing.Color
[System.Drawing]System.Drawing.Bitmap::GetPixel(int32, int32)
    IL_0080:  stobj      [System.Drawing]System.Drawing.Color
    IL_0085:  ldloc.1
    IL_0086:  ldc.i4.1
    IL_0087:  sub
    IL_0088:  stloc.1
    IL_0089:  ldloc.1
    IL_008a:  ldarg.1
    IL_008b:  bge.s      IL_006e

    IL_008d:  ldc.i4.0
    IL_008e:  stloc.1
    IL_008f:  br.s       IL_00aa
```

Summary

- Next we will study C#
- C# does not exist in isolation but has a close connection with the .NET framework
- .NET
  - CLR is a Java-like platform, but multi-language
  - Src→MSIL→JIT→Native Code
  - .NET framework includes many class libraries