PV178: Programming for .NET Framework

Introduction to .NET and C#

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Microsoft.Net Technology Suite

- **standards** (CLI) and their **implementations** (CLR)
- **programming languages** (C# among others)
- **development tools** (Microsoft Visual Studio, Microsoft .Net Framework SDK)
- **runtime** (Microsoft .Net Framework)
- **application toolkits** (ASP.Net, ADO.Net,. . .)

CLI Overview

- *Common Language Infrastructure*
- international standard (ECMA #335, ISO/IEC 23271:2003), see [7]
- a standard base for creating execution and development environments
- interoperability – languages and libraries conforming to the standard should work together seamlessly

CLI Components

CLI itself defines

- the Common Type System (CTS)
- the Common Language Specification (CLS)
- metadata (description of the code units, such as visibility, security requirements, etc.)
- portable and platform-agnostic file format for managed code
- common Intermediate Language (CIL) instruction set
- basic requirements on the Virtual Execution System
- a programming framework (a class library)

CTS: the Common Type System

The Complete set of types available to a CLI-compliant language

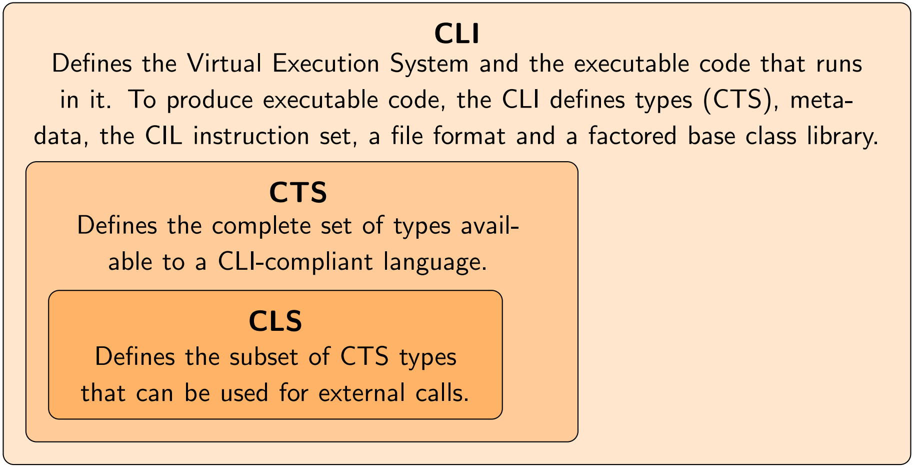
- based both on representation of values and their behaviour
- designed for language interoperability
- designed via set of rules – types are extensible (by derivation), type system is not
- designed for broad coverage: object-oriented, procedural and functional languages (C#, JScript, C++, F#, COBOL, J#, etc. – for more comprehensive list see [10]).

The Common Language Specification

Defines a subset of CTS types that can be used for external calls.

- actually a set of restrictions on the CTS
- used by standardised framework to ensure compatibility

CLI, CTS and CLS relationship



CLI

Defines the Virtual Execution System and the executable code that runs in it. To produce executable code, the CLI defines types (CTS), meta-data, the CIL instruction set, a file format and a factored base class library.

CTS

Defines the complete set of types available to a CLI-compliant language.

CLS

Defines the subset of CTS types that can be used for external calls.

Metadata

- stored directly in the executable file in the form of *attributes* and *tables*
- attributes attached to code units (assemblies, methods, types, etc.)
- tables list selected code units (methods, types, etc.)
- used to
  - manage code execution
  - versioning, deployment and maintenance
  - enable cross language interoperability
- contains
  - description of an executable file (Manifest)
  - description of all types stored in an executable file
  - signatures of all methods stored in an executable file
  - custom user defined attributes – the metadata system is extensible
  - ...

Executable File Format

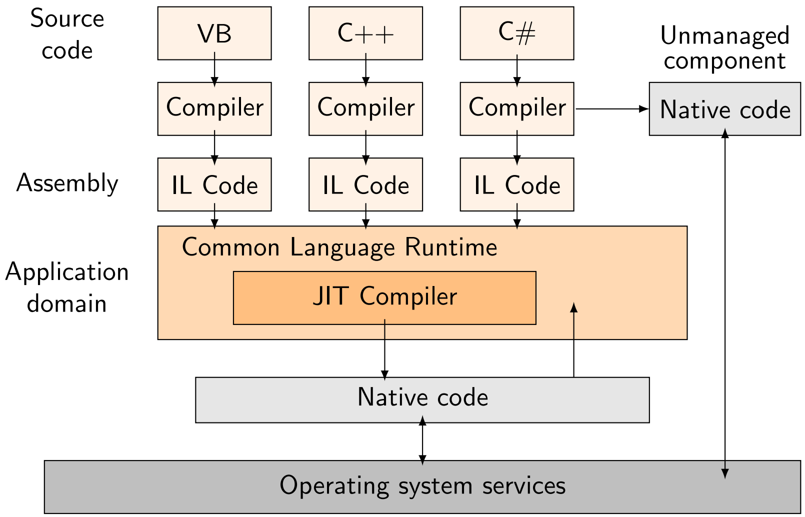
- executable file: Assembly (unit of deployment)
- conforms to the Portable Executable file format (PE)
- CLI PE file format is an extension to the Microsoft PE[1] file format
- Contains
  - Assembly metadata,
  - Type metadata,
  - IL code,
  - resources
- Microsoft PE is described in [9]

[1] Microsoft Portable Executable

VES – Virtual Execution System

- provides an environment for executing managed code
- provides direct support for built-in data types
- defines a virtual machine that provides support for executing the CIL instruction set
- VES implementation is usually denoted as CLR (*Common Language Runtime*) – Microsoft.Net Framework, Mono [4], Rotor – Shared Source CLI

CLR Execution Model



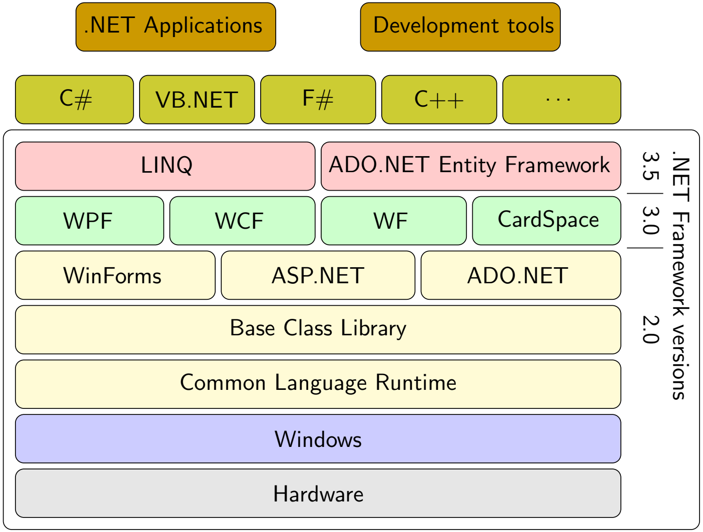
Compilation and Execution

1. source code is compiled by the compiler into the intermediate code (CIL)
2. generated CIL code is stored (by the compiler) in an assembly along with metadata
3. the assembly is deployed on the target machine (assembly usually platform independent)
4. the assembly is executed by CLR
5. the code stored in the assembly is compiled on demand

Microsoft.Net Framework

- ECMA #335
- ASP.Net, ADO.Net, Windows Forms, C# 3.0, Silverlight. . .
- runs on Microsoft Windows x86, x64, IA64
- Performance of Microsoft.Net Framework and Java VMs (Sun, IBM, BEA) is generally comparable (let the flame begin :-))

.NET Framework Structure



Mono

- ECMA #335 Compact Profile
- ASP.Net, ADO.Net, Windows Forms, GTK#, C#, Moonlight. . .
- `http://www.mono-project.com/Supported_Platforms`
- Microsoft.Net Framework is faster (better GC and JIT)

Example code

CSharpFeatures.cs

C# overview

- simple, easy to learn and use
- modular and block structured
- object oriented (class based language)
- component oriented
- strongly typed (static typing with implicit RTTI – *RunTime Type Information*), see [2], [3]
- descended from C, C++ ([8])
- part of the Microsoft.Net suite of technologies

C/C++

- curly braces
- C# more typesafe than C++ (e.g. only safe coercions)
- tricky features (templates) reinvented
- C# has support for low-level pointer manipulation (`unsafe` keyword) as has C++ (Java has not)

Java

- similar idea and motivation
- subtle syntactic differences
- C# includes lower level constructs (strictly optional)
- C# includes higher level constructs (convenience)
- Java is truly multi-platform – Microsoft has (almost) no interest in supporting non-Microsoft platforms
- **when C# came, Java was already here and well established**

Cω

- research programming language ([1])
- far beyond C# (and everything you've probably met)
- XML made easy (LINQ and beyond)
- a notion of *choice types*
- parallel constructs
- streams

Spec#

- experimental extension to C#, see [12]
- implements *Design by Contract* concept, pioneered by Eiffel (see [11])
- adds preconditions, postconditions, invariants to the language
- may eventually become mainstream
- for introductory material and samples refer to: [13]
- other frameworks - CodeContracts

Spec# Example

```
public float SquareRoot(float f)
    requires f > 0  // PRECONDITION
{
    return Math.sqrt(f);
}
```

Other Important Software

- nunit, rhinomock, chess, peck
- nant, cruisecontrol.net, teamcity

C# Evolution

- C# language evolves
- four editions so far:
  - C# 1.0 (year 2002)
  - C# 2.0 (year 2005)
  - C# 3.0 (year 2007)
  - C# 4.0 (in development)

C# 1.0

- first edition of C# available to public (sometimes denoted as C# 1.2)
- unveiled with Microsoft Visual Studio.Net 2002
- major features were there
- filled the language gap in Microsoft portfolio
- "killer" feature of Microsoft.Net suite

C# 2.0

- interesting new features:
  - generic types *(see example)*
  - anonymous methods
  - partial classes
  - ...
- mostly syntactic sugar, but generics are important

C# 3.0

- LINQ (*Language INtegrated Query* – query languages (SQL, XPath, XQuery) embedded *(see example)* directly in C# source code
- type inference *(see example)*
- lambda expressions *(see example)*
- bytecode compatible with C# 2.0 (interoperability)

C# Language Specification

- ECMA: *European Computer Manufacturers' Association*, `http://www.ecma-international.org`
- ECMA #334 (see [6]) – freely downloadable
- current: 3rd edition (corresponds to C# 2.0)
- 2nd (C# 1.0) edition submitted and approved by ISO (ISO/IEC 23270)
- useful reference, but not lightweight reading

Development Tools

Tools which are available to students at FI (Thanks go to the CVT FI):

- Microsoft Visual Studio 2008 (`B117`)
- Mono (computer hall – Linux and Windows), see: [4]
- Rotor: Shared Source CLI (`A104`, computer hall), see: [5]

Additional tools:

- MonoDevelop (open source IDE for Mono)

MSDN Academic Alliance

- Microsoft operating systems, development tools and server products for research and education
- for more information refer to: `http://www.fi.muni.cz/tech/win/msdnaa.xhtml`

HelloWorld.cs

```
using System; //like import of package in Java

namespace PV178 /* like package in Java */
{
 public class HelloWorld
 {
  static void Main(string[] agrs)
  {
   Console.WriteLine("Hello␣world");
  }
 }
}
```

`HelloWorld.cs` cont.

- compile with `csc HelloWorld.cs`
- then run `HelloWorld.exe`

References

[1] Microsoft Research, *Cω Website*. http://research.microsoft.com/Comega/.

[2] Wikipedia Article, *Data types*. http://en.wikipedia.org/wiki/Datatype.

[3] ______, *RunTime Type Information*. http://en.wikipedia.org/wiki/RTTI.

[4] *Mono Project Website*. http://www.mono-project.org.

[5] *Rotor: Shared Source CLI*. http://msdn.microsoft.com/net/sscli.

[6] ECMA International, *C# Language Specification*. http://www.ecma-international.org/publications/standards/Ecma-334.htm.

[7] ECMA Intenrational, *Common Language Infrastructure*. http://www.ecma-international.org/publications/standards/Ecma-335.htm.

[8] Lambda the Ultimate, *Genealogical Diagrams*. http://lambda-the-ultimate.org/node/7.

[9] *Microsoft Portable Executable and Common Object File Format Specification*, 1999. http://www.microsoft.com/whdc/system/platform/firmware/PECOFF.mspx.

[10] *.NET Languages*. http://www.dotnetlanguages.net/DNL/Resources.aspx.

[11] *Building bug-free O-O software: An introduction to Design by Contract*. http://archive.eiffel.com/doc/manuals/technology/contract/.

[12] *Spec# Programming System*. http://research.microsoft.com/specsharp/.

[13] *The Spec# Wiki at Channel9*. http://channel9.msdn.com/wiki/default.aspx/SpecSharp.HomePage.